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Original Research Article

Risk Assessment of Stoma Outlet Obstruction Development when a Temporary Ileostomy is Created during Rectal Cancer Surgery

Chiharu Yasui, Kyoichi Kihara, Ryo Ishiguro, Takuki Yagyu, Yusuke Kono, Manabu Yamamoto, Tomoyuki Matsunaga, Naruo Tokuyasu, Teruhisa Sakamoto and Yoshiyuki Fujiwara

Division of Gastrointestinal and Pediatric Surgery, Department of Surgery, School of Medicine, Faculty of Medicine, Tottori University, Yonago, Japan

Abstract

Objectives: In surgery for lower rectal cancer, temporary ileostomy can be created to avoid complications, such as anastomotic leakage. However, various complications may occur with the stoma, including stoma outlet obstruction (SOO). The occurrence of SOO can prolong the length of hospital stay and delay the introduction of adjuvant chemotherapy, which can negatively affect the prognosis. We retrospectively reviewed cases of temporary ileostomy at our hospital and evaluated the risk factors for SOO.

Methods: We extracted data pertaining to patients with temporary ileostomy created during surgery for rectal cancer from 2013 to 2023, and compared clinicopathologic factors or short-term outcomes, with or without SOO complications. We scored the independent factors obtained and created predictive scoring model for SOO.

Results: Total of 107 patients were included. SOO was observed in 21 patients (19.6%), all of whom were male. SOO was most frequently diagnosed on sixth postoperative day. In most cases, feeding resumed 4 days after the diagnosis of SOO. Age (≥67 years; $p = 0.002$), rectus abdominis muscle thickness (≥13.5 mm; $p < 0.001$) and the amount of stoma output greater than 1,500 ml/day within 3 days of surgery ($p < 0.001$) were independent risk factors for SOO. The preoperative and early postoperative predictive scoring model, created by adding one point to each risk factor, predicted SOO with sensitivity of 76.2%, specificity of 89.5%.

Conclusions: Age, gender, rectus abdominis muscle thickness, and high early postoperative output are risk factors for SOO. A scoring model may be useful for predicting SOO.

Keywords

stoma outlet obstruction, ileostomy, high-output stoma

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Introduction

In recent years, surgical techniques for lower rectal cancer have advanced, and more precise surgery is being performed using advanced technologies, such as laparoscopy and robotics. However, the incidence of anastomotic leakage, a serious complication of rectal cancer surgery, is still around 10%[1,2]. Anastomotic leakage leads to acute pan-peritonitis and increases the risk of local recurrence, thereby worsening the patient's prognosis[3-7]. A temporary ileostomy can be created during surgery for lower rectal cancer to reduce the risk of anastomotic leakage. However, the complications of ileostomy include skin and mucous membrane disorders, stoma ischemia, stoma retraction, high-output stoma, paras-

Corresponding author: Chiharu Yasui, yasui.c@tottori-u.ac.jp
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tomal hernia, bowel obstruction and stricture[8,9]. Among these, stoma outlet obstruction (SOO) causes abdominal distension, pain, and vomiting. It is often observed in cases where defecation through the stoma is impossible. In cases of SOO, treatment interventions such as insertion of a decompression tube into the stoma, fasting, or use of a nasal decompression tube may be necessary until symptoms recover. If these conservative treatments do not improve the patient's condition, the worst case would be to have to undergo further surgery. Furthermore, there are cases in which postponing adjuvant chemotherapy or closing the stoma unexpectedly is necessary. For this reason, although this is a complication that should be avoided, SOO occurs in approximately 7.0%-26.0% of patients who have undergone an ileostomy[10-15]. There are several reports on SOO, but there is little consensus on its causes, risk factors, or prevention methods.

In this study, we retrospectively investigated cases of patients who had temporary ileostomy after rectal cancer surgery at our hospital and compared them based on whether or not they had SOO complication and evaluated preoperative and postoperative risk factors. Furthermore, we created a scoring system using risk factors and proposed a method for predicting high-risk patients for SOO.

Methods

Patients

The patients were consecutive patients who underwent curative surgery for rectal cancer and temporary ileostomy simultaneously at Tottori University Hospital between January 2013 and December 2023. The stoma type was loop ileostomy in all cases. Patients with obstructive colitis due to a tumor before surgery or those who underwent stoma creation before rectal surgery were excluded.

