ORIGINAL ARTICLE

Incidence of adhesive small bowel obstruction after gastrectomy for gastric cancer and its risk factors: a long-term retrospective cohort study from a high-volume institution in China

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Abstract

Adhesive small bowel obstruction (ASBO) has a significant impact on quality of life and medical costs. However, data about ASBO after gastrectomy remain sparse. From January 2009 to December 2017, 3025 patients who underwent gastrectomy for gastric cancer were retrospectively collected and analyzed. Clinicopathological materials were obtained retrospectively, and univariate and multivariate regression analyses were performed to determine risk factors for ASBO. A nomogram for the prediction of ASBO was generated using the results of multivariable analyses. Bootstraps with 1000 resamples were performed for internal validation. The performance of the model was assessed with its discrimination, calibration, and clinical usefulness. A total of 330 (10.9%) patients experienced at least one ASBO episode with a median follow-up of 57.0 (interquartile range 31.0–85.0) months. Logistic regression analysis showed that independent risk factors for ASBO were previous abdominal surgery (odds ratio, OR = 2.03), open gastrectomy (OR = 3.12), non-Billroth-1 reconstruction (Billroth-2, OR = 2.61; Roux-en-Y, OR = 1.99; esophagogastrostomy, OR = 2.79), D2/D2 + lymphadenectomy (OR = 2.64), combined organ resection (OR = 2.76), and postoperative intraabdominal complication (OR = 2.73). The nomogram showed good discrimination, with a C-index of 0.702 and good calibration. Decision curve analysis demonstrated that the nomogram was clinically useful. Several risk factors associated with ASBO after gastrectomy for gastric cancer were identified. Nomogram generated based on these factors could serve as a reliable tool to predict the probability of ASBO.

Keywords Gastric cancer · Small bowel obstruction · Adhesion · Risk model

Tao Pan, Danil Galiullin, and Xiao-Long Chen have contributed equally to this work.

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Introduction

Small bowel obstruction is a common reason for admission worldwide, accounting for approximately 17% emergency admissions to a surgical service [1]. In the United States, total healthcare costs associated with it are estimated to exceed 2 billion dollars annually [2]. Approximately 75% of small bowel obstructions are due to intraabdominal adhesions, usually as a consequence of previous operation [3]. Adhesions are thought to occur in almost 95% of all abdominal operations [4], and are related to tissue trauma, the subsequent inflammatory response, and healing process [5].

Gastric cancer is the second leading cause of cancer death and the fourth most common cancer worldwide [6]. Gastrectomy with curative resection has been considered as the mainstay of treatment strategy [6]. Patients underwent gastrectomy experience gastrointestinal manipulation, lymphadenectomy, and damage to the normal anatomy of

peritoneum and mesentery. As such, the likelihood of ASBO is increased in these patients. However, there have been few studies [7–9] and no large cohort study about the incidence of ASBO after gastrectomy for gastric cancer. In addition, these studies were limited by heterogeneity of the causes of small bowel obstruction (adhesions, obstructive tumor, incarcerated hernia, etc.).

Therefore, we designed the study to specifically investigate the incidence of ASBO after gastrectomy for gastric cancer and analyze the perioperative risk factors for it in a large cohort with long-term follow-up. Determining the modifiable risk factors for ASBO will guide medical providers to prevent this complication. We also developed a predictive nomogram for the future identification of risk of ASBO.

Method

Study population

A total of 3743 consecutive patients who underwent potentially curative gastric cancer surgery from January 2009 to December 2017 were extracted from the database of Surgical Gastric Cancer Patient Registry in West China Hospital (Authorized by Surgical Treatment Group of Gastric cancer under registration number: WCH-SGCPR-2020-3). The establishment of this database was approved by the Research Ethics Committee of West China Hospital. Since the retrospective nature of the study, informed consent was waived. However, patient records were anonymized and de-identified before analysis.

The inclusion criteria were as follows: (1) preoperative upper gastrointestinal endoscopy and biopsy confirmed gastric cancer; (2) preoperative examinations confirmed no distant metastasis. The exclusion criteria were: (1) palliative surgery or exploration; (2) remnant gastric cancer; (3) patients died within 30 days after gastrectomy; (4) patients diagnosed with ASBO or unexplained bowel obstruction within 5 years prior to gastrectomy for gastric cancer; (5) patients with incomplete medical data; (6) patients lost to follow-up. Finally, a total of 3025 patients were enrolled in the study. The diagram is summarized in Fig. 1.

