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Clinical and Radiologic Predictors of Parastomal Hernia Development After End Colostomy

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OBJECTIVE. Parastomal hernia (PSH) is a common complication that can occur after end colostomy and may result in considerable morbidity. To select the best candidates for prophylactic measures, knowledge of preoperative PSH predictors is important. This study aimed to determine the value of clinical parameters, preoperative CT-based body metrics, and size of the abdominal wall defect created during end colostomy and measured at postoperative CT for predicting PSH development.

MATERIALS AND METHODS. Sixty-five patients who underwent permanent end colostomy with at least 1 year of follow-up were included. On preoperative CT, waist circumference, abdominal wall and psoas muscle indexes, rectus abdominis muscle diameter and diastasis, intra- and extraabdominal fat mass, and presence of other hernias were assessed. On postoperative CT, size of the abdominal wall defect and the presence of PSH were determined. To identify independent predictors of PSH development, univariate analysis with the Kaplan-Meier method and multivariate Cox regression analysis were performed.

RESULTS. PSH developed after surgery in 30 patients (46%). Three independent risk factors were identified: chronic obstructive pulmonary disease (COPD) as a comorbidity (hazard ratio [HR], 6.4; 95% CI, 1.9–22.0; $p = 0.003$), operation time longer than 395 minutes (HR, 3.9; 95% CI, 1.5–10.0; $p = 0.005$), and maximum aperture diameter of more than 34 mm (HR, 5.2; 95% CI, 2.1–12.7; $p < 0.001$). PSH developed in all nine patients with a maximum abdominal wall defect diameter of more than 50 mm at the ostomy site.

CONCLUSION. COPD, longer operation time, and larger abdominal wall defect at the colostomy site can predict PSH development. Intraoperative creation of an abdominal wall ostomy opening that is more than 34 mm in diameter should be avoided.

A parastomal hernia (PSH) is defined as an incisional hernia through an abdominal wall defect created during the placement of a colostomy, ileostomy, or ileal conduit stoma [1]. The reported incidence of PSH ranges between 30% and 65% [2, 3], with the highest incidence in patients with a colostomy (approximately 50%) [4].

Although PSHs can be asymptomatic, a significant number of patients with a PSH report a reduced quality of life [5]. The most common PSH-related symptoms are pain (35%) and problems with stoma appliance (28%), often resulting in leakage (27%). Leakage around the stoma appliance frequently results in significant peristomal dermatitis, unpleasant odor, and soilage of clothes. In addition, serious complications such as obstruction, perforation, and strangulation can occur in up to 15% of patients with a PSH [3]. In addition to the aforementioned morbidity, PSH has a significant impact on health care costs. For example, frequent changing of appliances and use of more expensive custom-fit appliances can increase health care expenditure [6]. Furthermore, PSH can incapacitate patients, leading to a substantial loss of work productivity.

Identification of preoperative factors that can predict the development of a postoperative PSH could help reduce the number of PSHs by allowing implementation of preventive measures such as mesh placement. Reported risk factors for the development of PSH are age older than 60 years old, history of abdominal hernia, abdominal obesity, malnutrition, long-term corticosteroid use, and factors increasing intraabdominal pressure (i.e., chronic cough, constipation, prostatism, and ascites) [7, 8]. However, these clinical parameters are insufficient for accurate prediction of PSH development.

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Because most patients undergo preoperative CT when they are scheduled for end colostomy, CT could provide a readily available means for assessing body metrics (such as waist circumference, amount of fat in different compartments, abdominal muscle status, and presence of other abdominal hernias) that may put patients at risk for PSH development. Deriving these anatomic parameters from CT may improve the prediction of PSH development. Another potentially important body metric that can be measured on postoperative CT is the size of the ostomy opening created in the abdominal wall during stoma surgery. An abdominal wall defect that is too large may lead to PSH development, so information on maximum safe limits might be of additional value during surgery. Hotouras et al. [9] reported that PSH development was unlikely with an aperture diameter smaller than 25 mm as measured on postoperative CT. However, that study only included 43 patients, in 25 of whom a PSH developed, and the data were not corrected for previously reported clinical parameters that predicted PSH development. Furthermore, body metrics derived from preoperative CT were not assessed. Other studies assessing the use of CT in predicting PSH development are lacking, so the value of CT for this purpose remains unclear.

The aim of our study was to determine the value of preoperative CT-based body metrics, size of the intraoperatively created ostomy opening in the abdominal wall as measured on postoperative CT, and clinical parameters for predicting PSH development in patients who have undergone end colostomy.