Study data

Clinical data of all patients were collected, and the patients were divided into two groups: a group that developed stoma outlet obstruction (SOO group) and a group that did not (non-SOO group). Clinical factors were compared and examined. The items examined were age, gender, body mass index (BMI), American Society of Anesthesiologists performance status (ASA-PS), existence of preoperative chemoradiotherapy, surgical approach (laparotomy/laparoscopy and robot-assisted laparoscopy, TNM stage (UICC/AJCC 8th edition)[16,17], implementation of pelvic lymph node dissection, operation time, intraoperative bleeding volume, and intraoperative infusion volume. Furthermore, the maximum rectus abdominis muscle thickness, the visceral fat area, and the subcutaneous fat area at the level of the umbilicus were assessed using axial section images from computed tomography (CT) scans taken before surgery. We also examined postoperative factors; including the amount of stoma output volume measured daily (24 hours), number of days of hospital stay after surgery, and whether the stoma was closed at the end.

Diagnosis of stoma outlet obstruction

The diagnostic criteria for SOO are shown. SOO was diagnosed in those who met criterion (1), (2), or (3) and criterion (4)[10,15,18]. (1) Symptoms of bowel obstruction, such as abdominal distension, nausea, vomiting, or abdominal pain; (2) X-ray showing dilation of the small intestine near the stoma; (3) CT showing an ileal stricture where the ileostomy passes through the abdominal wall and expansion of the proximal small bowel; (4) Improvement in symptoms and signs of bowel obstruction when a tube is inserted into the ileum proximal to the ileostomy for decompression.

Ileostomy procedure

In all patients for whom an ileostomy was planned, the stoma site was marked before surgery according to the Cleveland Clinic principles. The markings were performed by wound, ostomy, and continence nurses specialized in stoma care, in addition to the surgeons, before surgery. The site of the stoma was in the lower right abdomen, but it was selected based on the patient's body shape and the surgeon's experience. For preoperative mechanical bowel preparation, the patients fasted the day before surgery and were given laxatives. No preoperative antibiotics were administered. This method was consistent across all cases. The ileostomy was created after the mesorectum was completely resected, and anastomosis of the rectum was performed using the double-stapling technique. The procedure of ileostomy was performed after deactivating the pneumoperitoneum during laparoscopy and robot-assisted laparoscopy to avoid oblique passage of small intestine through the rectus muscle. The skin at the stoma site was incised in a circle with a diameter of approximately 2 cm, and the anterior and posterior sheaths of the rectus were incised in a craniocaudal direction. The rectus abdominis muscle is bluntly dissected through the abdominal cavity. The cavity is sufficiently large to fit two fingers. The ileum (30-40 cm proximal to the terminal ileum) was gently pulled to the abdominal wall. At this point, the proximal side of the intestine was opened at 6 o'clock without twisting. After fixing the small intestine to the abdominal wall, a finger was routinely inserted into the intestinal lumen to check for any narrowing.

Postoperative management

Postoperative management was performed according to the clinical pathway. Unless there was a complication, the patients were able to drink water again from the first postoperative day and started eating liquid food from second postoperative day. The meal form was gradually increased according to the patient's food intake condition, and the aim was to have a daily meal by the seventh postoperative day.

Definition of stoma output volume and high-output stoma (HOS)

Stoma output volume was measured from the first postoperative day, and the output volume from the first and third postoperative day was collected in the study. A stoma output volume ≥1,500 ml per day was defined as high-output stoma (HOS)[19,20].

Quantitative evaluation of CT scans

All CT scans were performed using scans obtained before the surgery. In patients who received neoadjuvant therapy, CT used was taken after the neoadjuvant therapy was complete. The slice thickness was between 1 and 5 mm. The rectus abdominis muscle thickness was measured as the length of the thickest part in the axial section of the CT scan. The visceral and subcutaneous fat areas were measured using SYNAPSE VINCENT Ver.6.8 (FUJIFILM, Tokyo, Japan) in the axial section at the level of the umbilicus on the CT scan.

Statistical analysis

Continuous variables are presented as median values. The chi-square test or Fisher's exact test was used to compare categorical variables, and the Mann-Whitney U-test was used to compare continuous variables. Multivariate analysis was performed using logistic regression analysis. For continuous variables, the optimal cut-off value was determined using Receiver Operating Characteristic (ROC) analysis. All variables confirmed to be significant in the univariate analysis were included as candidates for the multivariate analysis. In all analyses, $p < 0.05$ was defined as statistically significant. SPSS Statistics version 2.0 (IBM, Illinois, USA) was used for the statistical analysis.

