Prediction and Management of Strangulated Bowel Obstruction: A Multiomics Model Analysis

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Research article

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Abstract

Background

Distinguishing strangulated bowel obstruction (StBO) from simple bowel obstruction (SiBO) still poses a challenge for emergency surgeons. We aimed to construct a predictive model that could distinctly discriminate StBO from SiBO based on the degree of bowel ischemia.

Methods

A total of 281 patients diagnosed with intestinal obstruction were enrolled. According to pathological confirmation, patients were divided into a simple bowel obstruction (SiBO, n=236) group and a strangulated bowel obstruction (StBO, n=45) group. The clinical characteristics, laboratory tests and radiomics were compared between the groups via univariate analysis. Binary logistic regression was applied to identify independent risk factors, and then predictive models based on radiomics and multiomics models were constructed. Receiver operating characteristic (ROC) curves and the area under the curve (AUC) were calculated to assess the accuracy of the predicted models. Finally, via stratification analysis, we validated the multiomics model in the prediction of transmural necrosis.

Results

Of the 281 patients with SBO, 45 (16.0%) were found to have StBO, while 236(84.0%) with SiBO. Via univariate analysis, clinical characteristics including pain duration (p=0.036), abdominal pain(p=0.018), tenderness (p=0.020), rebound tenderness (p<0.001), bowel sounds (p=0.014), and laboratory parameters like white blood cell (WBC) (p=0.029), neutrophil (NE)% (p=0.007), low levels of sodium (p=0.009), abnormal potassium (p=0.003), high levels of blood urea nitrogen (BUN) (p<0.001) and glucose (p=0.002), as well as the radiomics consisting of mesenteric fluid (p=0.018), ascites (p=0.002), bowel spiral signs (p<0.001) and edema of bowel wall (p=0.037) were closely related to bowel ischemia. The ascites (OR=4.067) and bowel spiral signs (OR=5.506) were identified as independent risk factors of StBO in the radiomics model, the AUC for which was 0.706 (95%CI, 0.617–0.795). In the multivariate analysis, seven risk factors including pain duration≤3days (OR=3.775), rebound tenderness (OR=5.201), low-to-absent bowel sounds (OR=5.006), low levels of potassium (OR=3.696) and sodium (OR=3.753), high levels of BUN (OR=4.349), high radiomics score (OR=11.264) were identified. The area under the receiver operating characteristics (ROC) curve of the model was 0.857(95%CI, 0.793-0.920). The score of the mutiomics model can be calculated as following formula (1.328*Pd+1.649*Rt+1.611*Bs+1.307*K+1.323*Na+1.470*BUN+2.422*Rad-6.009). In the stratification of risk scores, the proportion of patients with transmural necrosis was significantly greater in the high-risk group (24%) than in the medium-risk group (3%). No transmural necrosis was found in the low-risk group.

Conclusion

The novel multiomics model consisting of risk factors for pain duration, rebound tenderness, bowel sounds, potassium, sodium, and BUN levels and radiomics offers a useful tool for predicting StBO.

Clinical management can be performed according to the multiomics score; for patients with low risk (scores≤ -3.91), conservative treatment is recommended. For the high-risk group (risk scores> -1.472), there was a strong suggestion for detection with laparotomy. For the remaining patients (-3.091< risk scores ≤ -1.472), dynamic observation is suggested.

Introduction

Small bowel obstruction (SBO) is a common disease, accounting for 12%-16% of all surgical admissions in the United States[1]. SBO can be divided into simple bowel obstruction (SiBO) and strangulated bowel obstruction (StBO). SiBO is usually resolved by nonoperative management, including bowel rest, nasogastric tubes and tube decompression, reducing the risk of emergency surgery[2]. Conversely, StBO requires immediate surgical intervention[3], as StBO may result in severe complications, including bowel perforation, peritonitis and septic shock, which increase the mortality of SBO up to 25%[4, 5]. In the case of bowel transmural necrosis, the mortality dramatically increases to 50%[6]. However, only 1/3 of StBO patients have the classical traits of abdominal pain, hematochezia and fever, and the remaining patients have nonspecific symptoms such as diarrhea, vomiting and bloating[7]. Consequently, it is difficult to accurately diagnose and intervene in StBO in the early stage. How to distinguish StBO from SiBO still poses a challenge to emergency surgeons.

Traditionally, clinical findings serve as major models for the prediction of StBO[8–10]; however, the accuracy of these models remains unsatisfactory[11]. More focus has been placed on radiomics[12–14], whereas the diagnostic performance of CT revealed poor prospective prediction[8, 15]. CTA (computed tomography angiography) is the gold standard of predicting bowel ischemia with 94% sensitivity and 96% specificity[16, 17]. However, CTA is rarely performed in emergency situations due to its high cost, insufficient medical support and high risk of nephropathy induced by iodine[18]. In previous studies for the detection of laboratory biomarkers to evaluate StBO, only L-lactate was deemed an effective biomarker for the prediction of bowel ischemia, with 78% sensitivity and 48% specificity[6, 19]. Therefore, predictive models integrating clinical features, laboratory tests and radiomics need to be studied for the prediction of StBO.

To date, few studies have focused on the prediction of bowel transmural necrosis for SBO, most of which enrolled patients with acute mesenteric ischemia (AMI)[20–22]. Among these studies, only laboratory biomarkers were primarily considered indicative factors of bowel transmural necrosis[20, 21]. To our knowledge, no efforts have been made to predict transmural necrosis in patients with SBO. Therefore, a multiomics model to predict transmural necrosis in patients with SBO is urgently needed.

In this study, we constructed an accurate predictive model consisting of clinical features, laboratory tests and radiomics for the diagnosis of StBO. Based on the predictive model, we could distinctly discriminate StBO from SiBO, especially for transmural necrosis from simple bowel ischemia.

Materials And Methods

Patient Population

From October 2016 to February 2021, 479 patients diagnosed with intestinal obstruction at Fujian Medical University Union Hospital were included in the study. After excluding 180 patients with large bowel obstruction, 4 patients with missing CT images and 13 patients with incomplete clinical data, 281 patients were recruited in the final study (shown in Figure 1).

A total of 281 patients were divided into two groups 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. The study protocol was approved by the Institutional Review Board of Fujian Medical University Union Hospital (FJMUUH), and all patients provided written informed consent for the procedure.

Clinical characteristics and laboratory tests

Clinical parameters, including pain duration, symptoms of abdominal pain, tenderness, rebound tenderness, and bowel sounds, and laboratory tests, including white blood cell count (WBC), prothrombin time (PT), and potassium, sodium, blood urea nitrogen (BUN), and D-dimer (DDI) levels, were recorded in our database for intestinal bowel obstruction. Categorical variables, especially potassium, sodium, BUN, PT and DDI levels, were transformed from continuous variables according to laboratory references. The levels of WBC and NE%, were sorted by quartile. In addition, procalcitonin (PCT) levels were divided into three categories based on a previous study[19].