Clinicopathological materials

The demographic and surgical-related parameters of the patients, including gender, age, body mass index (BMI), previous abdominal surgery, surgical approach, surgical

Fig. 1 Patient inclusion and exclusion criteria. *ASBO* adhesive small bowel obstruction
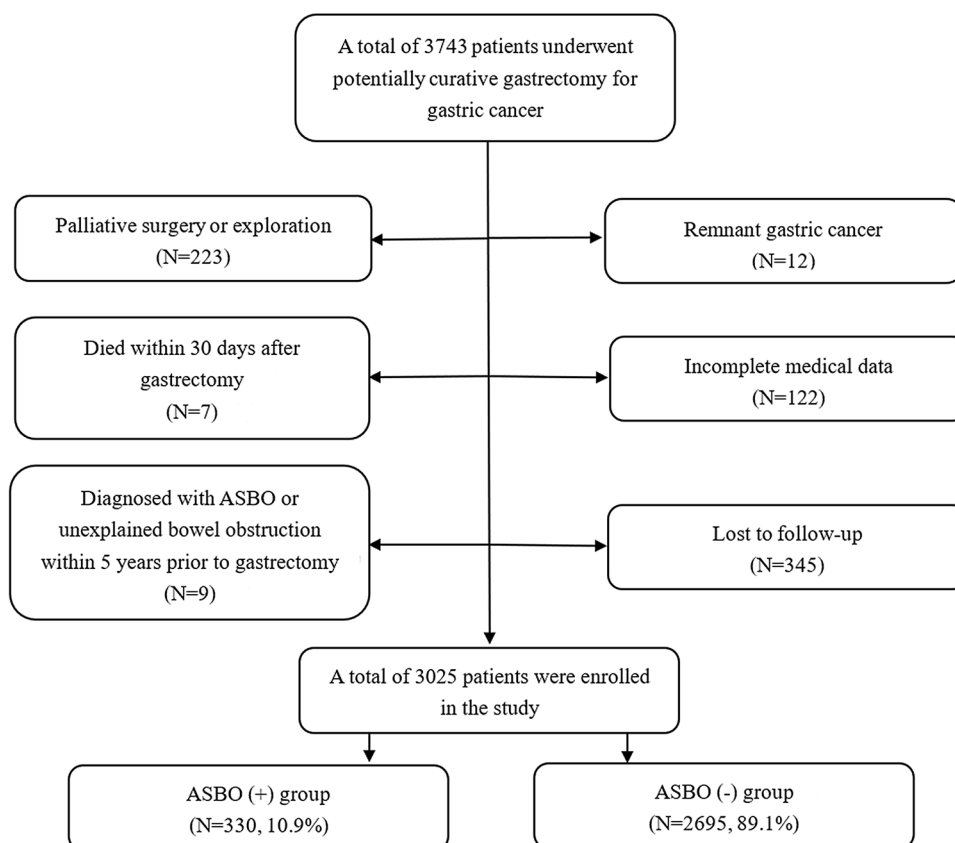
procedure, reconstruction method, number of retrieved lymph nodes, extent of lymphadenectomy, combined organ resection, tumor size (cm), macroscopic type, the pathological TNM stage, perioperative blood transfusion, postoperative intensive-care unit (ICU) admission, postoperative surgical complications, postoperative intraabdominal complications, postoperative non-surgical complications, postoperative hospital stay (day), reoperation after gastrectomy, and postoperative chemotherapy, were retrieved for analysis.

The pathological TNM stage was recorded according to the 8th staging manual of American Joint Committee on Cancer [10]. Postoperative complications were defined as any deviation from the normal postoperative course [11]. The severity of postoperative complications was determined according to the Clavien–Dindo classification [11].

Postoperative complications included surgical complications and non-surgical complications. Surgical complications were defined as one of the following events during the postoperative course: wound problem, anastomotic/stump leakage, intraabdominal collections/abscesses, traumatic pancreatitis, lymphatic leakage, intraabdominal bleeding, intraluminal bleeding, ileus, and cholecystitis. Postoperative complications other than surgical complications were defined as non-surgical complications.

Surgical technique

The principles of gastrectomy were based on the Japanese Gastric Cancer Treatment Guidelines [12, 13]. Intraoperative frozen section was routinely performed to secure tumor-free margins. Standard D2 lymphadenectomy was routinely adopted, while D2 + lymphadenectomy was adopted if the nodes beyond the D2 tier were suspicious for metastasis and D1/D1 + lymphadenectomy was selectively adopted for tumors in early stage. Surgical procedure was determined intraoperatively according to the tumor location and the margin of safety. For the reconstruction, esophagogastrostomy was adopted in proximal gastrectomy and Roux-en-Y anastomosis in total gastrectomy. Billroth-1 anastomosis, Billroth-2 anastomosis, and Roux-en-Y anastomosis were adopted in distal gastrectomy according to the surgeons' preference and experience. Combined organ resection was selectively performed for the purpose of curative resection, or for patients with other comorbidities (such as cholecystectomy for gallbladder stone).

Follow-up

Patients were systematically followed up through consultations or phone calls. All patients were followed up at 6 months in the first 3 years and annually thereafter. The latest follow-up information was updated on Jan 1, 2020. Duration of follow-up was recorded as time from gastrectomy until time of death, or latest follow-up, whichever came first.

Definition of ASBO

ASBO was confirmed by surgery or based on a combination of clinical symptoms (nausea, vomiting, abdominal pain, abdominal distension, and the absence of defecation or flatus in the previous 24 h), physical findings (abdominal tenderness, accentuation of bowel sounds, and tympanitic sounds on percussion), and positive radiologic findings on abdominal X-ray and/or abdominal computed tomography (CT) scans (small bowel distension with air-fluid level). The etiology for the obstruction was determined on the findings at operation and imaging. Patients with small bowel obstruction due to reasons other than adhesions (such as mesenteric defect internal hernia, carcinomatosis, etc.) were not considered to have developed ASBO. Patients were classified into the ASBO (+) group if they had any episode of ASBO after gastrectomy; otherwise, the patients were classified into the ASBO (−) group (Fig. 1).