Ethics approval

All research involving human participants was conducted in accordance with the ethical standards of the Institutional Research Committee and the Helsinki Declaration of 1964 and its subsequent revisions or equivalent ethical standards. This study was approved by the Institutional Review Board of Tottori University Hospital Ethics Committee [21A075].

Consent

Written consent was obtained from all patients and relevant persons (such as the parents or legal guardians) to publish the information, including photographs.

Results

Patient characteristics

A total of 107 patients were included in the study, and the characteristics of the patients are presented in Table 1. The median age of the patients was 66 years, and 85 patients (79.4%) were male. Only 5 patients underwent laparotomy, and the remaining 102 patients underwent minimally invasive surgery (robot-assisted surgery: 59 patients, laparoscopic surgery: 43 patients). A total of 33.6% (n = 36) of patients received neoadjuvant therapy, of whom 72.2% (n = 26) received neoadjuvant chemoradiotherapy. The median abdominal rectus muscle thickness was 11.5 mm. The median total stoma outputs per day were 195, 600, and 690 ml on the first, second, and third postoperative days, respectively. Of these, 28 patients (26.1%) were diagnosed with HOS between day 1 and day 3 (Table 1).

Clinical features of SOO patients

Of the 107 cases, 21 (19.6%) developed SOO after ileostomy. The characteristics of patients who developed SOO are presented in Table 2. The median number of days between surgery and the start of SOO were 6 days. The median maximum stoma output volume before the onset of SOO was 1,350 ml, and 10 patients (47.6%) had HOS before the onset of SOO. In 18 cases (85.7%), CT or X-ray images were used for diagnosis. In 16 patients (76.1%), decompression therapy was performed by inserting a tube into the oral side of the stoma, and the median time to resume eating was 4 days after the diagnosis of SOO. The median length of hospital stay after surgery was 22 days. In 20 patients (95.2%), the stoma was closed later (Table 2). No patients underwent early stoma closure.

Comparison between the SOO and non-SOO groups

The SOO group had a higher proportion of males (100.0% vs. 74.4%; $p = 0.006$), a thicker rectus abdominis muscle (14.5 vs. 11.1; $p < 0.001$), and a higher proportion of patients who developed HOS (stoma output volume ≥1,500 ml/day) within 3 days of surgery (47.6% vs. 20.9%; $p = 0.013$), as well as a longer hospital stay after surgery (22 vs. 14; $p < 0.001$). Conversely, there were no significant differences between the SOO and non-SOO groups in terms of the presence or absence of neoadjuvant therapy (19.0% vs. 37.2%; $p = 0.114$) or the amount of infusion volume of the operation (2,950 vs. 2,950; $p = 0.583$) (Table 3).

Risk factors for SOO

The results of the univariate and multivariate analyses of the risk factors for SOO are presented in Table 4. The cutoff values for the continuous variables were all determined by performing a ROC analysis for each parameter and selecting

Table 1. Patient Characteristics and Surgical Outcomes.

Variables	All patients (n=107)
Age (years)	66 (30-85)
Gender (male)	85 (79.4%)
BMI (kg/m^2)	23.0 (16.5-36.4)
ASA-PS (1/2/3)	22/69/16
Rectus abdominis muscle thickness (mm)	11.5 (7.2-20.0)
Visceral fat area (cm^2)	106.6 (6.6-418.7)
Subcutaneous fat area (cm^2)	111.2 (3.3-320.4)
Neoadjuvant therapy (chemotherapy/chemoradiotherapy)	10/26
Surgical approach (laparotomy/laparoscopy and robot-assisted laparoscopy)	5/102
TNM Stage (I, II/III, IV)	72/35
Pelvic lymph node dissection	7 (6.5%)
Operation duration (min)	402 (242-835)
Operation blood loss (ml)	20 (5-1,055)
Operation infusion volume (ml)	2,950 (1,150-7,900)
Stoma output volume at day 1 (ml)	195 (5-3,370)
Stoma output volume at day 2 (ml)	600 (0-5,280)
Stoma output volume at day 3 (ml)	690 (0-4,290)
High output (output volume ≥1,500 ml/day) within 3 days of surgery	28 (26.1%)
Hospital stay after surgery (days)	15 (8-93)
Stoma closure after surgery	98 (91.6%)

BMI: body mass index; ASA-PS: American Society of Anesthesiologists performance status
Data are presented as median (range) or number (percentage).