CT findings

All patients with suspected SBO underwent CT scans before receiving treatment. The features of the CT scans 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[4, 23–27]. All CT scan images were cross-reviewed and judged by two senior radiologists (radiologist Lin Lin had 10 years of experience in abdominal radiology, and radiologist Ying-qian Geng had 8 years of experience in general radiology). The discriminate portions were independently judged by a general surgeon, Xian-qiang Chen who had over 10 years of experience in abdominal emergency surgery. The definitions of CT characteristics were showed in Figure 2 and supplied in Supplementary Table 2.

Statistical analysis

The differences between the two groups were compared using the chi-square test or Fisher's exact test for categorical variables. For continuous variables, we used an independent t-test. For continuous nonparametric variables, the Wilcoxon rank-sum test was adopted to analyze the differences between the groups. Independent risk factors were confirmed via binary logistic regression. Receiver operating characteristic (ROC) curves and the area under the curve (AUC) were calculated to assess the accuracy of the predicted models. A logistic nomogram was generated by using tools in Hiplot (https://hiplot.com.cn),

a comprehensive web platform for scientific data visualization. The other statistical analyses were performed with SPSS software (SPSS, version 23.0, SPSS Inc.).

Results

Background and clinical-laboratory features

Of the 281 patients with SBO who were included in this study, 45 (16.0%) were found to have StBO, while 236 (84.0%) were found to have SiBO. No remarkable differences were observed between the groups for the baseline parameters, including age, sex, BMI, and comorbidity status (all *p* value>0.05, Table 1). Via univariate analysis, several clinical characteristics, including pain duration (p=0.036), abdominal pain (p=0.018), tenderness (p=0.020), rebound tenderness (p<0.001), and bowel sounds (p=0.014), were significantly different between the two groups. High levels of inflammatory biomarkers, such as WBC (p=0.029) and NE% (p=0.007), and abnormal electrolyte and metabolic changes, such as low levels of sodium (p=0.009), abnormal potassium (p=0.003), and high levels of BUN (p<0.001) and glucose (p=0.002), were closely related to bowel ischemia.

Table 1
Compared the clinical and laboratory characteristics of the patients with or without strangulated bowel obstruction

Characteristics	SiBO(n=236)	iStBO(n=45)	*p*-value
Gender, n(%)			0.124
male	164(69.5%)	26(57.8%)	
female	72(30.5%)	19(42.2%)	
Age(median)	61	63	0.421*
BMI, n(%)			0.432
18.5-23.9	114(59.1%)	19(52.8%)	
≤18.5	45(23.3%)	12(33.3%)	
≥23.9	34(17.6%)	5(13.9%)	
Comorbidity, n(%)			0.406
none	175(74.2%)	36(80.0%)	
yes	61(25.8%)	9(20.0%)	
Pain duration, n(%)			**0.036**
≤3days	133(56.6%)	33(73.3%)	
≥3days	102(43.4%)	12(26.7%)	
History of abdominal operation, n(%)			0.716
none	62(26.3%)	13(28.9%)	
yes	174(73.7%)	32(71.1%)	
Fever, n(%)			1.000
none	215(92.7%)	41(93.2%)	
yes	17(7.3%)	3(6.8%)	
Abdominal pain, n(%)			**0.018**
none or mild	35(14.9%)	1(2.2%)	
moderate	142(60.4%)	26(57.8%)	

SiBO: simple bowel obstruction; StBO: strangulated bowel obstruction; BMI: body mass index; WBC: white blood cell; NE%: neutrophil percentage; PCT: procalcitonin; BUN: blood urea nitrogen; PT: prothrombin time; DDI: D-dimer.

Values marked with “*” were compared using Wilcoxon rank-sum test.

Characteristics	SiBO(n=236)	iStBO(n=45)	*p*-value
severe	58(20.7%)	18(40.0%)	
Abdominal distention, n(%)			0.761
none	63(26.7%)	13(28.9%)	
yes	173(73.3%)	32(71.1%)	
Vomiting, n(%)			0.702
none	75(31.8%)	13(28.9%)	
yes	161(68.2%)	32(71.1%)	
Retention of stool and flatus, n(%)			0.077
none	96(40.7%)	12(26.7%)	
yes	140(59.3%)	33(73.3%)	
Tenderness, n(%)			**0.020**
none	35(14.8%)	1(2.2%)	
yes	201(85.2%)	44(97.8%)	
Rebound tenderness, n(%)			**<0.001**
none	190(80.5%)	22(48.9%)	
yes	46(19.5%)	23(51.1%)	
Bowel sounds, n(%)			**0.014**
normal	104(44.1%)	13(28.9%)	
none or low	82(34.7%)	26(57.8%)	
high or hyperactive	50(21.2%)	6(13.3%)	
WBC, (10^9/L), n(%)			**0.029**
≤10.14	183(77.5%)	28(62.2%)	
10.14	53(22.5%)	17(37.8%)	
NE%, n(%)			**0.007**
≤84.35	186(78.8%)	27(60.0%)	

SiBO: simple bowel obstruction; StBO: strangulated bowel obstruction; BMI: body mass index; WBC: white blood cell; NE%: neutrophil percentage; PCT: procalcitonin; BUN: blood urea nitrogen; PT: prothrombin time; DDI: D-dimer.

Values marked with “*” were compared using Wilcoxon rank-sum test.

Characteristics	SiBO(n=236)	iStBO(n=45)	*p*-value
≥84.35	50(21.2%)	18(40.0%)	
HCO3-, n(%)(mean)	23.78	23.62	0.789
PCT,n(%)			0.080
≥0.02	4(3.4%)	1(6.2%)	
0.02-1	102(87.9%)	11(68.8%)	
≥1	10(8.6%)	4(25%)	
Potassium, n(%)			**0.003**
3.5-5.5	204(86.8%)	32(71.1%)	
≤3.5	30(12.8%)	10(22.2%)	
≥5.5	1(0.4%)	3(6.7%)	
Sodium, n(%)			**0.009**
≥135	196(83.4%)	30(66.7%)	
≤135	39(16.6%)	15(33.3%)	
Glucose(median)	6.80	8.34	**0.002***
BUN, n(%)			**<0.001**
≤8.3	185(81.5%)	24(57.1%)	
≥8.3	42(18.5%)	18(42.9%)	
PT, n(%)			0.056
≤16s	219(94.0%)	38(84.4%)	
≥16s	14(6.0%)	7(15.6%)	
DDI, n(%)			0.251
≤0.5	29(13.6%)	3(7.1%)	
≥0.5	185(86.4%)	39(92.9%)	

SiBO: simple bowel obstruction; StBO: strangulated bowel obstruction; BMI: body mass index; WBC: white blood cell; NE%: neutrophil percentage; PCT: procalcitonin; BUN: blood urea nitrogen; PT: prothrombin time; DDI: D-dimer.

