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Advanced T stage and thick rectus abdominis muscle triggers outlet obstruction and high-output stoma following ileostomy in patients with rectal cancer

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Abstract

Background

Ileostomy creation is an excellent approach to prevent leakage in patients undergoing low anterior resection for the treatment of rectal cancer. However, the two major complications of ileostomy are outlet obstruction and high-output stoma, and these complications remain unavoidable postoperative problems of ileostomy.

Methods

Risk factors associated with outlet obstruction and high-output stoma were retrospectively analyzed. The study included 83 patients with rectal cancer who underwent surgery. Of these patients, 34 underwent ileostomy creation.

Results

We found that outlet obstruction and high-output stoma were highly related ($p = 0.03$). Additionally, a thick rectus abdominis muscle and advanced T stage were the common risk factors of outlet obstruction ($p = 0.0005$ and $p = 0.01$, respectively) and high-output stoma ($p = 0.04$ and $p = 0.03$, respectively).

Conclusions

Our findings suggest that rectus abdominis muscle thickness and advanced T stage are predictive markers of outlet obstruction and high-output stoma.

Background

Colorectal cancer (CRC), one of the most frequently occurring malignancies worldwide, is the second leading cause of cancer-related deaths in Western countries [1]. The National Comprehensive Cancer Network guidelines recommend surgical treatment for patients with CRC without distant metastasis [2]. However, the complication rate is reportedly higher in rectal cancer surgery than that in colon cancer surgery [3]. One of the most severe complications is anastomotic leakage. When low anterior resection is performed for rectal cancer treatment, an ileostomy is often created to prevent anastomotic leakage [4, 5]. Temporal ileostomy is often created at the right side of the abdomen, through the right rectus abdominis (R-A) muscle, to prevent parastomal hernia [6]. Several months after rectal resection, the ileostomy is closed.

Although ileostomy creation is an excellent approach to prevent leakage, surgeons need to pay attention to the complications of ileostomy itself. The two major complications of ileostomy are outlet obstruction, which can result in ileus, and high-output stoma (HOS), which can result in dehydration. However, these complications remain as the unavoidable postoperative problems of ileostomy.

The present study aimed to identify the factors associated with outlet obstruction and HOS following ileostomy, and we believe that the findings will enable in the prevention of these complications.

Material And Methods

Patients

This retrospective study included 83 patients with rectal cancer who underwent low anterior resection of the rectum at Okayama University Hospital from 2015 to 2018. The diagnosis of CRC was confirmed based on clinicopathological findings in all the enrolled patients. The tumor, node, metastasis (TNM) staging system of the American Joint Committee on Cancer was used for pathological tumor staging of CRC. Patients with distant metastasis were excluded from this study. The institutional review board of Okayama University approved this study (approval no.: 1905-002).

Creation of ileostomy

Among the 83 patients with rectal cancer who underwent anterior resection, an ileostomy was created in 34 patients. The circle of skin flap with diameter of 2 cm was cut at first, and subcutaneous fat was cut up to the fascia of R-A muscle sheath. The incision on the muscle was made, and R-A muscle was split wide enough to admit three fingers into the abdominal cavity. Finally, terminal ileum was pulled up to the skin level, and loop ileostomy was created.

Measurement of the R-A muscle

The R-A muscle is located on the anterior part of the abdomen (Fig. 1A). The R-A muscle thickness was measured using computed tomography (CT). Preoperative CT images were obtained for all the patients. After the surgery, when outlet obstruction or HOS occurred, CT images were obtained. The R-A muscle thickness, which was one of the risk factor candidates, was retrospectively measured at the internal side of the ileostomy using CT before and after the occurrence of outlet obstruction (Fig. 1B). Even when no complications occurred, CT images were obtained within 3 months after the surgery for postoperative surveillance.

Statistical analysis

Data are expressed as mean ± standard deviation (SD). Differences between groups were estimated using the Wilcoxon's rank-sum test or χ^2 test, as appropriate. ROC curves were constructed to determine cut-off values for analyzing the risk factors for outlet obstruction by the Youden index. Logistic regression analysis was used for univariate and multivariate statistical evaluation. All statistical analyses were performed using JMP software (ver. 10.0, SAS Institute Inc., Cary, NC, USA). All p-values were two-sided. The p-value ≤ 0.1 was defined as having tendency, and a p-value ≤ 0.05 was considered statistically significant.

Results

Advanced T stage and anatomical feature of ileostomy might be risk factors of outlet obstruction following ileostomy.