Table 2. Clinical Data of Patients with Stoma Outlet Obstruction.

Clinical data	Obstruction (n=21)
Days of stoma outlet obstruction diagnosis (days)	6 (1-13)
Max volume of stoma output before stoma outlet obstruction (ml)	1,350 (40-2,550)
High output (output volume ≥1,500 ml/day) before stoma outlet obstruction	10 (47.6%)
Patient symptoms (distention/nausea/abdominal pain) *1	17/12/5
Diagnostic methods (CT/X-ray/clinical findings)	12/6/3
Intervention (insertion of decompression tube/long tube/only fasting)	14/2/5
Days until oral intake resumed (days)	4 (2-12)
Complications (anastomotic leakage/infection/others/no complication) *1	2/5/1/11
Hospital stay after surgery (days)	22 (14-61)
Stoma closure after surgery	20 (95.2%)

CT: Computed tomography, *1: overlapped.
Data are presented as median (range) or number (percentage).

the values with the highest sensitivity and specificity. The areas under the curve of age (AUC), BMI, rectus abdominis muscle thickness, and subcutaneous fat area, found to be significant in univariate analysis, were 0.606, 0.617, 0.734, and 0.561, respectively. The results of the univariate analysis showed that age (≥67 years; $p = 0.046$), BMI (≥23.1; $p = 0.03$), rectus abdominis muscle thickness (≥13.5 mm; $p < 0.001$), subcutaneous fat area (≥81.9 cm^2; $p = 0.036$) and the presence of HOS within 3 days of surgery were risk factors for SOO. Furthermore, the results of the multivariate analysis of these items showed that age (≥67 years; $p = 0.002$), rectus abdominis muscle thickness (≥ 13.5 mm; $p < 0.001$) and the presence of HOS within 3 days of surgery were considered independent risk factors for SOO (Table 4).

Predictive scoring model for SOO

Based on the results of the multivariate analysis, we created an original scoring system to predict the risk of SOO. We assigned a score of 1 point for each of the following criteria if they were met: age; ≥67 years, gender; male, rectus abdominis muscle thickness; ≥13.5 mm, HOS within 3 days of surgery. The reason for assigning a point to each item was that the odds ratios (OR) in the multivariate analysis were all similar (12.435-13.731) (Table 4). Among them, we

Table 3. A Comparison between Stoma Outlet Obstruction and Clinicopathological Features.

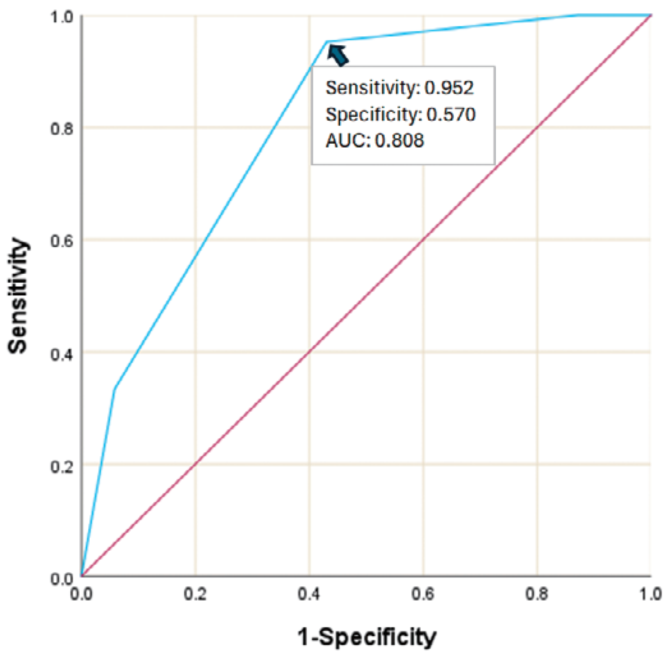
Clinical Characteristics	Stoma outlet obstruction		*p*-Value
	Yes (n=21)	No (n=86)	
Age (years)	69 (30-85)	65 (35-84)	0.134
Gender (male/female)	21/0	64/22	0.006**
BMI (kg/m^2)	24.2 (17.7-28.9)	22.75 (16.5-36.4)	0.097
ASA-PS (1/2 or 3)	6/15	16/70	0.368
Rectus abdominis muscle thickness (mm)	14.5 (9.1-17.3)	11.1 (7.2-19.8)	<0.001***
Visceral fat area (cm^2)	120.5 (12.1-227.5)	98.4 (6.6-418.7)	0.249
Subcutaneous fat area (cm^2)	115.6 (3.3-216.0)	111.2 (4.9-320.4)	0.384
Neoadjuvant therapy (yes/no)	4/17	32/54	0.114
Surgical Approach (laparotomy/laparoscopy and robot-assisted laparoscopy)	1/20	4/82	1.000
TNM Stage (I, II/III, IV)	12/9	60/26	0.269
Pelvic lymph node dissection (yes/no)	2/19	5/81	0.621
Operation duration (min)	426 (277-835)	391 (242-767)	0.435
Operation blood loss (ml)	15 (5-440)	20 (5-1,055)	0.620
Operation infusion volume (ml)	2,950 (1,950-5,300)	2,950 (1,150-7,900)	0.583
Stoma output volume at day 1 (ml)	180 (15-1,935)	198 (5-3,370)	0.772
Stoma output volume at day 2 (ml)	850 (0-3,140)	510 (25-5,280)	0.345
Stoma output volume at day 3 (ml)	800 (0-2,550)	688 (35-4,290)	0.947
High output (output volume ≥1,500 ml/day) within 3 days of surgery	10/11	18/68	0.013*
Hospital stay after surgery (days)	22 (14-61)	14 (8-93)	<0.001***
Stoma closure after surgery (yes/no)	20/1	78/8	0.685