Statistical analysis

Statistical analysis was performed using the statistical software package R version 3.6.1 (http://www.r-project.org/) and SPSS 20.0 (SPSS®, Chicago, IL, USA). Continuous variables are reported as the mean ± standard deviation, while categorical variables are reported as number and percentage. A logistic regression analysis was applied to test univariate and multivariate associations between variables to investigate risk factors for ASBO. The risk of ASBO for the respective groups over time was calculated using Kaplan–Meier method, and the differences among them were calculated using log-rank test. A nomogram for the prediction of ASBO was generated using the results of multivariable analyses and the rms package in R. Bootstraps with 1000 resamples were performed for internal validation of the nomogram. The predictive performance of the nomogram was determined by Harrell's concordance index (C-index). Calibration plot was generated to assess the calibration of the nomogram. A

decision curve analysis was generated to evaluate the clinical usefulness of the nomogram. A p value < 0.05 was considered significant.

Results

Baseline characteristics

A total of 3743 consecutive patients who underwent potentially curative gastric cancer surgery from January 2009 to December 2017 were extracted from the database of Surgical Gastric Cancer Patient Registry in West China Hospital. Finally, a total of 3025 patients were included for analysis. These patients had a mean age of 58.2 ± 11.3 years and a male predominance (69.3%). The median follow-up was 57.0 (interquartile range 31.0–85.0) months. The baseline characteristics are indicated in Table 1. The detailed information on previous abdominal surgery and postoperative complication is indicated in Supplementary Table 1 and Supplementary Table 2, respectively.

Incidence of ASBO after gastrectomy for gastric cancer

A total of 330 patients (10.9%) experienced at least one episode of ASBO. The mean time to the first episode of ASBO was 18.2 ± 17.1 months after gastrectomy. Among 330 ASBO patients, 31 patients (9.4%) had recurrent ASBO. 273 patients (82.7%) were managed non-operatively, while 57 patients (17.3%) required operation for their obstruction. These involved laparotomy and lysis of adhesions without bowel resection in 44 patients (13.3%) and with bowel resection in 13 patients (4.0%). The cumulative incidence of ASBO is shown in Fig. 2a. The 3- and 5-year cumulative incidences of ASBO were 10.2% and 12.2%, respectively.

Risk factors for ASBO after gastrectomy for gastric cancer

Table 2 shows the results of univariate and multivariate logistic regression analyses for the relationship between factors and ASBO. The results showed that previous abdominal surgery [odds ratio (OR) = 2.03, 95% confidence interval (95% CI) 1.55–2.66, $p < 0.001$], open gastrectomy (OR = 3.12, 95% CI 2.10–5.55, $p < 0.001$), non-Billroth-1 reconstruction (Billroth-2, OR = 2.61, 95% CI 1.63–4.16, $p < 0.001$; Roux-en-Y, OR = 1.99, 95% CI 1.22–3.25, $p = 0.008$; esophagogastrostomy, OR = 2.79, 95% CI 1.60–4.90, $p < 0.001$), D2/D2 + lymphadenectomy (OR = 2.64, 95% CI 1.77–3.94, $p < 0.001$), combined organ resection (OR = 2.76, 95% CI 1.88–4.06, $p < 0.001$), and postoperative intraabdominal complication (OR = 2.73, 95%

Table 1 Baseline characteristics of entire cohort

Characteristics	$N = 3025$
Gender	
Male	2097 (69.3%)
Female	928 (30.7%)
Age at gastrectomy*	
Years	58.2 ± 11.3
BMI*	
kg/m^2	22.1 ± 2.9
Previous abdominal surgery	
No	2494 (82.4%)
Yes	531 (17.6%)
Surgical approach	
Laparoscopic	454 (15.0%)
Open	2571 (85.0%)
Surgical procedure	
Distal gastrectomy	1866 (61.7%)
Total gastrectomy	825 (27.3%)
Proximal gastrectomy	332 (11.0%)
Reconstruction method	
Billroth-1	472 (15.6%)
Billroth-2	1316 (43.5%)
Roux-en-Y	905 (29.9%)
Esophagogastrostomy	332 (11.0%)
Number of retrieved lymph nodes*	31.1 ± 13.8
Extent of lymphadenectomy	
D1/D1 +	578 (19.1%)
D2/D2 +	2447 (80.9%)
Combined organ resection	
No	2855 (94.4%)
Yes	170 (5.6%)
Tumor size*	
Cm	4.8 ± 2.7
Macroscopic type	
Early gastric cancer	680 (22.5%)
Borrmann-1	61 (2.0%)
Borrmann-2	1100 (36.4%)
Borrmann-3	1034 (34.2%)
Borrmann-4	150 (4.9%)
Pathological TNM stage	
I	801 (26.5%)
II	781 (25.8%)
III	1443 (47.7%)
Perioperative blood transfusion	
No	2656 (87.8%)
Yes	369 (12.2%)
Postoperative ICU admission	
No	2760 (91.3%)
Yes	265 (8.7%)
Postoperative surgical complication	
No	2728 (91.2%)
Yes	297 (9.8%)