Among the 83 patients with rectal cancer who underwent anterior resection, an ileostomy was created in 34 patients. Of these 34 patients, 7 (21%) experienced outlet obstruction (Table 1).

Table 1
Clinicopathological characteristics and outlet obstruction

Variable		n	Outlet obstruction		p-value
			Negative	Positive	
			(n = 27)	(n = 7)	
Physical parameter					
Sex	Male	23	16	7	0.04*
	Female	11	11	0	
Age (y)	< 70[#]	21	15	6	0.14
	≥ 70	13	12	1	
Body Mass Index	< 25.7[§]	29	22	7	0.21
	≥ 25.7	5	5	0	
Tumor					
Location	Ra	8	5	3	0.18
	Rb	26	22	4	
Pathological T category	pT1/2	16	15	1	0.05*
	pT3/4	18	12	6	
Lymph node metastasis	Absent	27	22	5	0.56
	Present	7	5	2	
Treatment					
Neoadjuvant chemo	Absent	21	15	6	0.14
	Present	13	12	1	
Laparoscopic or open	Open	2	2	0	0.46
	Laparoscopic	32	25	7	
Operation time (min)	< 388[§]	30	24	6	0.82
	≥ 388	4	3	1	
Anastomotic complication	Absent	30	25	5	0.12

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Variable		n	Outlet obstruction		p-value
			Negative	Positive	
			(n = 27)	(n = 7)	
	Present	4	2	2	
Blood exam					
WBC (preop, /μl)	< 5050§	13	12	1	0.13
	≥ 5050	20	14	6	
WBC (postop, /μl)	< 11600§	29	25	4	0.005*
	≥ 11600	4	1	3	
Neutrophil (preop, %)	< 72.5§	30	25	5	0.04*
	≥ 72.5	3	1	2	
Neutrophil (postop, %)	< 82.6§	25	21	4	0.13
	≥ 82.6	7	4	3	
CRP (preop, mg/dl)	< 0.79§	31	24	7	0.45
	≥ 0.79	2	2	0	
CRP (postop, mg/dl)	< 13.5§	22	19	3	0.13
	≥ 13.5	11	7	4	
Ileostomy					
Horizontal diameter (mm)	< 10.8§	5	1	4	0.0004*
	≥ 10.8	29	26	3	
Craniocaudal diameter (mm)	< 35§	31	25	6	0.57
	≥ 35	3	2	1	
R-A muscle (postop, mm)	< 14.5§	26	25	1	< 0.0001*
	≥ 14.5	8	2	6	

#The median age at surgery is 70 years in this cohort. §Cut off value was calculated using Yoden index. *p ≤ 0.05

Outlet obstruction was associated with male ($p = 0.04$), advanced T stage ($p = 0.05$), postoperative high white blood cell count ($p = 0.005$), preoperative high neutrophil rate ($p = 0.04$), long horizontal diameter of ileostomy ($p = 0.0004$), and thick R-A muscle ($p < 0.0001$).

Univariate logistic regression analysis showed that male ($p = 0.01$), advanced T stage ($p = 0.04$), postoperative high white blood cell count ($p = 0.01$), preoperative high neutrophil rate ($p = 0.07$), long horizontal diameter of ileostomy ($p = 0.001$), and thick R-A muscle ($p < 0.0001$) were risk factor of outlet obstruction. Finally, multivariate logistic regression analysis demonstrated that advanced T stage ($p = 0.10$), long horizontal diameter of ileostomy ($p = 0.01$), and thick R-A muscle ($p = 0.0005$) were independent risk factor of outlet obstruction (Table 2). These results suggest that advanced T stage and anatomical feature of ileostomy might be risk factors of outlet obstruction following an ileostomy.

Table 2

Univariate and multivariate analyses for the predictors of outlet obstruction

Variable	Univariate		Multivariate	
	OR	p-value	OR	p-value
Physical parameter				
Sex (Male)	1.61e + 8	0.01*	4.10	1.00
Age (< 70 y[#])	4.80	0.12		
Body Mass Index (< 25.7[§])	4.0.3e + 7	0.11		
Tumor				
Location (Ra)	3.30	0.20		
Pathological T category (pT3/4)	7.50	0.04*	1.69e + 14	0.10
Lymph node metastasis (Present)	1.76	0.57		
Treatment				
Neoadjuvant chemo (Absent)	4.80	0.12		
Laparoscopic or open (Laparoscopic)	3.05e + 6	0.33		
Operation time (≥ 388 min[§])	1.33	0.82		
Anastomotic complication (Present)	5.00	0.16		
Blood exam				
WBC (preop, ≥ 5050 /μl[§])	5.14	0.11		
WBC (postop, ≥ 11600 /μl[§])	18.75	0.01*	2.31	1.00
Neutrophil (preop, ≥ 72.5%[§])	10.00	0.07		
Neutrophil (postop, ≥ 82.6%[§])	3.94	0.15		
CRP (preop, ≥ 0.79 mg/dl[§])	3.15e-7	0.32		
CRP (postop, ≥ 13.5 mg/dl[§])	3.62	0.14		
Ileostomy				
Horizontal diameter (< 10.8 mm[§])	34.7	0.001*	5.84e + 14	0.01*