BMI: body mass index; ASA-PS: American Society of Anesthesiologists performance status
The data are presented as median (range) or number of patients.
*: p < 0.05, **: p < 0.01, ***: p < 0.001.

Table 4. Univariate and Multivariate Analyses of Stoma Outlet Obstruction (SOO).

Clinicopathological features	Univariate analysis			Multivariate analysis		
	OR	95%CI	*p*-Value	OR	95%CI	*p*-Value
Age (≥67 years)	2.778	1.018-7.576	0.046*	12.435	2.556-60.501	0.002**
Gender (male)	IC	IC	IC			
BMI (≥23.1)	3.158	1.118-8.917	0.030*	1.685	0.327-8.671	0.533
ASA-PS (≥2)	1.750	0.558-5.213	0.315			
Rectus abdominis muscle thickness (≥13.5 mm)	6.596	2.359-18.443	<0.001***	13.731	3.058-61.660	<0.001***
Visceral fat area (≥96.9 cm^2)	2.500	0.886-7.051	0.083			
Subcutaneous fat area (≥81.9 cm^2)	5.089	1.110-23.339	0.036*	7.524	0.904-62.625	0.062
Neoadjuvant therapy (yes)	0.397	0.123-1.284	0.123			
Surgical approach (laparoscopy and robot-assisted laparoscopy)	0.976	0.103-9.212	0.983			
TNM stage (III, IV)	1.731	0.650-4.608	0.272			
Pelvic lymph node dissection (yes)	1.705	0.307-9.468	0.542			
Operation duration (≥478 min)	2.054	0.765-5.514	0.153			
Operation blood loss (≥103 ml)	3.812	0.926-15.690	0.064			
Operation infusion volume (≥3,775 ml)	2.187	0.760-6.298	0.147			
High output (output volume ≥1,500 ml/day) within 3 days of surgery	3.434	1.261-9.351	0.016*	13.000	2.925-57.774	<0.001***

BMI: body mass index; ASA-PS: American Society of Anesthesiologists performance status
IC: incalculable because none of the women developed SOO
OR: odds ratio; 95%CI: 95% confidence interval
*: p < 0.05, **: p < 0.01, ***: p < 0.001.