Values marked with "*" were compared using Wilcoxon rank-sum test.

Univariate and multivariate analyses of radiomics

Through univariate analysis of the radiomics, we determined that StBO was closely related to the presence of mesenteric fluid (p=0.018), ascites (p=0.002), bowel spiral signs (p<0.001) and edema of the bowel wall (p=0.037) (Table 2). Via binary logistic regression analysis, we defined only ascites (OR=4.067, 95% CI: 1.506-10.983, p=0.006) and bowel spiral signs (OR=5.506, 95% CI: 2.609-11.623, p<0.001) as independent risk factors for StBO.

Table 2
Univariate and multivariate analysis of CT findings in patients with or without StBO

	Univariate analysis(n=281)			**Multivariate analysis(n=281)**	
CT characteristics	SiBO(n=236)	StBO(n=45)	*p*-value	OR (95%*CI*)	*p*-value
Mesenteric fluid			**0.018**		
none	44(18.6%)	2(4.4%)			
yes	192(81.4%)	43(95.6%)			
Ascites			**0.002**	4.067(1.506-10.983)	**0.006**
none	81(34.3%)	5(11.1%)			
yes	155(65.7%)	40(88.9%)			
Spiral signs			**<0.001**	5.506(2.609-11.623)	**<0.001**
none	211(89.4%)	27(60.0%)			
yes	25(10.6%)	18(40.0%)			
Concentric circle sign			0.476		
none	225(95.3%)	42(93.3%)			
yes	11(4.7%)	3(6.7%)			
Small bowel feces sign			0.901		
none	113(47.9%)	22(48.3%)			
yes	123(52.1%)	23(51.1%)			
Edema of bowel wall			**0.037**		
none	85(36.0%)	9(20.0%)			
yes	151(64.0%)	36(80.0%)			
Bowel wall thickness (median)	3.33	3.48	0.110*****		

SiBO: simple bowel obstruction; StBO: strangulated bowel obstruction; OR: odds ratio,

Based on the results of multivariate analysis, we built a radiomics scoring system to predict the occurrence of StBO. The area under the curve (AUC) of the receiver operating characteristic (ROC) curve for this model was 0.706 (95% CI, 0.617–0.795) (Figure 3). Furthermore, we observed that the discriminative ability of this model was better when comparing the radiomics score of the 2 group with

the score of the 0 group (54.5% vs. 6.6%). However, it was difficult to separate the radiomics score of the 1 group from the score of the 0 group (12.8% vs. 6.6%) (Supplementary Table 3.).

Multiomics analysis and model construction

Furthermore, we analyzed all essential factors (*p* value<0.05) from clinical characteristics, laboratory tests and radiomics via binary logistic regression. To obtain better discrimination ability, we transformed three factors, bowel sounds, potassium level and radiomics score, into two categories of variables. Finally, we found that pain duration (OR= 3.775), rebound tenderness (OR= 5.201), bowel sounds (OR = 5.006), levels of potassium (OR= 3.696), sodium (OR= 3.753) and BUN (OR=4.349) and radiomics score (OR=11.264) were independent risk factors for the prediction of StBO (*p* value<0.05, Table 3). Based on the regression coefficient for each factor, we constructed a multiomics model with an AUC value of 0.857 (95% CI: 0.793-0.920) (Figure 4, model formula is shown in Figure 7). A nomogram was also drawn to directly calculate the probability of the occurrence of StBO (Figure 5). As the risk factors accumulated, the incidence of StBO dramatically increased.

Table 3
Multi-omics analysis for StBO

	Multivariate analysis		
characteristics	Regression coefficient	OR (95%*CI*)	*p*-value
Pain duration(≤3 days)	1.328	3.775(1.429-9.973)	**0.007**
Rebound tenderness	1.649	5.201(2.241-12.069)	**<0.001**
Low-to-absent bowel sounds	1.611	5.006(1.244-20.151)	**0.023**
Low potassium	1.307	3.696(1.184-11.533)	**0.024**
Low sodium	1.323	3.753(1.483-9.498)	**0.005**
High BUN	1.470	4.349(1.793-10.552)	**0.001**
High radiomic score	2.422	11.264(4.086-31.047)	**<0.001**
BUN: blood urea nitrogen; OR: odds ratio; *CI*: confidence interval			

Validation of multiomics models for the prediction of StBO

Patients were further divided into three groups based on the fourth quartile of the multiomics model scores: a low risk group (risk scores≤-3.091, n=71), a medium risk group (-3.091< risk scores ≤-1.472, n=130) and a high risk group (risk scores>-1.472, n=67). Obviously, strangulated bowel was rarely observed in patients in the low-risk group (1%), but it was strongly associated with patients in the high-risk group (45%) (Figure 5). The predictive value for the two cutoff points was as follows: a sensitivity of 97.6% and specificity of 40.0% for a lower score (-3.091) and a sensitivity of 71.4% and specificity of

83.6% for a score of -1.472. Moreover, to evaluate the properties of the model for predicting the degree of ischemia, we stratified the patients into a simple bowel ischemia group and a transmural necrosis group (Figure 6). The proportion of patients with transmural necrosis was significantly greater in the high-risk group (24%) than in the medium-risk group (3%). No transmural necrosis was found in the low-risk group.

Discussion

SBO is always a dilemma for emergency surgeons in providing care. First, delayed surgery for StBO leads to severe complications such as intestinal ischemia, necrosis, perforation, peritonitis, sepsis, and multiple organ failure, with a dramatically increased mortality of 20%-40%[28]. However, unnecessary surgery for SiBO may aggravate the formation of adhesive bands. The prompt and accurate diagnosis of StBO still poses challenges for clinicians.

Previous studies have confirmed the discriminative efficacy of CT findings in the diagnosis of StBO, especially the presence of mesenteric fluid, ascites, edema of the bowel wall and whirl signs in CTA[12, 13, 20, 29]. Similarly, in our radiomics analysis, mesenteric fluid, ascites, bowel spiral signs and edema of the bowel wall in emergency CT scans seemed closely related to StBO. Based on multivariate analysis, only ascites and bowel spiral signs were independent risk factors for StBO. This might be due to the classical characteristics of high metabolic activity and terminal artery perfusion in the small intestine mucosa. In the presence of mechanical SBO with mesenteric spirals, the permeability of the impaired mucosa increases[23, 27], which results in the transudative loss of fluid from the lumen into the peritoneal cavity. According to our etiology analysis, volvulus and hernias occupied a greater proportion of factors in StBO than in SiBO (Supplementary Table 1). Moreover, with the stasis of intestinal contents and bowel dilation, it may evolve into low or absent bowel sounds when SBO is aggravated, which could account for low-to-absent bowel sounds as an independent risk factor for StBO. The AUC of the radiomics model based on emergency CT scans in our study reached only 0.706. In addition, CTA has been recommended as the gold standard for the diagnosis of bowel ischemia, with AUCs ranging from 0.87 to 0.91[8, 30]. The limitations include the potential risk of nephropathy induced by iodine, high costs and unavailability for most primary medical institutions[18], which hamper the performance of CTA.