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Variable	Univariate		Multivariate	
	OR	p-value	OR	p-value
Craniocaudal diameter (≥ 35mm[§])	2.08	0.59		
R-A muscle (postop, ≥ 14.5 mm[§])	75.0	< 0.0001*	1.59e + 15	0.0005*

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Outlet obstruction following ileostomy was a risk factor of HOS

Not only outlet obstruction, but also HOS is an important complication of ileostomy. We next examined the relationship between outlet obstruction and HOS. HOS was defined as more than 1500 mL of ileostomy discharge. Ileostomy discharge was determined at postoperative days 3, 4, and 5 in the outlet obstruction positive and negative groups.

The amount of ileostomy discharge was higher in the outlet obstruction positive group than in the outlet obstruction negative group (day 3: p = 0.06, day 4: p = 0.03, day 5: p = 0.007; Fig. 2A). When HOS was defined as more than 1500 mL of ileostomy discharge, the probability of HOS was higher in the outlet obstruction positive group than in the outlet obstruction negative group (day 3: p = 0.05, day 4: p = 0.02, day 5: p = 0.06; Fig. 2B). These results suggest that outlet obstruction might be a risk factor of HOS.

Advanced T stage and anatomical feature of ileostomy might be risk factors of HOS

Considering that advanced T stage and anatomical feature of ileostomy were risk factors of outlet obstruction, we next assessed whether these factors were also associated with HOS, which showed significant correlation with outlet obstruction.

HOS was related to high BMI (p = 0.07), advanced T stage (p = 0.02), preoperative high white blood cell count (p = 0.06), postoperative high white blood cell count (p = 0.07), postoperative high neutrophil rate (p = 0.08), and thick R-A muscle (p = 0.02; Table 3).

Table 3

Clinicopathological characteristics and high-output stoma

Variable		n	High-output stoma (day4)		p-value
			Negative	Positive	
			(n = 21)	(n = 11)	
Physical parameter					
Sex	Male	21	12	9	0.16
	Female	11	9	2	
Age (y)	< 70[#]	20	12	8	0.39
	≥ 70	12	9	3	
Body Mass Index	< 25.7[§]	28	20	8	0.07
	≥ 25.7	4	1	3	
Tumor					
Location	Ra	8	5	3	0.83
	Rb	24	16	8	
Pathological T category	pT1/2	15	13	2	0.02*
	pT3/4	17	8	9	
Lymph node metastasis	Absent	25	17	8	0.59
	Present	7	4	3	
Treatment					
Neoadjuvant chemo	Absent	20	13	7	0.92
	Present	12	8	4	
Laparoscopic or open	Open	2	2	0	0.29
	Laparoscopic	30	19	11	
Operation time (min)	< 388[§]	29	19	10	0.97
	≥ 388	3	2	1	
Anastomotic complication	Absent	29	20	9	0.22

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Variable		n	High-output stoma (day4)		p-value
			Negative	Positive	
			(n = 21)	(n = 11)	
	Present	3	1	2	
Blood exam					
WBC (preop, /μl)	< 5050§	13	11	2	0.06
	≥ 5050	19	10	9	
WBC (postop, /μl)	< 11600§	28	20	8	0.07
	≥ 11600	4	1	3	
Neutrophil (preop, %)	< 72.5§	29	20	9	0.22
	≥ 72.5	3	1	2	
Neutrophil (postop, %)	< 82.6§	25	18	7	0.08
	≥ 82.6	6	2	4	
CRP (preop, mg/dl)	< 0.79§	30	20	10	0.63
	≥ 0.79	2	1	1	
CRP (postop, mg/dl)	< 13.5§	22	16	6	0.21
	≥ 13.5	10	5	5	
Ileostomy					
Horizontal diameter (mm)	< 10.8§	5	3	2	0.77
	≥ 10.8	27	18	9	
Craniocaudal diameter (mm)	< 35§	29	18	11	0.19
	≥ 35	3	3	0	
R-A muscle (postop, mm)	< 14.5§	25	19	6	0.02*
	≥ 14.5	7	2	5	