Table 1 (continued)

Characteristics	$N = 3025$
Postoperative intraabdominal complication	
No	2905 (96.0%)
Yes	120 (4.0%)
Postoperative non-surgical complication	
No	2649 (87.6%)
Yes	376 (12.4%)
Postoperative hospital stay*	
Day	10.8 ± 3.9
Postoperative chemotherapy	
No	1224 (40.5%)
Yes	1801 (59.5%)
ASBO	
Not	2695 (89.1%)
Yes	330 (10.9%)

Values in parentheses are percentages unless indicated otherwise; *values are mean ± standard deviation; *BMI* body mass index, *ICU* intensive-care unit, *ASBO* adhesive small bowel obstruction

CI 1.74–4.28, $p < 0.001$) were significant independent risk factors for ASBO.

The results of Kaplan–Meier analysis for each risk factor are shown in Fig. 2b–g. The 5-year cumulative incidences for previous abdominal surgery history, open gastrectomy, Billroth-1 reconstruction, D2/D2 + lymphadenectomy, combined organ resection, and postoperative intraabdominal complication were 19.3% (vs 10.7%, without previous abdominal surgery), 13.1% (vs 4.7%, laparoscopic gastrectomy), 4.3% (vs 15.1%, Billroth-2 reconstruction; vs 11.8%, Roux-en-Y reconstruction; vs 12.6%, esophagogastrostomy), 13.5% (vs 5.6%, D1/D1 + lymphadenectomy), 27.3% (vs 10.9%, without combined organ resection), and 29.2% (vs 11.4%, without postoperative intraabdominal complication), respectively.

Nomogram and validation

A nomogram for the prediction of ASBO was generated using the results of multivariable analyses (Fig. 3). The predictive model was internally validated using the bootstrap validation method. The nomogram demonstrated good accuracy in estimating the probability of ASBO, with a C-index of 0.702. In addition, model fit was assessed using a bias-corrected calibration plot with 1000-sample bootstrapping for the prediction of ASBO (Fig. 4a). The calibration plot showed adequate fit of the model predicting the risk of ASBO.

Clinical usefulness

The decision curve analysis for the nomogram is presented in Fig. 4b. This analysis indicated that, when the threshold probability is within the range 0.22–0.96, using the nomogram to predict ASBO adds more net benefit than the treat-all or treat-none strategies.

Discussion

The marked morbidity and mortality incidences and the healthcare costs highlight the importance of ASBO. The present study was the first large cohort study with a long-term follow-up that specifically investigated the incidence of ASBO and its risk factors after gastrectomy. Numerous and wide-ranging potential risk factors were included and analyzed. Identified risk factors for ASBO were used to generate a nomogram that was able to predict the probability of ASBO.

In the present study, we excluded patients who died within 30 days after gastrectomy and those with remnant gastric cancer. The reason why we excluded patients who died within 30 days after gastrectomy was that ASBO was a relatively long complication after gastrectomy [14]. For remnant gastric cancer, it differs from primary gastric cancer in the following aspects. First, compared with primary gastric cancer, the staging system and guidelines for remnant gastric cancer are not fully established [15]. Second, remnant gastric cancers are mostly limited to the upper third of the stomach [16]. Since lymph nodes were completely removed at the initial operation, all lymphatic flow from the remnant stomach reportedly goes to the greater curvature, regardless of its location. Therefore, total gastrectomy with splenectomy is recommended for remnant gastric cancer [17]. Third, the mean interval after surgeries for gastric cancer is approximately 10 years. Therefore, the majority of patients with remnant gastric cancer are elderly, a population usually has several comorbidities [18]. Considering the above factors, if remnant gastric cancer was included for analysis, many confounding factors would be introduced.