Furthermore, we developed a multiomics model based on clinical features, laboratory tests and radiomics for the prediction of StBO. Once strangulated bowel develops, with increasing translocation of bacterial products from the intestinal lumen to blood circulation, a severe inflammatory response, including leukocytosis and neutrophilia, tends to occur[27, 31]. Similar to our findings, the levels of WBC and NE% were much higher in the StBO group, and the symptom of peritonitis with rebound tenderness was confirmed as an independent risk factor for StBO. An imbalance between the absorption and secretion of impaired intestinal mucosa also triggers electrolyte disturbances[2, 32]. In our multiomics model, we defined hyponatremia, hypokalemia and rising levels of BUN as independent risk factors for StBO. In addition, insufficient renal perfusion due to extrasecretion in the intestinal lumen and the accumulation of lactic acid produced by intestinal anaerobic glycolysis deteriorate renal function with increasing levels of BUN in peripheral blood[21, 33]. Consequently, the distal convoluted tubule response to aldosterone

results in the reabsorption of Na+ by exchanging K+ or H+, thus, hyponatremia and hypokalemia occur[2]. Usually, unlike a long pain duration indicating a chronic and reversible phase of disease, a short pain duration might indicate a status of acute and severe inflammation. Comprehensively, we constructed a multiomics model for the prediction of StBO based on seven risk factors, including a radiomics score, pain duration, bowel sounds, rebound tenderness, and the levels of sodium, potassium and BUN. The AUC of this multiomics model was 0.857 (95% CI: 0.793-0.920), which was much higher than that of the model that only consisted of radiomics[15] and equal to that of the previous CTA model[8, 30] (Supplementary Table 5). According to a previous study, we calculated the scores of our multiomics model by summing the respective regression coefficients of the risk factors[21]. The formula is shown in Figure 7. Furthermore, a nomogram was also constructed to reveal the weights for each factor, and radiomics played a dominant role in predicting StBO. Secondary to radiomics, the clinical symptoms were found to be crucial factors in the prediction of StBO.

Recently, most studies have focused on the prediction of bowel transmural necrosis in AMI[21, 22, 34], and few studies have focused on StBO. Although great advancements have been made in the detection of novel biomarkers associated with bowel ischemia[35–39], only I-FABP and PCT have been focused on in the prediction of bowel transmural necrosis with unsatisfactory accuracy[38, 39]. Here, by stratifying all patients into low-risk, medium-risk and high-risk groups according to their multiomics scores (Figure 6), we revaluated the discriminative ability of the multiomics model for the prediction of transmural necrotic bowel obstruction. Excitedly, our models showed great efficacy not only for identifying patients with StBO but also recognizing transmural necrosis. Patients with bowel ischemia were primarily observed in the high-risk group, and the proportion of patients with bowel transmural necrosis was significantly higher than that in the medium-risk group. No transmural necrosis cases were found in the low-risk group. Only one patient in the low-risk group developed bowel ischemia without necrosis (Supplementary Table 4), which proved mild ischemia in this case. Additionally, another four patients with bowel transmural necrosis were observed in the medium-risk group. Although the specificity of our model largely improved with the rising score endpoint, there inevitably existed a loss of sensitivity, which is a shortcoming of the model. However, aggressive exploration is of greater importance than passively waiting for patients to show signs of suspected bowel transmural necrosis. Constant and dynamic observation is also necessary for patients in the low- or medium-risk group.

The limitations of the present study are as follows. First, this study was a retrospective study conducted in a single center. Second, some parameters may not be identified due to the small-scale sample. Further efforts are needed in large-scale and porspective studies.

Conclusion

The novel multiomics model consisting of risk factors for pain duration, rebound tenderness, bowel sounds, potassium, sodium, and BUN levels and radiomics offers a useful tool for predicting StBO. Clinical management can be performed according to the multiomics score; for patients with low risk (scores≤ -3.91), conservative treatment is recommended. For the high-risk group (risk scores> -1.472),

there was a strong suggestion for detection with laparotomy. For the remaining patients (-3.091< risk scores ≤ -1.472), dynamic observation is suggested.

Abbreviations

StBO**,** Strangulated bowel obstruction; SiBO, Simple bowel obstruction; ROC, Receiver operating characteristic; AUC, area under the curve; AMI, acute mesentery ischemia; BMI, body mass index; WBC, white blood cell; NE%, neutrophil percentage; PCT, procalcitonin; BUN, blood urea nitrogen; PT, prothrombin time; DDI, D-dimer. CTA, computed tomography angiography.

Declarations

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Author contributions

Conceptualization: Jun-rong Zhang, Wei-xuan Xu and Xian-qiang Chen; **Data curation**: Wei-xuan Xu, Qi-hong Zhong, Yong Cai, and Can-hong Zhan; **Formal analysis**: Jun-rong Zhang, Wei-xuan Xu, and Shuai Chen; **Funding acquisition**: Jun-rong Zhang, Ping Hou and Xian-qiang Chen; **Investigation**: Wei-xuan Xu, Qi-hong Zhong, Yong Cai, and Can-hong Zhan; **Methodology**: Jun-rong Zhang, Lin Lin, Ying-qian Geng, Xian-qiang Chen and Hui Wang; **Project administration**: Xian-qiang Chen, Jun-rong Zhang and Wei-xuan Xu; **Resources**: Jun-rong Zhang, Ping Hou, Xian-qiang Chen; **Software**: Jun-rong Zhang and Wei-xuan Xu; **Supervision**: Xian-qiang Chen; **Validation**: Wei-xuan Xu, Qi-hong Zhong, Yong Cai, and Can-hong Zhan; **Visualization**: Jun-rong Zhang, Qi-hong Zhong and Wei-xuan Xu; **Roles/Writing – original draft**: Jun-rong Zhang and Wei-xuan Xu; **Writing – review & editing**: Jun-rong Zhang, Wei-xuan Xu.

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Availability of data and materials

We have not filed for permission to publish the study material.

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Fujian Medical University Union Hospital.

Consent for publication

All authors approve this version for publication and are accountable for its content.