#The median age at surgery is 70 years in this cohort. §Cut off value was calculated using Yoden index. *p ≤ 0.05

Univariate logistic regression analysis demonstrated that high BMI (p = 0.07), advanced T stage (p = 0.02), preoperative high white blood cell count (p = 0.05), postoperative high white blood cell count (p = 0.07), postoperative high neutrophil rate (p = 0.08), long craniocaudal diameter of ileostomy (p = 0.10), and thick R-A muscle (p = 0.02) were risk factor of HOS. Finally, multivariate logistic regression analysis demonstrated that advanced T stage (p = 0.03), and thick R-A muscle (p = 0.04) were independent risk factor of HOS (Table 4). These results suggest that advanced T stage and anatomical feature of ileostomy might be also risk factors of HOS, similar to outlet obstruction.

Table 4
Univariate and multivariate analysis for the predictors of high-output stoma

Variable	Univariate		Multivariate	
	OR	p-value	OR	p-value
Physical parameter				
Sex (Male)	3.38	0.15		
Age (< 70 y[#])	2.00	0.38		
Body Mass Index (≥ 25.7[§])	7.5	0.07		
Tumor				
Location (Ra)	1.2	0.83		
Pathological T category (pT3/4)	7.31	0.02*	6.88	0.03*
Lymph node metastasis (Present)	1.59	0.60		
Treatment				
Neoadjuvant chemo (Absent)	1.08	0.92		
Laparoscopic or open (Laparoscopic)	5.98e + 7	0.33		
Operation time (< 388 min[§])	1.05	0.97		
Anastomotic complication (Present)	4.44	0.23		
Blood exam				
WBC (preop, ≥ 5050 /μl[§])	4.95	0.05		
WBC (postop, ≥ 11600 /μl[§])	7.50	0.07		
Neutrophil (preop, ≥ 72.5%[§])	4.44	0.23		
Neutrophil (postop, ≥ 82.6%[§])	5.14	0.08		
CRP (preop, ≥ 0.79 mg/dl[§])	2.00	0.64		
CRP (postop, ≥ 13.5 mg/dl[§])	2.67	0.21		
Ileostomy				
Horizontal diameter (< 10.8 mm[§])	1.33	0.78		

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Variable	Univariate		Multivariate	
	OR	p-value	OR	p-value
Craniocaudal diameter (< 35mm[§])	7.53e + 7	0.10		
R-A muscle (postop, ≥ 14.5 mm[§])	7.92	0.02*	7.35	0.04*

[#]The median age at surgery is 70 years in this cohort. [§]Cut off value was calculated using Yoden index. *p ≤ 0.05

Ileostomy location was important to prevent outlet obstruction and HOS following ileostomy

Our investigation of the clinical data suggested that advanced T stage and thick R-A muscle were the common risk factors of outlet obstruction and HOS. Although it is difficult to prove a relationship between these two phenomena, we would like to propose the “malignant cycle theory” that considers these phenomena (Fig. 3A).

The trigger of this cycle is incomplete ileostomy obstruction, mainly because of a thick R-A muscle causing high resistance. Owing to the incomplete obstruction, the amount of upper intestinal secretion increases via mucosal edema. Even when the amount of ileostomy discharge appears to be enough, the condition of the intestinal fluid reservoir worsens because of fluid supply overload, and this is followed by progressive relative ileostomy obstruction. Additionally, advanced T stage induces preoperative intestinal obstruction, edema, and inflammation, leading to high output stoma and relative outlet obstruction. Elevated white blood cell count (p = 0.05) in patients with advanced CRC supports this hypothesis (Table 5). After the initiation of this malignant cycle, it will be difficult to stop outlet obstruction and HOS, and ileostomy drainage by tubing will be needed.

Table 5
Clinicopathological characteristics and pathological T stage

Variable		n	Pathological T category		p-value
			pT1/2	pT3/4	
			(n = 16)	(n = 18)	
Treatment					
Laparoscopic or open	Open	2	0	2	0.17
	Laparoscopic	32	16	16	
Operation time (min)	< 388§	30	14	16	0.90
	≥ 388	4	2	2	
Anastomotic complication	Absent	30	14	16	0.90
	Present	4	2	2	
Blood exam					
WBC (preop, /μl)	< 5050§	13	9	4	0.05*
	≥ 5050	20	7	13	
WBC (postop, /μl)	< 11600§	29	15	14	0.32
	≥ 11600	4	1	3	
Neutrophil (preop, %)	< 72.5§	30	16	14	0.08
	≥ 72.5	3	0	3	
Neutrophil (postop, %)	< 82.6§	25	13	12	0.27
	≥ 82.6	7	2	5	
CRP (preop, mg/dl)	< 0.79§	31	16	15	0.16
	≥ 0.79	2	0	2	
CRP (postop, mg/dl)	< 13.5§	22	12	10	0.32
	≥ 13.5	11	4	7	
Ileostomy					