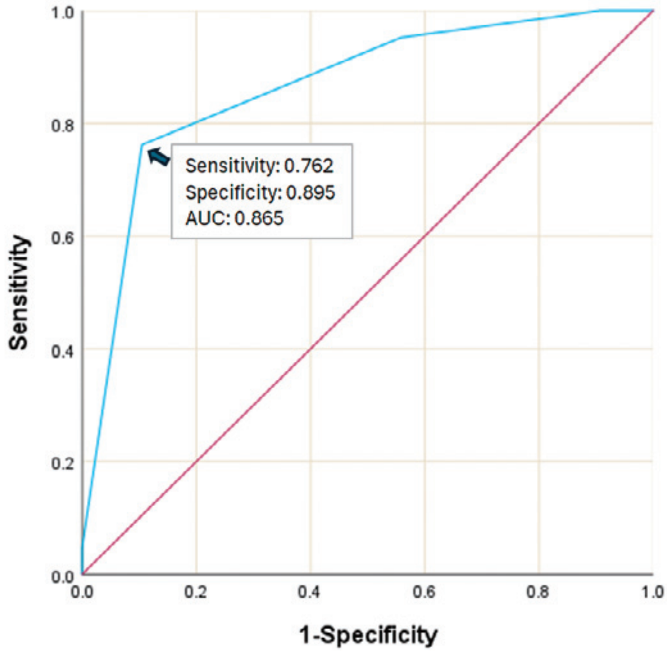
Scoring		Score
Age (years)	≥67	1
	<67	0
Gender	male	1
	female	0
Rectus abdominis muscle thickness (mm)	≥13.5	1
	<13.5	0
	total	3

Figure 1. ROC curve showing the preoperative prediction score for stoma outlet obstruction (SOO).
The preoperative prediction score for SOO was created using the following three items: age; ≥67 years, gender; male, rectus abdominis muscle thickness; ≥13.5 mm. Each item was scored 1 point, out of 3 points, and ROC analysis was performed for SOO occurrence. The AUC of the preoperative prediction score for SOO was 0.808 ($p < 0.001$), with a cut-off value of 1.5, sensitivity of 95.2%, and specificity of 57.0%.
ROC: Receiver operating characteristic, AUC: Area under the curve

created a preoperative prediction score (3 criteria) for SOO based on the preoperative factors of age, gender, and rectus abdominis muscle thickness. As a result of the ROC analysis, the AUC of the preoperative prediction score (3 items) was 0.808 ($p < 0.001$), and the cut-off value was 1.5 (sensitivity: 95.2% specificity: 57.0%) (Figure 1). In other words, if the preoperative prediction score (3 items) is ≥2 points, the risk of SOO is high. Furthermore, we created a preoperative and early postoperative prediction score (4 criteria) for SOO, with the additional criteria of HOS within 3 days of surgery added to the preoperative factors. The ROC analysis showed that the AUC for the preoperative and early postoperative prediction score (4 items) was 0.865 ($p < 0.001$), and the cut-off value was 2.5 (sensitivity: 76.2%, specificity: 89.5%) (Figure 2). This indicates that if the preoperative and early postoperative prediction score (4 items) is ≥3 points, the risk of SOO is high. Conversely, as the specificity is also high, if the score ≤2 points, the risk of SOO is low.

Discussion

The etiology of SOO was recognized earlier, and in the 1950s, the phenomenon accompanied by abdominal pain and excessive stoma output was also called “ileostomy dysfunction”[21]. Subsequently, obstruction at the stoma outlet was reported, and it became widely known that SOO is one of the causes of bowel obstruction after ileostomy[22]. Ileostomy is mainly performed during low anterior resection or intersphincteric resection for lower rectal cancer, with the aim of preventing anastomotic leakage after surgery by preventing feces from passing through the anastomosis site. The effectiveness of this method for creating temporary ileostomy was demonstrated in a meta-analysis conducted by Norbert et al.[23]. However, there are several complications associated with ileostomy. Among them, SOO, in which intestinal stricture is observed at the stoma opening, is said to occur at a relatively high frequency in patients who have had an ileostomy created, and in the study, as in previous reports, 19.6% of patients with ileostomy developed SOO[11,14,15]. When SOO occurs, the patient must fast until the bowel obstruction resolves. As a result, it is inevitable that the discharge date will be postponed; therefore, it is easy to assume that the hospital stay will be prolonged after surgery. In the study, the SOO group had a significantly longer hospital stay after surgery than the non-SOO group (22 vs. 14 days). This extended hospitalization could also delay the start of adjuvant chemotherapy. If SOO treatment is difficult, early closure of the stoma may be unavoidable[15]. Even if an ileostomy is created to avoid anastomotic leakage, the patient’s prognosis may worsen due to the complication of SOO, so it seems significant to consider