Competing interests

The authors have no competing interests to declare

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Figures

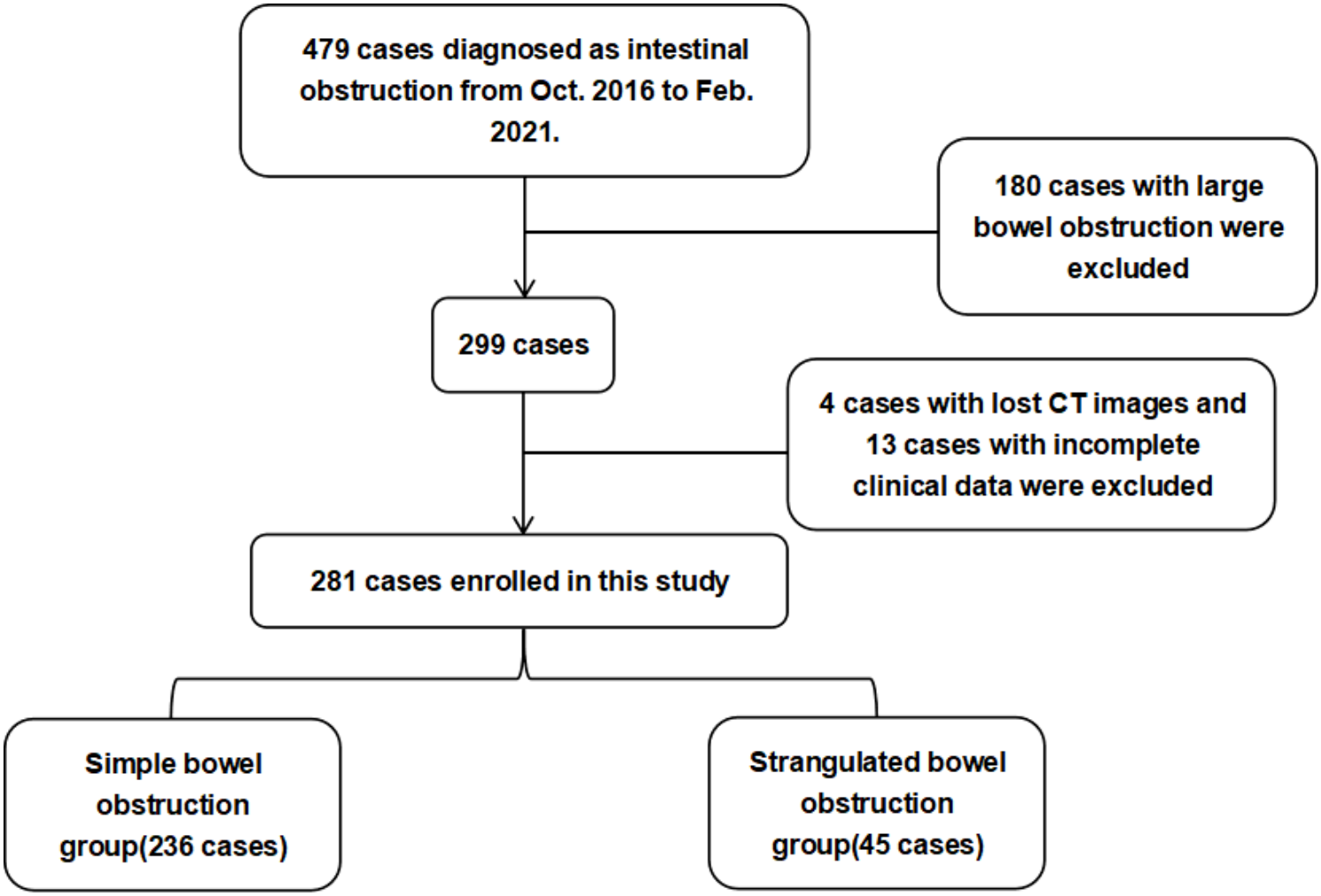

Figure 1

Workflow of this study.