§Cut off value was calculated using Yoden index. *p ≤ 0.05

Variable		n	Pathological T category		p-value
			pT1/2	pT3/4	
			(n = 16)	(n = 18)	
Horizontal diameter (mm)	< 10.8§	5	2	3	0.73
	≥ 10.8	29	14	15	
Craniocaudal diameter (mm)	< 35§	31	14	17	0.48
	≥ 35	3	2	1	
R-A muscle (preop, mm)	< 11.2§	23	14	9	0.007*
	≥ 11.2	10	1	9	
R-A muscle (postop, mm)	< 14.5§	26	14	12	0.15
	≥ 14.5	8	2	6	
§Cut off value was calculated using Yoden index. *p ≤ 0.05					

As the initiator of outlet obstruction is a thick R-A muscle, we believe that the most important point is ileostomy location. On cross-section assessment, the R-A muscle has a flat, oval shape, and it is thinner at the lateral side. Thus, even if a patient has a thick R-A muscle, when an ileostomy is created at the lateral side, the R-A muscle thickness close to the ileostomy will be lower than that at the middle, resulting in the prevention of outlet obstruction and HOS following the ileostomy (Fig. 3B). Considering that the pipe flow resistance is proportional to its length and inversely proportional to its diameter (Darcy–Weisbach Equation), our hypothesis will be also supported by the theory of fluid mechanics [7].

Discussion

The present study found that outlet obstruction and HOS were highly related in patients with rectal cancer who underwent low anterior resection. Furthermore, a thick R-A muscle was the common risk factor of outlet obstruction and HOS. Patients with a thick R-A muscle had high occurrence rates of outlet obstruction and HOS. Our findings suggest that R-A muscle thickness is a predictive marker of outlet obstruction and HOS. Additionally, advanced T stage induces preoperative intestinal obstruction, edema, and inflammation, leading to high output stoma and relative outlet obstruction. High risk patients with advanced CRC and thick R-A muscle will need clinical counterplan to prevent these complications.

Recent advances in the treatment of rectal cancer are remarkable, and laparoscopic surgery has especially shown outstanding progress in the last decade [8–11]. However, anastomotic procedures have not greatly changed. The most common approach is the double-stapling technique using linear and

circular staplers [12]. The risk of leakage depends on the location of anastomosis, and the risk increases when the anastomotic site is close to the dentate line. An ileostomy is usually created to prevent anastomotic leakage [4, 5]. Even when the anastomosis between the residual rectum and sigmoid colon is incomplete, an ileostomy can keep the anastomotic site stable [13].

Although ileostomy creation is a useful approach for anastomosis protection, the complications of outlet obstruction and HOS are very difficult to prevent, as their causes and solutions remain unknown, with limited information [14–18]. The occurrence rates of outlet obstruction and HOS have been reported to be 7.7–8.7% and 23–45%, respectively [18–22]. The risk factors of outlet obstruction have been reported to be operation type, high age, thick subcutaneous fat, and high white blood cell count [21]. Additionally, the risk factors of HOS have been reported to be abdominal sepsis, short bowel, obstruction, medication, overload with intravenous saline solution, enteritis, diabetes mellitus, proctocolectomy, high white blood cell count [18, 19, 23–26]. However, there is no consistent theory to explain the cause and linkage of outlet obstruction and HOS.

In the present study, we statistically demonstrated that both outlet obstruction and HOS were associated with a thick R-A muscle causing high resistance for passage, and advanced T stage causing intestinal obstruction and edema. Thick R-A muscle and advanced T stage were independent risk factors of both outlet obstruction and HOS. Considering the clinical evidence, we proposed the “malignant cycle theory” that links a thick R-A muscle, advanced T stage outlet obstruction, and HOS. To prevent this malignant cycle in the high risk patients with thick R-A muscle and advanced CRC, the ileostomy location should be at the thinner lateral side of the R-A muscle to reduce resistance for discharge flow. Additionally, preventive tubing to avoid obstruction of ileostomy may be effective in terminating the progression the malignant cycle.