In the present study, postoperative ASBO occurred in 10.9% of gastric cancer patients. The reported incidence of ASBO after gastrectomy for gastric cancer ranged from
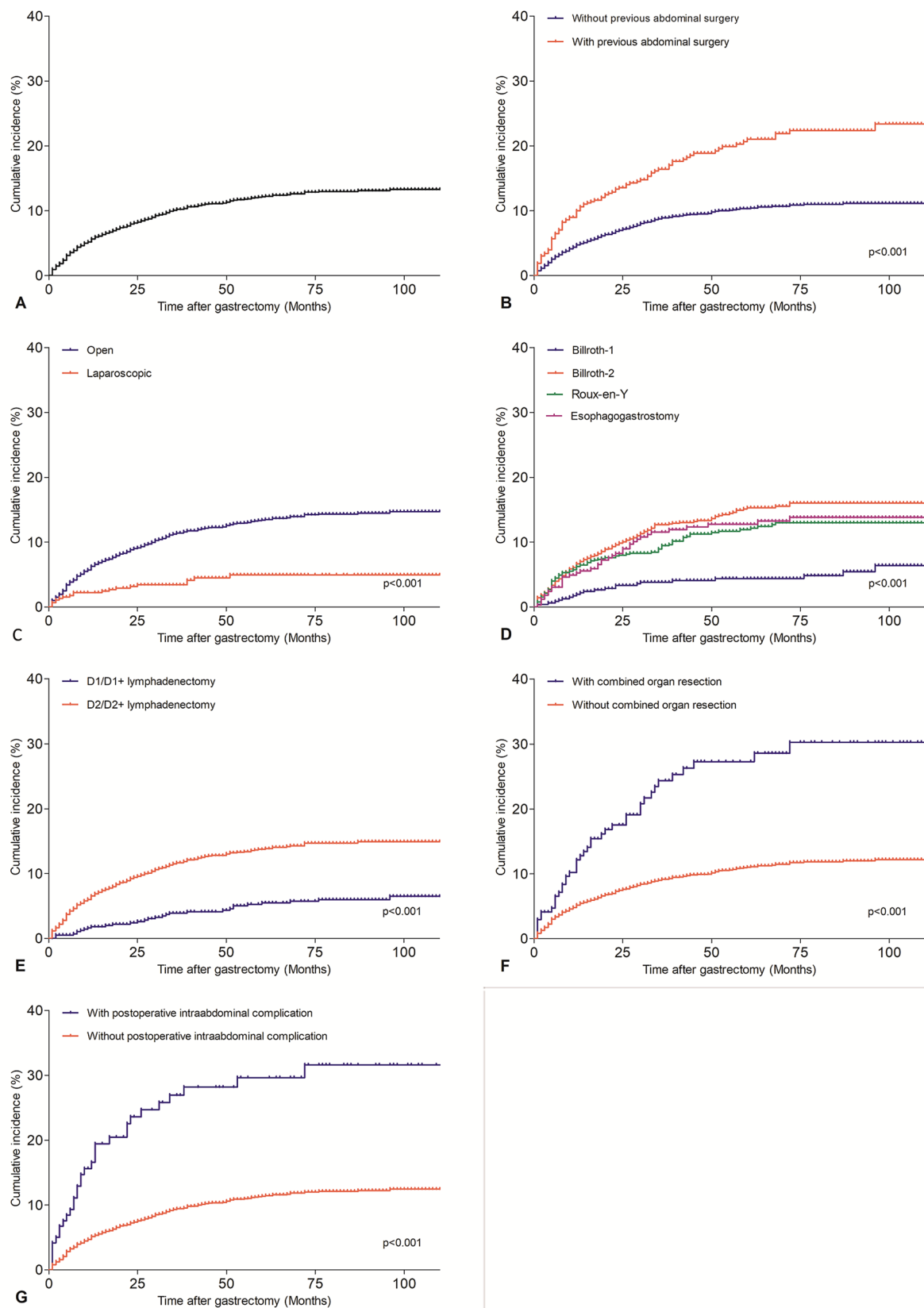
◄Fig. 2 Kaplan–Meier analysis of each risk factor and the log-rank test among respective groups. **a** Total patients; **b** previous abdominal surgery (with vs. without); **c** surgical approach (open vs. laparoscopic); **d** reconstruction method (Billroth-1 vs. Billroth-2 vs. Roux-en-Y vs. esophagogastrostomy); **e** extent of lymphadenectomy (D1/D1 + vs. D2/D2 +); **f** combined organ resection (with vs. without); **g** postoperative intraabdominal complication (with vs. without)

6.3% to 11.0% in the previous studies [7–9]. Our reported incidence seems consistent with those reported in the previous studies. However, the studies were limited by small sample size, short follow-up, and heterogeneity of the causes of small bowel obstruction. Even the largest study conducted by Inaba et al. included only 395 patients [7]. There was only one study that addressed the risk factors for small bowel obstruction after gastrectomy [9]. The study included only 136 patients for analysis, and the causes of small bowel obstruction included adhesions and incarcerated hernias. Our study was designed to specifically investigate the incidence of ASBO after gastrectomy for gastric cancer in a large cohort with long-term follow-up to overcome these shortcomings.

The study also identified several independent risk factors for ASBO after gastrectomy for gastric cancer. The first factor was surgical approach. Three clinical trials have investigated the impact of surgical approach on the incidence of ASBO following colorectal cancer surgery, but have reported mixed results. The LAFA study [19] showed a protective effect of laparoscopic surgery, while the COLOR [20] and CLASICC [21] trials did not show a statistically significant effect. However, all of the clinical trials were limited by short follow-up and small sample size. These trials had between 2 and 5 years of follow-up and the largest trial involved 786 patients. The highest reported incidence of ASBO in the three trials was 5.2%, a relatively rare incidence. Therefore, a larger number of patients and longer follow-up are needed to achieve sufficient statistical power. In contrast, a recent meta-analysis has demonstrated a protective effect of laparoscopic approach for several abdominal surgeries [22]. Possible reasons for this is that laparoscopic approach involves less tissue trauma and shorter incisions, leads to less bleeding, and reduces the potential for contamination and desiccation of the bowel [23]. An experimental study has also shown that carbon dioxide insufflation may have anti-inflammatory properties, further decreasing the probability of adhesion formation [24].