Materials and Methods

Study Population

All consecutive patients who underwent abdominoperineal resection (APR) or colostomy surgery with construction of a permanent end colostomy in the lower-left quadrant of the abdomen at a tertiary care medical center between 2010 and 2016 were considered for inclusion in the study. Patients were identified from the prospectively maintained database at our institution (University Medical Center Groningen), and their data were retrospectively analyzed.

Inclusion criteria were age 18 years old or older, malignant or premalignant colorectal or anal disease, APR or colostomy surgery performed at our hospital and resulting in creation of a permanent end colostomy in the lower-left quadrant of the abdomen,availability of full-dose contrast-enhanced portal venous phase CT with a minimum reconstructed slice thickness of 2 mm obtained 2 months or less before surgery, and availability of an adequate postoperative CT scan (similar to preoperative CT scan) obtained at least 1 year after surgery. Patients with a history of extensive abdominal surgery (other than cholecystectomy, appendectomy, or cesarean section) and those who died within 1 year after surgery (leading to insufficient follow-up) were excluded from the study. A follow-up period of at least 1 year was chosen because most PSHs occur during the early postoperative period [10].

The study was approved by our institutional review board, and the requirement for obtaining informed consent was waived.

Diagnostic Workup

Depending on the diagnosis, patients were oncologically staged according to national guidelines, which suggest using preoperative abdominal CT, chest radiography or chest CT, colonoscopy, and measurement of carcinoembryonic antigen level. For each patient, histologic confirmation of the primary diagnosis was obtained before surgery. All radiologic images were stored in our institutional PACS. All treatment decisions were made during repeat multidisciplinary team meetings that focused on colorectal malignancies.

Surgical Techniques and Follow-Up

Each patient in this study underwent APR or colostomy surgery that involved standard construction of a permanent end colostomy in the lower-left quadrant of the abdomen; surgeries were performed by a specialized colorectal surgeon. All resection specimens underwent a postoperative routine histopathologic examination.

Follow-up examinations were performed according to national guidelines and included chest and abdominal CT every 6 months during the first 2 years and then every 12 months for the next 5 years.

Radiologic Measurements

An abdominal radiologist, who was blind to all other parameters measured in the study, determined whether a PSH was present at follow-up CT after surgery. All available follow-up CT scans were reviewed for this purpose. A PSH was defined as an incisional hernia occurring at or adjacent to the end colostomy [10] with the hernia sac containing the omentum, small bowel, colon, or a combination of the three (Fig. 1).

At preoperative CT, another abdominal radiologist and a research fellow, who were unaware of the occurrence of a postoperative PSH, independently obtained the following data: waist circumference, rectus abdominis muscle diameter, rectus abdominis muscle diastasis, presence of inguinal or abdominal wall hernia, abdominal wall and psoas muscle indexes, and both extraabdominal (subcutaneous) and intraabdominal (visceral) fat mass. The muscle indexes were calculated by dividing the muscle mass cross-sectional area (square centimeters) by the patient's height (square meters). The muscle mass cross-sectional areas were measured on an axial CT slice at the level of the third lumbar vertebra. Waist circumference and rectus abdominis muscle diameter and diastasis were determined on an axial CT image at the level of the umbilicus. Aquarius iNtuition software (version 4.4.13.P4, TeraRecon) was used to calculate the extraabdominal and intraabdominal fat mass for each patient in a plane between the cranial endplate of the first lumbar vertebra and the cranial part of the pubic bone. The abdominal wall and psoas muscles were manually outlined on the CT images using software developed at our institution (Fig. 2), and the muscle areas and indexes were computed using the usual thresholds for skeletal muscle density (–29 to 150 HU) [11].

At follow-up CT, horizontal, vertical, and largest diameters (in the horizontal, vertical, and oblique coronal direction, respectively) of the abdominal wall defect at the end colostomy site were determined by a research fellow. The total surface area of the abdominal wall defect at the end colostomy site, which was almost always elliptic-shaped, was calculated with the following formula: $\pi \times [(0.5 \times \text{left-to-right distance}) \times (0.5 \times \text{cranial-to-caudal distance})]$.