A limitation of this study is that only retrospective analyses were performed. Currently, we are planning a prospective study, in which an ileostomy will be created at the thinner lateral side of the R-A muscle in patients with a thick R-A muscle and the occurrence rates of obstruction and HOS will be compared between these patients and controls.

Conclusions

In conclusion, a thick R-A muscle and advanced T stage is associated with the occurrence of outlet obstruction and HOS following ileostomy. An appropriate ileostomy location according to the R-A muscle thickness, and preventive tubing into ileostomy may prevent these complications.

Abbreviations

R-A muscle: rectus abdominis muscle, HOS: high-output stoma, CRC: Colorectal cancer, CT: computed tomography

Declarations

Ethics approval and consent to participate

The institutional review board of Okayama University approved this study (approval no.: 1905-002).

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceived and designed projects: Y. Komatsu, KS, YM, YK, SK, SY, S. Kuroda, Y. Kondo, FT, TF; Data analysis: Y. Komatsu, KS, KT, ST, NH, S. Kagawa; Wrote the manuscript: Y. Komatsu, KS.

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Figures

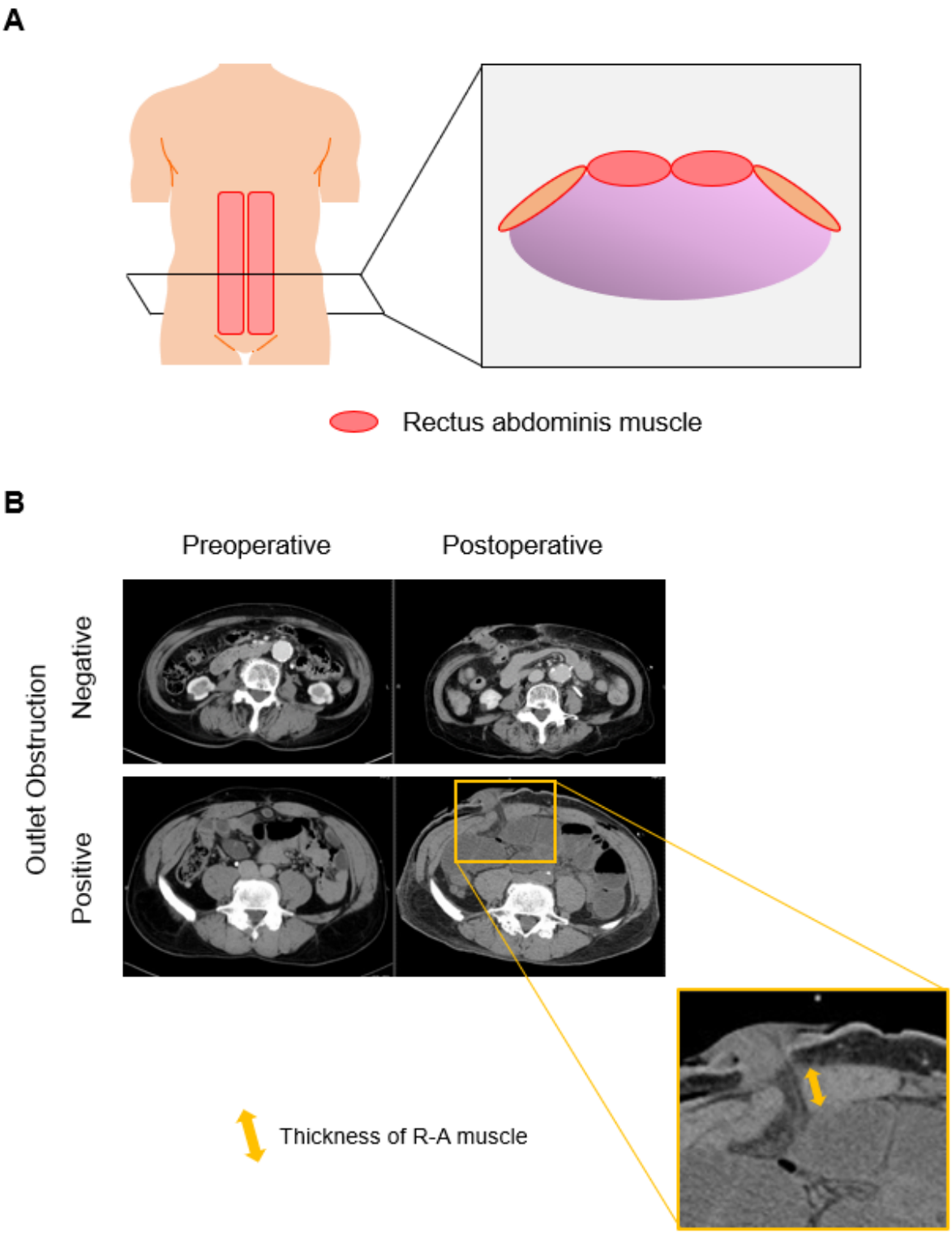

Figure 1

Clinical parameters related to outlet obstruction following ileostomy. The R-A muscle thickness was retrospectively measured at the internal side of the ileostomy using computed tomography. R-A, rectus abdominis