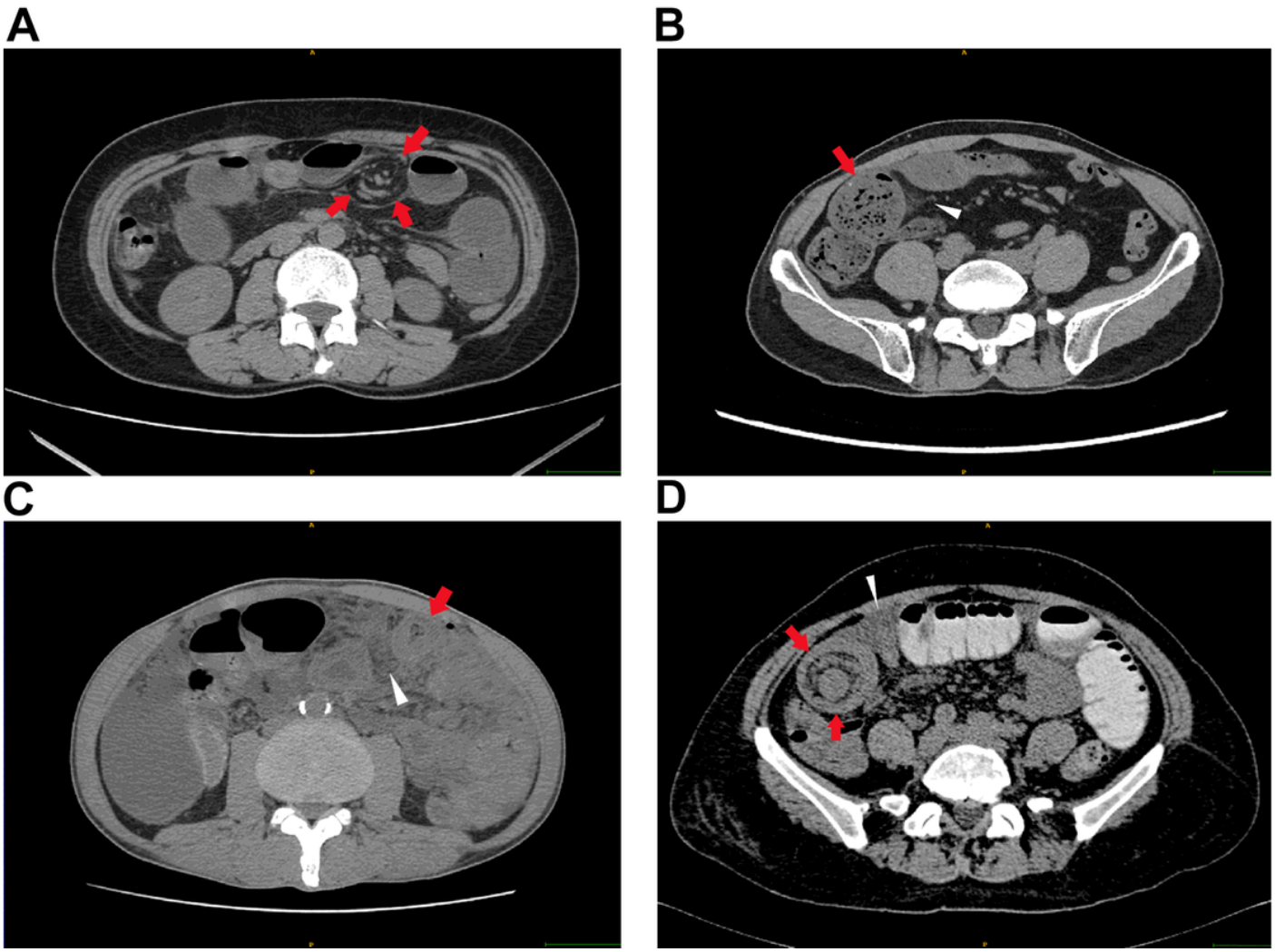

Figure 2

Images of CT findings. A. a 49-year-old woman with adhesive small bowel obstruction. Axial CT of the abdomen confirmed the spiral sign of small bowel (red arrow). B. a 51-year-old man with adhesive small bowel obstruction. Axial CT of the pelvis confirmed the small bowel feces sign(red arrow) and the mesenteric fluid (white triangle). C. a 51-year-old man with inflammatory small bowel obstruction. Dilated, thickened loops of small bowel (red arrow) and mesenteric fluid (white triangle) could be observed. D. a 70-year-old woman with intussusception. Axial CT images showed the concentric circle sign of small bowel (red arrow) and ascites (white triangle).

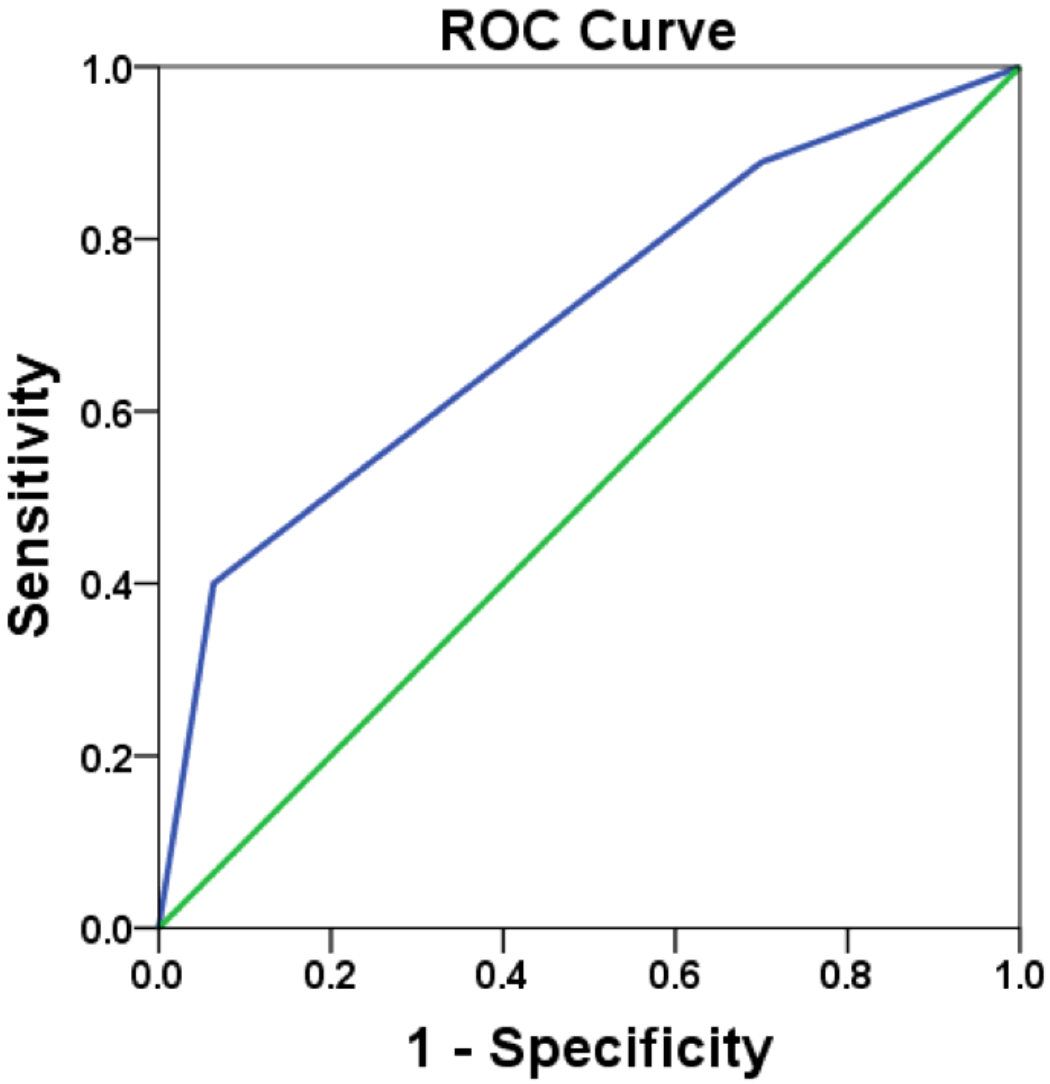

Figure 3

Receiver operating characteristic (ROC) curve for the radiomics prediction model. The area under the curve was 0.706(95% CI,0.617-0.795).