TABLE 1: Patient and Tumor Characteristics

Characteristic	Value
Patients	
Total no.	65
Men	36 (55)
Women	29 (45)
Median age at preoperative CT	62.0 (52.5–69.0)
Median body mass index[a]	25.4 (23.2–28.4)
Comorbidities and medical history	
Chronic obstructive pulmonary disease	6 (9)
Smoking	21 (32)
Abdominal wall or inguinal hernia	13 (20)
Immunodeficiency	4 (6)
Prior minor abdominal surgery	38 (58)
Indication for surgery	
Rectal cancer	30 (46)
Locally advanced rectal cancer	29 (45)
Anal cancer	4 (6)
Other[b]	2 (3)
Type of surgery	
Abdominoperineal resection	59 (91)
End colostomy[c]	6 (9)
Neoadjuvant treatment ($n = 61$)	
Chemoradiotherapy	54 (83)
Radiotherapy (five sessions at 5 Gy)	7 (11)
Median operation time (min)	395.0 (312.5–495.5)
Postoperative TNM classification[d]	
T category ($n = 64$)	
0	8 (12)
1	4 (6)
2	13 (20)
3	33 (51)
4	6 (9)
N category ($n = 63$)	
0	45 (69)
1	10 (15)
2	8 (12)

Note—Values are the number (percentage) or median (interquartile range).
[a]Weight in kilograms divided by the square of height in meters.
[b]One patient had a gastrointestinal stromal tumor in the distal rectum, and the other had a giant condyloma acuminatum.
[c]Five patients subsequently underwent abdominoperineal resection without changes to their existing end colostomy site.
[d]Based on histopathology report.

Statistical Analysis

Patient characteristics are expressed as the median with interquartile range (IQR) for continuous data and as the frequency for categoric data. To identify factors significantly associated with PSH development, we performed a univariate analysis by using the Kaplan-Meier method, taking into account the length of follow-up and considering the presence of a PSH as an event. The log-rank test was used to calculate univariate *p* values for each factor. To identify independent predictors of PSH development, we performed a multivariate Cox regression analysis that included all factors with *p* values of 0.10 or less at univariate analysis. A *p* value of 0.05 or less was considered statistically significant. SPSS software (version 23.0, IBM) was used for all statistical analyses.

Results

Study Population

Between 2010 and 2016, a total of 65 patients who underwent APR or colostomy surgery with construction of a permanent end colostomy fulfilled the inclusion criteria (Fig. 3). The study population consisted of 36 men (55%) and 29 women (45%) with a median age of 62.0 years (IQR, 52.5–69.0 years). Thirteen patients (20%) had an inguinal or abdominal wall hernia in their medical history, and 38 patients (58%) previously underwent minor abdominal surgery. The median body mass index was 25.4 (weight in kilograms divided by the square of height in meters; IQR, 23.2–28.4). In 59 patients (91%), the primary tumor was located in the rectum. Other baseline characteristics are reported in Table 1.

Preoperative Radiologic Measurements

The median waist circumference was 98.4 cm (IQR, 89.9–103.0 cm), the median total muscle index was 44.8 cm^2/m^2 (IQR, 38.8–51.7 cm^2/m^2), the median density of the total muscle mass was 40.2 HU (IQR, 34.5–45.3 HU), and the median diameter of the rectus muscle was 8.9 mm (IQR, 7.5–10.6 mm). The median amount of visceral and subcutaneous adipose tissue was 3195.0 cm^3 (IQR, 1962.5–4650.0 cm^3) and 4390.0 cm^3 (IQR, 3298.0–5947.5 cm^3), respectively. Other muscle indexes are reported in Table 2. A total of 24 patients (37%) had an inguinal or abdominal wall hernia at preoperative CT, and in all cases, the hernia sac contained only adipose tissue.

Postoperative Radiologic Measurements

A total of 30 patients (46%) had a PSH at follow-up CT, which was performed after a median postoperative period of 11.8 months (IQR, 9.7–18.4 months). Twelve of these 30 patients (40%) experienced symptoms related to PSH (discomfort in two patients, pain in six patients, and obstruction in four patients).

The median total surface area and median maximum diameter of the abdominal wall defect at the end colostomy site at follow-up CT were 5.3 cm^2 (IQR, 3.1–9.2 cm^2) and 33.8 mm (IQR, 27.9–44.6 mm), respectively. Other variables that were measured at follow-up CT are reported in Table 2.

Predictors of Parastomal Hernia Development

Univariate analysis found nine factors that were associated with the development of a PSH ($p \leq 0.10$) (Table 3): chronic obstructive pulmonary disease (COPD) as a comorbidity, abdominal wall or inguinal hernia at preoperative CT or in medical history, operation time longer than 395 minutes, body mass index greater than 25, age over 62 years old at preoperative CT, waist circumference greater than 98 cm at preoperative CT, abdominal adipose tissue volume ratio greater than 42%, maximum diameter of the abdominal wall defect at the end colostomy site

TABLE 2: CT Findings in Patient Population (*n* = 65)