Scoring		Score
Age (years)	≥67	1
	<67	0
Gender	male	1
	female	0
Rectus abdominis muscle thickness (mm)	≥13.5	1
	<13.5	0
High output within 3 days of surgery (output volume ≥1,500 ml/day)	yes	1
	no	0
	total	4

Figure 2. ROC curve of the preoperative and early postoperative prediction scores for stoma outlet obstruction (SOO). Preoperative and early postoperative prediction scores for SOO were created using the following 4 items: age; ≥67 years, gender; male, rectus abdominis muscle thickness; ≥13.5 mm, and HOS (output volume ≥ 1,500 ml/day) within 3 days of surgery. Each item was scored 1 point out of 4 points, and ROC analysis was performed for SOO occurrence. The AUC of the preoperative prediction score for SOO was 0.865 ($p < 0.001$), with a cut-off value of 2.5, sensitivity of 76.2%, and specificity of 89.5%.
ROC: Receiver operating characteristic, AUC: Area under the curve

the risk of SOO.

There are various opinions on the causes of SOO, but no single view has been established yet. Although we were unable to find any recent studies that compared intraluminal pressure in the small intestine and that in the colon in the same paper, different studies that used the same unit of measurement (mmHg) to describe intraluminal pressure in the small intestine and colon[24,25] suggest that the small intestine is more easily compressed from the outside. Therefore, SOO is more likely to occur in ileostomy than in colostomy. Some reports have suggested that a thick rectus abdominis muscle is a risk factor for SOO. This is because the rectus abdominis muscle compresses the intestinal tract, causing it to narrow and resulting in difficulty defecating[10,14-18,26]. Additionally, the rapid change in the course of the intestinal tract owing to the small intestine obliquely passing through the rectus abdominis muscle easily cause SOO[27]. To prevent obliqueness, we devised a method of performing stoma construction after ending pneumoperitoneum and releasing the tightness of the abdominal wall; however, the longer the length of the rectus abdominis muscle through which the small intestine passes, the higher the risk of SOO[27]. Herein, the rectus abdominis muscle thickness (≥13.5 mm) was recognized as a significant factor in the multivariate analysis and as an independent risk factor for SOO (Table 4). Furthermore, abdominal wall thickness and subcutaneous fat thickness were also thought to be involved as other anatomical factors. However, in the report by Imaizumi et al.[14], abdominal wall thickness and subcutaneous fat thickness were not independent risk factors for SOO. The visceral and subcutaneous fat areas were examined in our study. None of the patients were significant in the multivariate analysis (Table 4). These results revealed that rectus abdominis muscle thickness can be an independent risk factor for SOO. According to Abe et al.[15], the rectus abdominis muscle is thicker in younger people, and the results of their analysis also state that age <60 years is a risk factor for SOO. However, in this study, age ≥67 years was a significant factor in the multivariate analysis, which resulted in the opposite conclusion that the elderly are a risk factor for SOO (Table 4). The location of our hospital in an area with a higher proportion of elderly people may explain the difference in the results. As muscle strength decreases with age, it is believed that there is a correlation between being young and having a thick rectus abdominis muscle, as previously reported, but in the group of patients we studied, there was no correlation between rectus abdominis muscle thickness and being young, and the results showed that being elderly and having a thick rectus abdominis muscle were independent prognostic factors for SOO. Meanwhile, the rectus abdominis muscle is thicker in men than in women, suggesting that if the rectus abdominis muscle thickness is a risk factor for SOO, men may have a risk for SOO. Herein, all cases of SOO were of men. Although no previous reports discuss the association between SOO and sex, difference in physique towing to sex may indirectly affect the development of SOO.

Suggestibly, laparoscopic surgery is more likely to cause SOO than laparotomy[10,11,27,28]. This is because laparoscopic surgery is less likely to cause adhesions and more likely to cause twisting of the small intestine. Herein, no significant difference was observed in the incidence of SOO between laparotomy and laparoscopy or robot-assisted laparoscopy surgery. However, laparotomy was only performed in 4.6% (n = 5) of all cases; thus, the possibility that the small number of cases had an effect cannot be denied.

In recent years, neoadjuvant therapy has been widely used to treat colorectal cancer. Neoadjuvant therapy reduces the risk of local recurrence and improves long-term prognosis. It is interesting to consider whether neoadjuvant radiation and/or chemotherapy have any effect on the intestinal tract and increase the risk of complications of SOO. The results of our study showed that neoadjuvant therapy was not a risk factor for SOO.