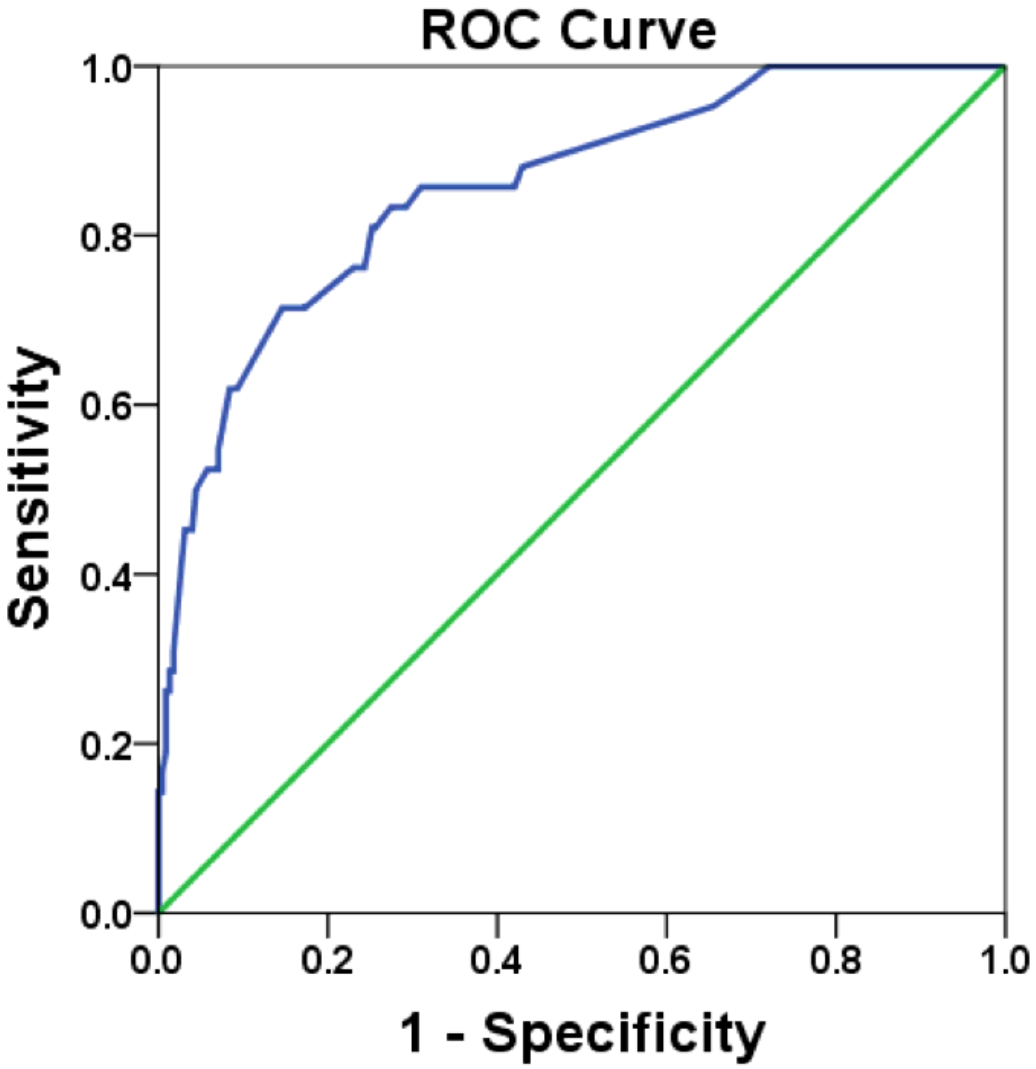

Figure 4

Receiver operating characteristic (ROC) curve for prediction model of combination of clinical characteristics and radiomics. The area under the curve was 0.857(95% CI,0.793–0.920).

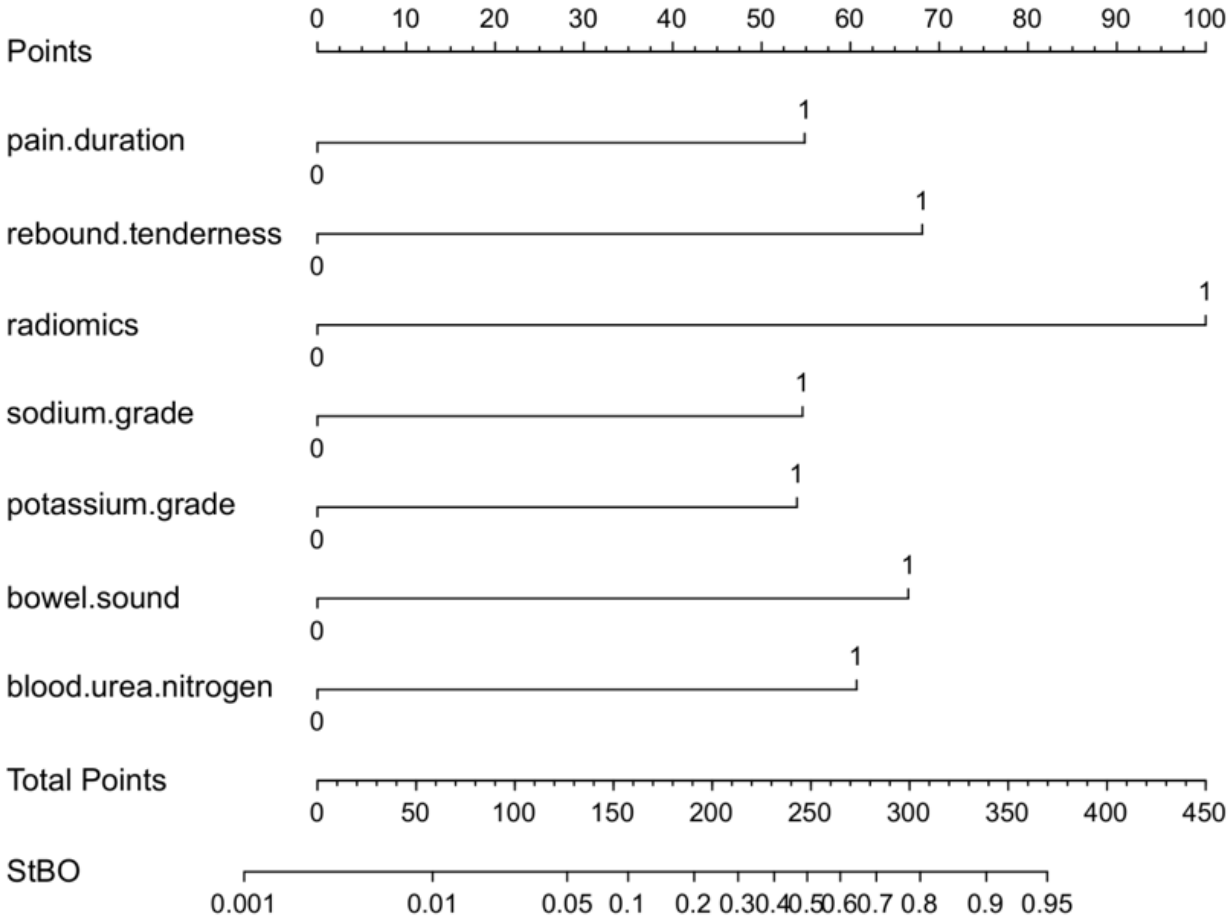

Figure 5

Nomogram for the predictive multi-omics model of StBO.