In the present study, D2/D2 + lymphadenectomy, combined organ resection, and postoperative intraabdominal complication were also identified as independent risk factors for ASBO. Nowadays, D2 lymphadenectomy has been widely accepted as the standard procedure for gastric cancer patients, since it has been proved to improve the overall survival and reduce the risk of tumor recurrence [25]. In our center, D2 + lymphadenectomy was adopted if the nodes beyond the D2 tier were suspicious for metastasis and D1/D1 + lymphadenectomy was selectively adopted for tumors in the early stage. Combined organ resection was selectively performed for the purpose of curative resection, or for patients with other comorbidities. It is generally accepted that the risk of ASBO depends largely on the magnitude of the operation [26]. To our knowledge, this was the first study that demonstrated an association between postoperative complication and ASBO. Postoperative intraabdominal complications are related to peritoneal inflammation, intraabdominal tissue ischemia, and presence of blood, bile, or feces. All of these factors have been demonstrated to be key factors in the formation of adhesions in the previous studies [26, 27].

Interestingly, Billroth-1 reconstruction was found to be a protective factor for ASBO. The possible reasons why Billroth-2 and Roux-en-Y reconstruction lead to more ASBOs than Billroth-1 reconstruction are as follows. First, Billroth-1 reconstruction involves only one anastomosis site without stumps, while Billroth-2 and R-Y involve more anastomosis sites or stumps. Anastomosis site and stump might elicit stronger local inflammatory response, which in turn eventually have resulted in more adhesions. Second, both Billroth-2 reconstruction and Roux-en-Y reconstruction have potential internal hernia defects, while Billroth-1 reconstruction does not [28]; therefore, it is possible that some of the ASBOs may have been caused by mesenteric defect internal hernia, although we excluded bowel obstructions that were caused by mesenteric defect internal hernia as far as possible. The reasons why esophagogastrostomy leads to more ASBOs than Billroth-1 reconstruction are as follows. The splenic flexure of colon may move upward the spleen recess after esophagogastrostomy, which may cause the small bowel to move upward the surgical site, resulting in adhesions between the small bowel and the surgical site.

Table 2 Univariate and multivariate logistic regression analyses for the relationship between factors and ASBO

Factors	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p	OR (95% CI)	p
Gender				
Female	1.00 (reference)			
Male	1.02 (0.80–1.31)	0.876		
Age at gastrectomy (years)				
<65	1.00 (reference)			
≥65	0.82 (0.59–1.14)	0.614		
BMI (kg/m^2)				
<25	1.00 (reference)			
≥25	1.23 (0.88–1.71)	0.228		
Previous abdominal surgery				
No	1.00 (reference)			
Yes	2.21 (1.71–2.86)	<0.001[*]	2.03 (1.55–2.66)	<0.001[*]
Surgical approach				
Laparoscopic	1.00 (reference)			
Open	3.55 (1.96–5.76)	<0.001[*]	3.12 (2.10–5.55)	<0.001[*]
Surgical procedure				
Distal gastrectomy	1.00 (reference)			
Total gastrectomy	0.90 (0.69–1.18)	0.901		
Proximal gastrectomy	1.13 (0.79–1.61)	0.510		
Reconstruction method				
Billroth-1	1.00 (reference)			
Billroth-2	3.10 (1.96–4.89)	<0.001[*]	2.61 (1.63–4.16)	<0.001[*]
Roux-en-Y	2.40 (1.49–3.87)	0.001[*]	1.99 (1.22–3.25)	0.008[*]
Esophagogastrostomy	2.83 (1.63–4.95)	<0.001[*]	2.79 (1.60–4.90)	<0.001[*]
Extent of lymphadenectomy				
D1/D1+	1.00 (reference)			
D2/D2+	3.14 (2.06–4.52)	<0.001[*]	2.64 (1.77–3.94)	<0.001[*]
Combined organ resection				
No	1.00 (reference)			
Yes	3.36 (2.34–4.81)	<0.001[*]	2.76 (1.88–4.06)	<0.001[*]
TNM stage				
I	1.00 (reference)			
II	0.91 (0.67–1.25)	0.574		
III	0.92 (0.70–1.21)	0.568		
Perioperative blood transfusion				
No	1.00 (reference)			
Yes	0.78 (0.54–1.14)	0.203		
Postoperative ICU admission				
No	1.00 (reference)			
Yes	1.16 (0.80–1.67)	0.436		
Postoperative surgical complication				
No	1.00 (reference)			
Yes	1.27 (0.89–1.81)	0.197		
Postoperative intraabdominal complication				
No	1.00 (reference)			
Yes	2.90 (1.88–4.45)	<0.001[*]	2.73 (1.74–4.28)	0.001[*]
Postoperative non-surgical complication				
No	1.00 (reference)			
Yes	1.56 (1.14–2.18)	0.005[*]	1.37 (0.99–1.86)	0.057

Table 2 (continued)

Factors	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p	OR (95% CI)	p
Postoperative hospital stay (days)				
< 11	1.00 (reference)			
≥ 11	1.60 (1.27–2.01)	< 0.001[*]	1.17 (0.92–1.50)	0.203