Reportedly, the combination of mechanical bowel preparation and oral antibiotics notably reduces surgical site infections (SSI), anastomotic leakage, and postoperative ileus in colorectal surgery[29]. It is unclear whether or how these preoperative preparations are involved in stoma-related complications and if they affect SOO. Herein, only patients who received mechanical bowel preparation were included. Further research that includes patients who undergo chemical bowel preparation using oral antibiotics may clarify the influence of preoperative bowel preparation methods on SOO.

HOS may be involved in the onset of SOO[14,15,30]. HOS is one of the complications that commonly occur in patients undergoing ileostomy. Due to the excessive loss of body fluid from the stoma, it can cause dehydration, mineral imbalance and malnutrition, so it is necessary to carry out adequate fluid replacement[31,32]. HOS was defined as a daily stoma output volume of 1,500-2,000 ml or more[19,20,33,34]. In our hospital, we recorded the amount of stoma output over time and found that the SOO group had a significantly higher proportion of patients with HOS within 3 days of surgery than the non-SOO group (Table 3). Furthermore, multivariate analysis identified HOS within 3 days post-surgery as an independent risk factor for SOO (Table 4). HOS triggers SOO through the following mechanism: a sudden surge in intestinal fluid causes intestinal distention. When the stoma cannot adequately drain this increased output, it leads to pressure-induced intestinal edema near the stoma opening, ultimately resulting in SOO[14]. Given that HOS is a potential risk factor for SOO, understanding its cause is important. However, there is currently no consensus on what causes HOS. Increased oral intake is thought to contribute to higher stoma output volume[14]. In addition, in our hospital, most patients are allowed to start drinking water again from the first postoperative day and to start eating again from the second postoperative day; therefore, the first to third postoperative day is a period in which HOS is likely to occur. However, the refilling period, during which the extracellular fluid that accumulated in the third space during surgery returns to the intravascular volume, also corresponds to the period from the first to the third postoperative day. We therefore included a study to determine if the intraoperative infusion volume was related to the occurrence of SOO, but no significant relationship was found (Table 4). To investigate the causes of HOS and understand the risk of SOO, more research is needed.

An original SOO risk assessment score was proposed based on the results of this study (Figure 1, 2). By using this preoperative predictive score to assess the risk of SOO before surgery, one should take extra precautions and ensure the abdominal wall opening for the stoma is adequately sized during the procedure. Furthermore, when using the preoperative and early postoperative prediction scores, one can place a decompression tube promptly if SOO is suspected, or consider delaying oral intake. In real clinical practice, there may be cases in which SOO is suspected, but it is difficult to establish a definitive diagnosis, although in these cases, this score can help determine the next step more immediately. Early treatment intervention can help improve the patient's prognosis, avoiding an increased hospital stay after surgery and delaying the start of adjuvant chemotherapy. There are several limitations. In this study, we only observed SOO in males, and not in females; thus, we were unable to conduct a comparative test of gender differences. Even when we added the gender factor to the multivariate analysis to test the correlation with other factors, the factors that were significant did not change, and because the test values for gender differences could not be calculated, gender differences were excluded from the multivariate analysis. However, it seems reasonable to assume that males are at a higher risk of SOO in this cohort; thus, we have added it to the risk scoring model. Owing to the statistical weaknesses described above, validation in a larger population is necessary to establish evidence in this study. The scoring system is based on the results of a single-center, retrospective, observational study of a small number of cases. The small sample size may lead to insufficient information for estimating OR and wide 95% confidence intervals. Generalizing the results to other populations is difficult because of the effects of bias. A multicenter and prospective study involving more cases should be conducted to elucidate universal risk factors for SOO.

In conclusion, age, gender, rectus abdominis muscle thickness, and HOS in the early postoperative period were independent risk factors for SOO. The proposed scoring model based on these factors may be useful for predicting and avoiding SOO.

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Conflicts of Interest
There are no conflicts of interest.

Author Contributions
Chiharu Yasui and Kyoichi Kihara contributed to the conception, design, acquisition, analysis, and interpretation of data. Ryo Ishiguro, Takuki Yagyu, Yusuke Kono, Manabu Yamamoto, Tomoyuki Matsunaga, Naruo Tokuyasu, Teruhisa Sakamoto, and Yoshiyuki Fujiwara contributed to the acquisition and analysis of data.

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