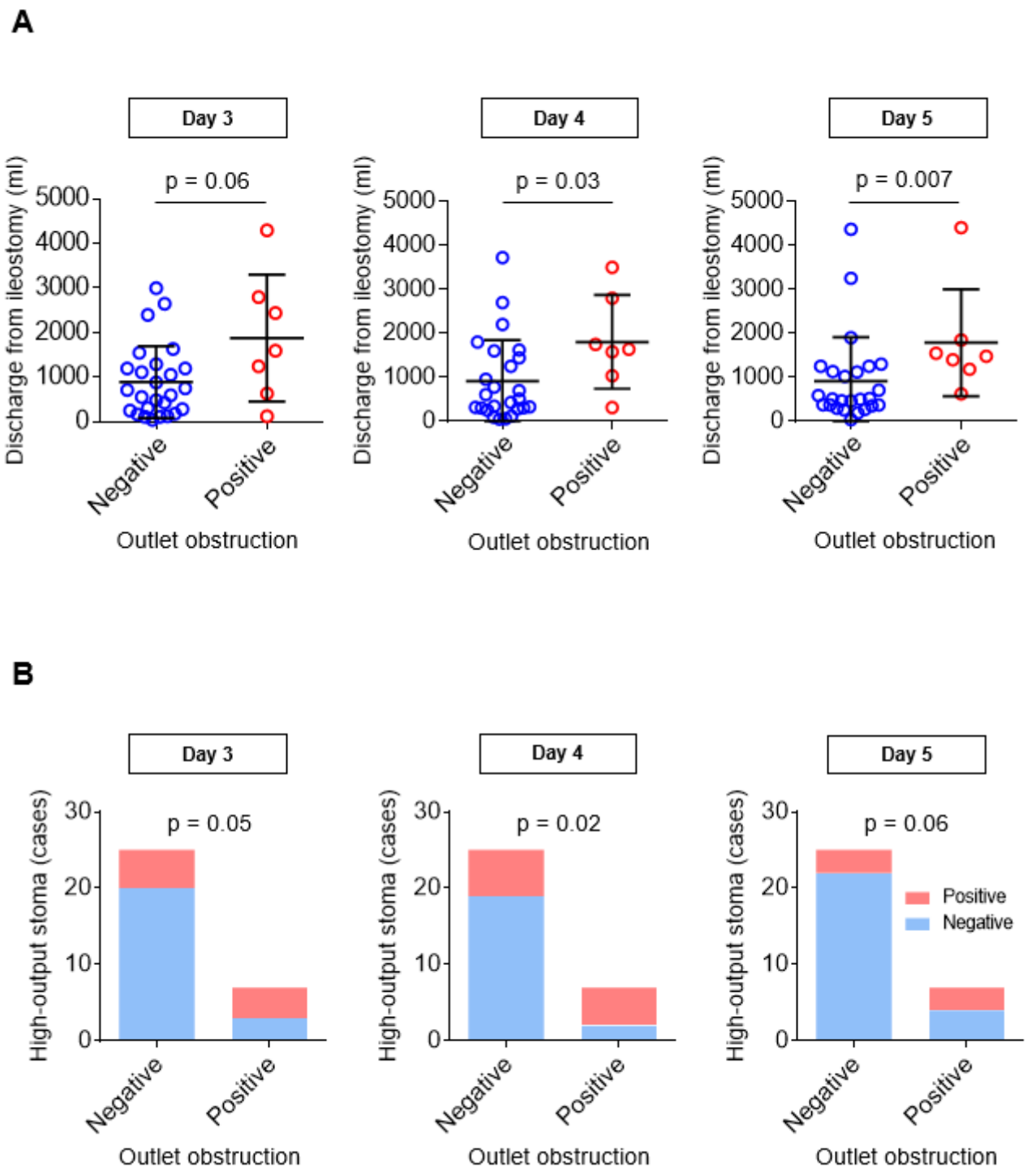

Figure 2

Relationship between outlet obstruction and high-output stoma following ileostomy. (A) The amount of ileostomy discharge is higher in the outlet obstruction positive group than in the outlet obstruction negative group (Wilcoxon's signed-rank test). (B) When high-output stoma is defined as more than 1500 mL of discharge from ileostomy, the probability of high-output stoma is higher in the outlet obstruction positive group than in the outlet obstruction negative group (χ2 test).