[*]Significant risk factor ($p < 0.05$); *ICU* intensive-care unit, *OR* odds ratio, *CI* confidence interval

To our knowledge, this was the first nomogram model to predict the probability of ASBO. Medical providers could make an individualized prediction of the probability of ASBO with this easy-to-use model, which is consistent with the current trend toward personalized medicine [29]. We can identify which patients were at high risk for ASBO based on the nomogram. First, for high-risk patients, the possibility of ASBO should always be considered when typical symptoms occur. The patients are advised to seek medical advice as soon as possible, which may help to avoid some serious complications, such as bowel necrosis. Second, there were several randomized clinical trials on ASBO prevention, such as the use of bioresorbable membrane [8]. This nomogram may provide shreds for future studies. In our personal opinion, risk factors that were incorporated into this nomogram should be balanced before inclusion. Third, we have identified six risk factors for ASBO in the present study. Take surgical approach as an example, laparoscopic gastrectomy was a protective factor for ASBO in the study. Several randomized-controlled trials have demonstrated laparoscopic distal gastrectomy did not result in inferior disease-free survival among patients with both preoperative clinical stages indicating early [30] and locally advanced gastric cancer [31]. Then, upon achieving radical resection and surgical safety, surgeons could adopt laparoscopic gastrectomy for these patients without contraindications to reduce the risk of ASBO.

The most important argument for the use of the model is based on the need to interpret an individual's need for additional care or treatment. However, the calibration and discrimination cannot capture the clinical consequences of particular degrees of miscalibration or levels of discrimination [32]. Therefore, instead of the multicenter prospective validation of the model, which is largely impractical, we applied decision curve analysis to justify the clinical usefulness in the study. The decision curve demonstrated that using the nomogram in the present study to predict the probability of ASBO is more beneficial than the treat-all or the treat-none strategies if the threshold probability of a patient is within 0.22–0.96.

The study also has some limitations. First, the study is a monocentric retrospective cohort study, it is questionable whether these findings can be applied to other hospitals. Second, our model has not been validated externally. However, we used bootstrapping, which has been shown to provide stable estimates with low bias [33], to internally validate our model, which provided good optimism adjusted estimates of its predictive capability. Furthermore, decision curve analysis demonstrated that the nomogram was clinically useful.

Conclusions

In the present study, several risk factors associated with ASBO after gastrectomy for gastric cancer were identified. Nomogram generated based on these factors could serve as a reliable tool to predict the probability of ASBO. These findings may provide health care providers' warnings about risk factors for ASBO after gastrectomy, and they may also be useful for further research on the prevention and treatment of ASBO.
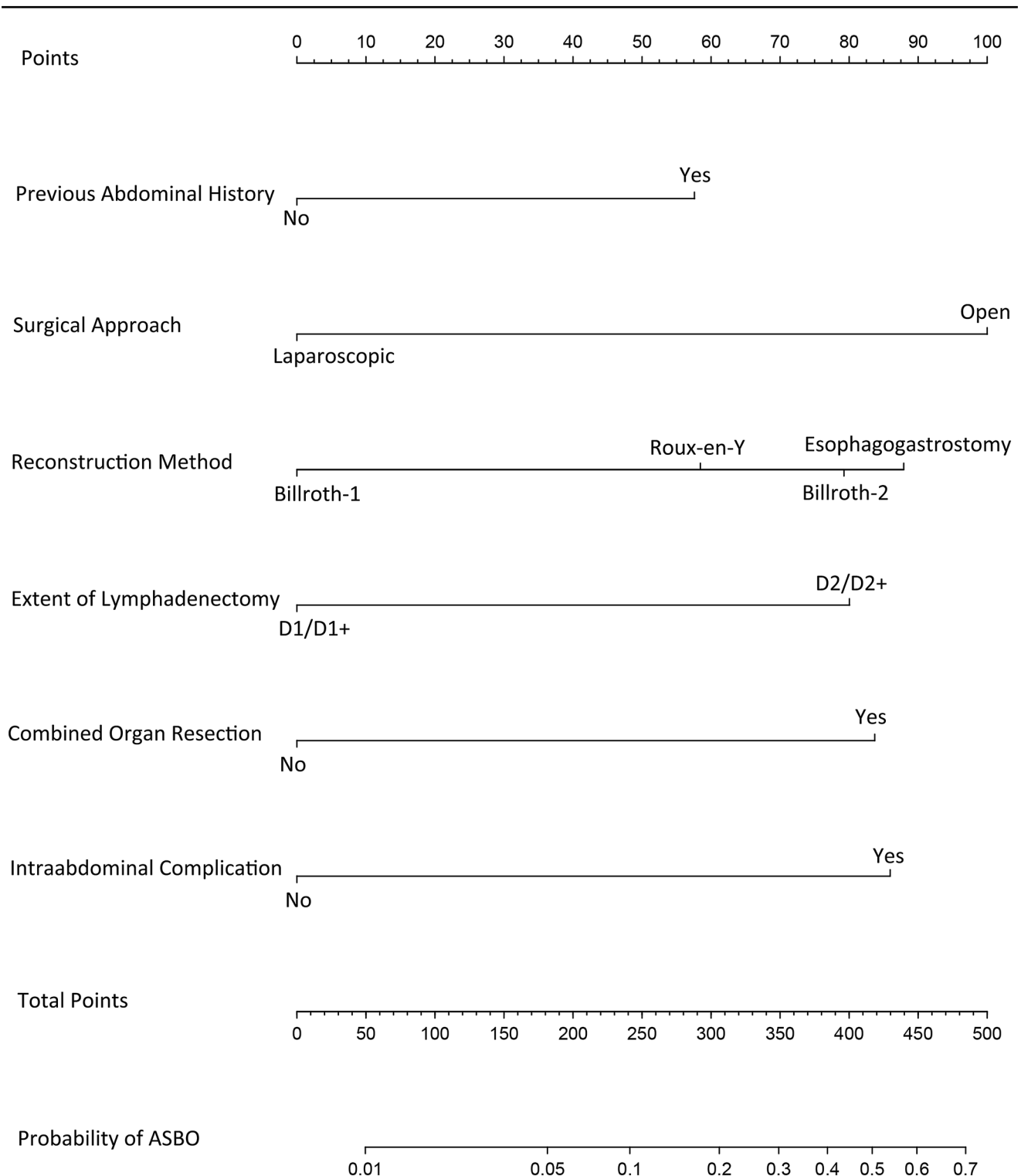
Points