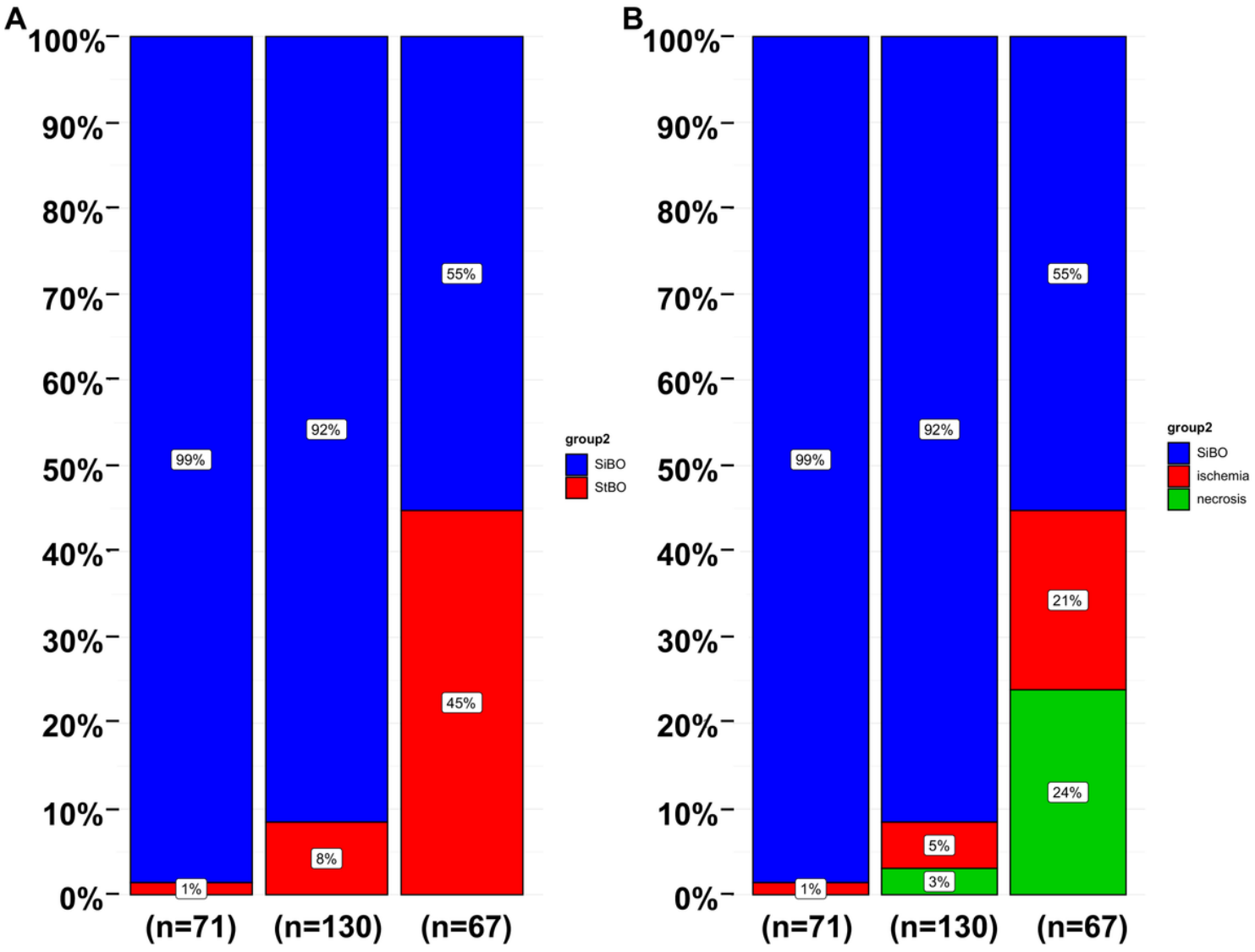

Figure 6

Validation of multi-omics models for prediction of StBO in different status.

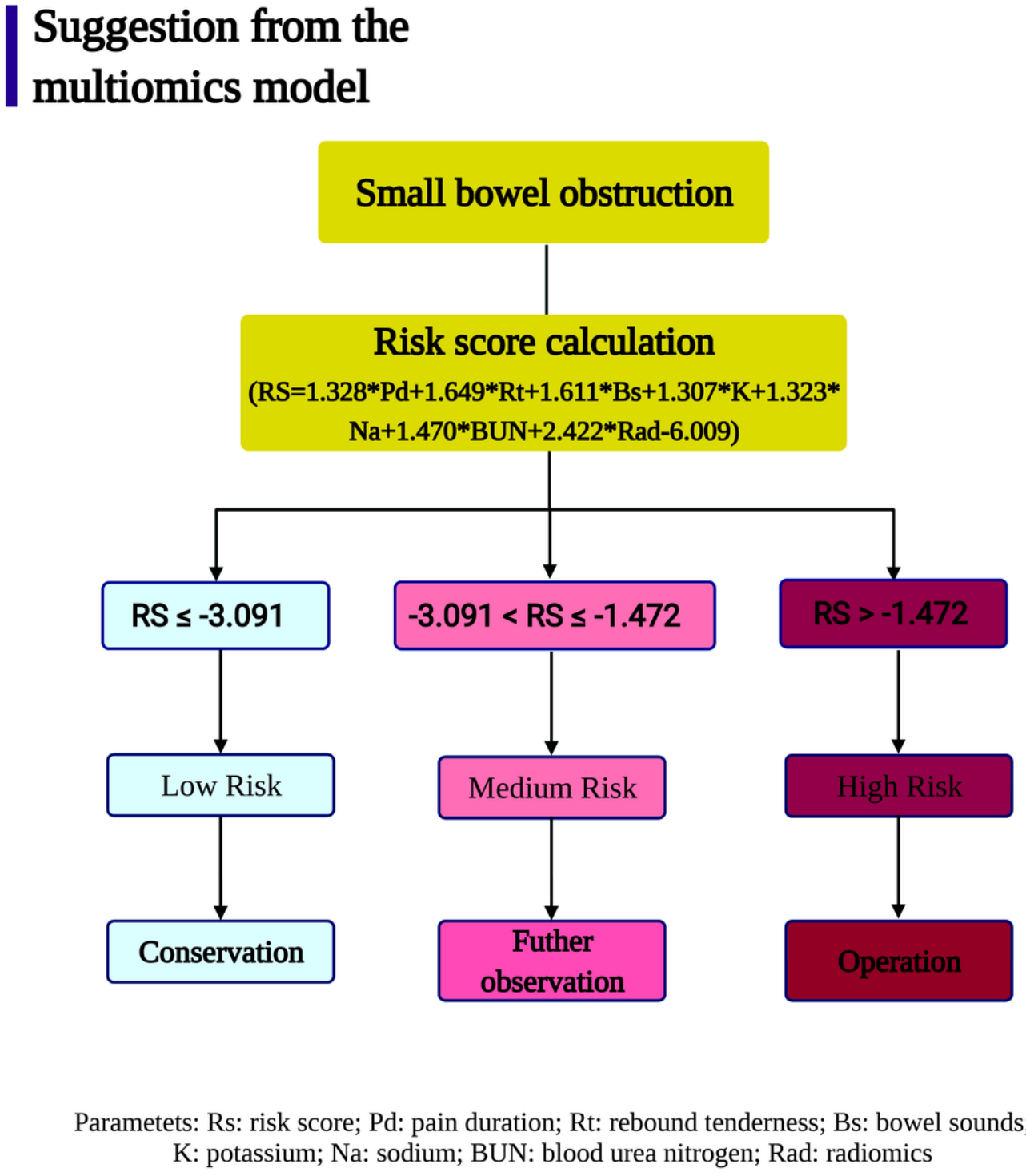

Figure 7

Proposal management for different calculated scores deriving from patient information. Rs: risk score; Pd: pain duration; Rt: rebound tenderness; Bs: bowel sounds; K: potassium; Na: sodium; BUN: blood urea nitrogen; Rad: radiomics

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarytables.docx