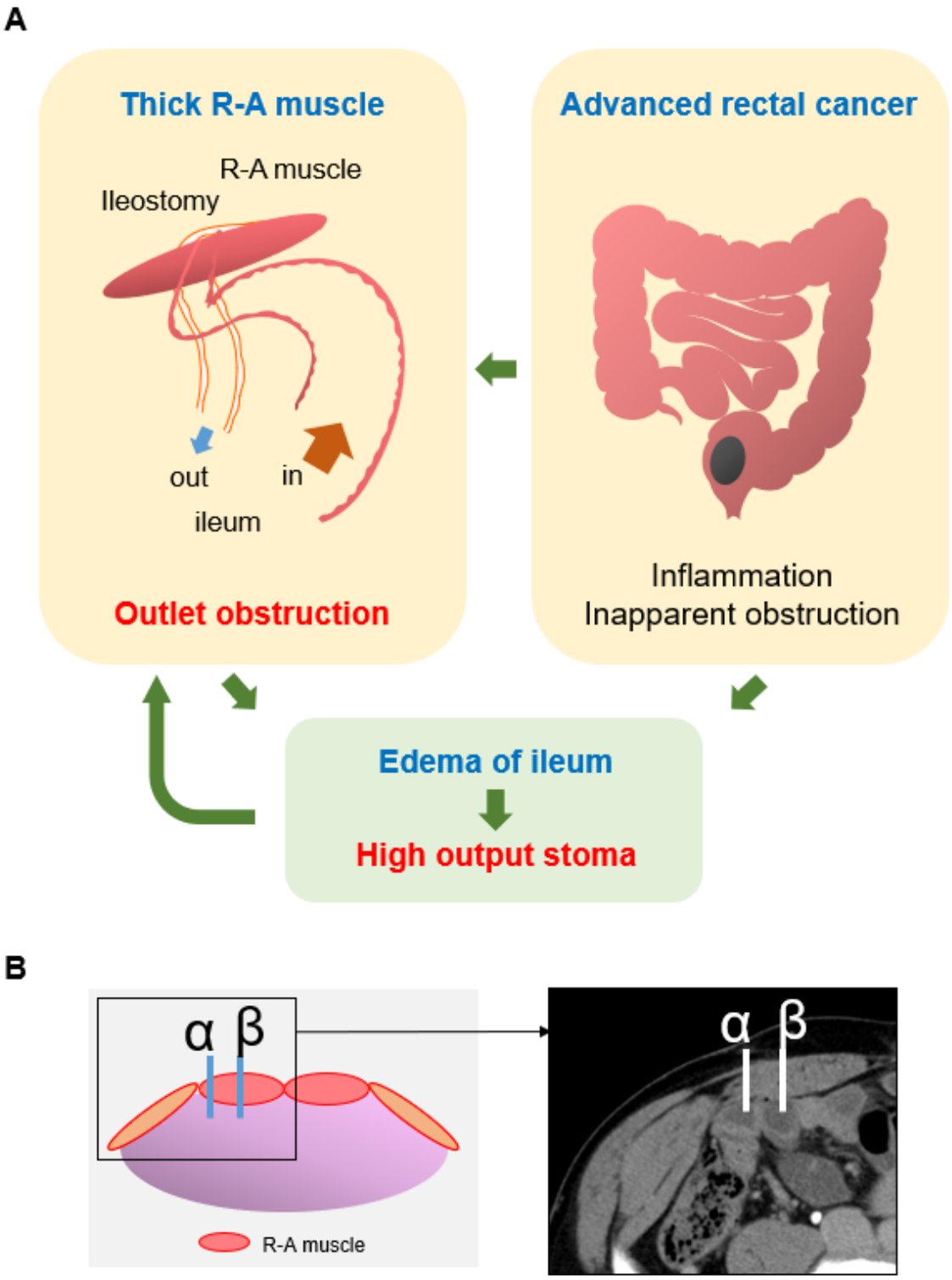

Figure 3

A thick R-A muscle is a cause of outlet obstruction and high-output stoma. (A) The malignant cycle theory that includes outlet obstruction and high-output stoma. (B) When an ileostomy is created at the lateral side (α), the R-A muscle thickness close to the ileostomy will be lower than that at the middle (β), resulting in the prevention of outlet obstruction and HOS following ileostomy. R-A, rectus abdominis