Previous Abdominal History

Surgical Approach

Reconstruction Method

Extent of Lymphadenectomy

Combined Organ Resection

Intraabdominal Complication

Total Points

Probability of ASBO

Fig. 3 Nomogram predicting the probability of adhesive small bowel obstruction (ASBO). For an individual patient, points for each of the six risk factors are summed to give a total point. The horizontal axis representing the total points is then used to calculate the corresponding probability of ASBO
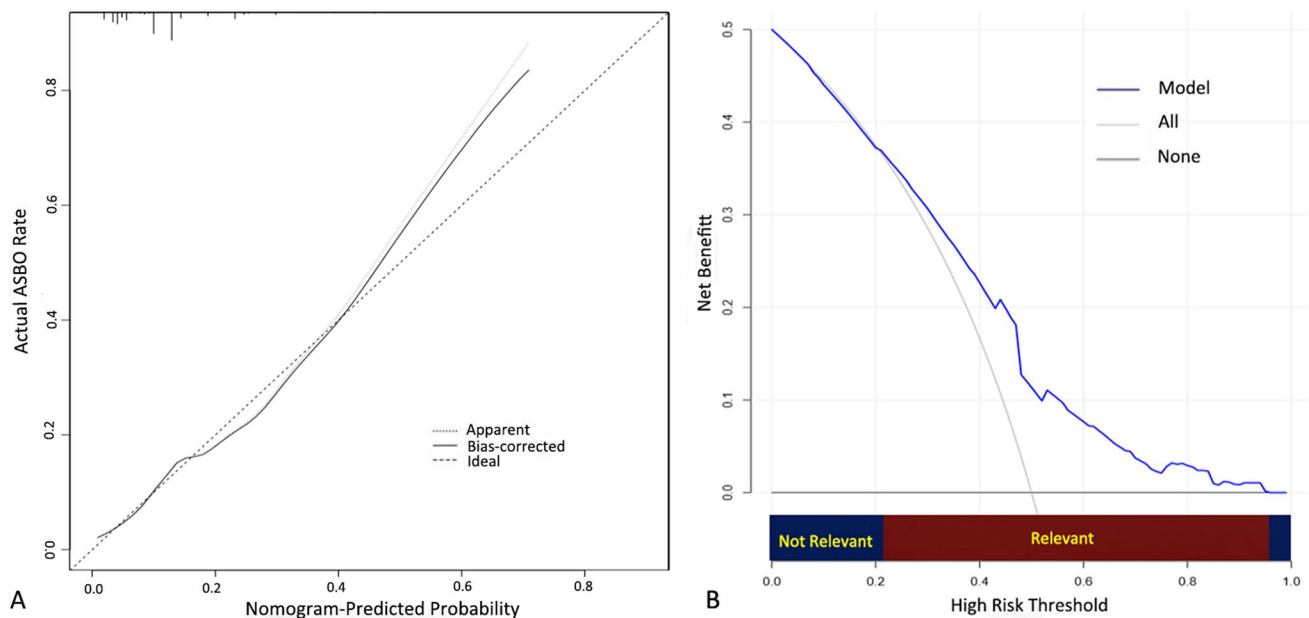
Fig. 4 **a** Calibration plot for nomogram prediction of adhesive small bowel obstruction (ASBO) after gastrectomy for gastric cancer. **b** Decision curve analysis for the nomogram. The *y*-axis represents net benefit. The *x*-axis shows the threshold probability. "All" refers to the assumption that all patients develop ASBO and "None" to the assumption that no patient develops ASBO. When the score is within the range 0.22–0.96 (Relevant), using the nomogram to predict ASBO adds more net benefit than the treat-all or treat-none strategies

Compliance with ethical standards

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