Findings	Value
Preoperative CT	
Waist circumference (cm)	98.4 (89.9–103.0)
Total muscle index (cm^2/m^2)	44.8 (38.8–51.7)
Total abdominal wall muscle index (cm^2/m^2)	38.8 (33.5–44.8)
Right psoas muscle index (cm^2/m^2)	2.6 (2.2–3.5)
Left psoas muscle index (cm^2/m^2)	2.7 (2.1–3.8)
Total muscle mass attenuation (HU)	40.2 (34.5–45.3)
Right abdominal wall muscle index (cm^2/m^2)	19.0 (16.6–23.1)
Left abdominal wall muscle index (cm^2/m^2)	19.5 (16.7–22.9)
Rectus muscle diameter (mm)	8.9 (7.5–10.6)
Diameter of rectus muscle diastasis (mm)	22.6 (16.1–32.9)
Inguinal or abdominal wall hernia	24 (37)
Total amount of visceral adipose tissue (cm^3)	3195.0 (1962.5–4650.0)
Total amount of subcutaneous adipose tissue (cm^3)	4390.0 (3298.0–5947.5)
Abdominal adipose tissue volume ratio (%)[a]	41.9 (31.4–51.8)
Follow-up CT	
Left-to-right diameter of colostomy (mm)	19.3 (12.1–28.9)
Craniocaudal diameter of colostomy (mm)	33.7 (27.9–44.5)
Maximum diameter of colostomy (mm)	33.8 (27.9–44.6)
Colostomy surface area (cm^2)[b]	5.3 (3.1–9.2)
Parastomal hernia	30 (46)

Note—Values are the number (percentage) or median (interquartile range).
[a]Calculated as [visceral adipose tissue / (visceral + subcutaneous adipose tissue)] × 100%.
[b]Calculated as $\pi \times [(0.5 \times \text{left-to-right distance}) \times (0.5 \times \text{anterior-to-posterior distance})]$.

of more than 34 mm, and total muscle mass density of 40 HU or less.

After entering all variables with a univariate *p* value of 0.10 or less into the multivariate Cox regression analysis, three factors emerged as independent predictors for the development of a PSH (Table 3, Fig. 4): COPD as a comorbidity (hazard ratio [HR], 6.4; 95% CI, 1.9–22.0; $p = 0.003$), operation time more than 395 minutes (HR, 3.9; 95% CI, 1.5–10.0; $p = 0.005$), and maximum diameter of the abdominal wall defect at the end colostomy site of more than 34 mm (HR, 5.2; 95% CI, 2.1–12.7; $p < 0.001$).

Post Hoc Analysis

ROC curves were constructed to illustrate the diagnostic value of the cutoff points for the total colostomy surface area and largest diameter of the anterior abdominal wall defect. The AUC of the ROC curve was 0.85 (95% CI, 0.75–0.94; $p < 0.001$) for total colostomy surface area (Fig. 5A) and 0.81 (95% CI, 0.71–0.92; $p < 0.001$) for largest diameter of the abdominal wall defect at the colostomy site (Fig. 5B).

The distribution of PSHs according to the size and maximum diameter of the abdominal wall defect at the end colostomy site is shown in Figure 6. PSH developed in all patients with a total abdominal wall defect surface area larger than 10 cm^2 ($n = 13$) or diameter greater than 50 mm in the largest dimension ($n = 9$).

Correlation analyses were performed to determine the association between all variables that had a *p* value less than 0.10 on univariate analysis but were not significant independent predictors of PSH development on multivariate analysis (i.e., waist circumference at preoperative CT, abdominal adipose tissue volume ratio, and density of total muscle mass) and all variables that were still significant predictors on multivariate analysis (i.e., COPD, operation time, and maximum diameter of the abdominal wall defect at the end colostomy site). Pearson correlation coefficients or Kendall tau correlation coefficients were calculated as appropriate. These correlation analyses showed predominantly weak to moderate correlations, with the highest correlations observed for both waist circumference at preoperative CT and abdominal adipose tissue volume ratio versus maximum diameter of the abdominal wall defect at the end colostomy site (Table 4).

Discussion

This study investigated clinical parameters, preoperative CT parameters, and abdominal wall defect size at the ostomy site on postoperative CT scans in patients who have undergone end colostomy as predictors of PSH development. Three independent predictors of PSH development were identified: COPD as a comorbidity, longer operation time, and a larger diameter of the abdominal wall defect at the ostomy site. PSH developed in all patients with an abdominal wall defect surface area larger than 10 cm^2 ($n = 13$) or maximum diameter of more than 50 mm ($n = 9$).

A study investigating sarcopenic obesity prevalence and associated health outcomes in bariatric patients found a higher prevalence of hernias in patients with sarcopenic obesity [12]. In addition, obesity has been described as a risk factor for developing postoperative complications, such as wound infections, and for the development of PSH [7, 8]. Furthermore, morphologic measurements, such as abdominal circumference and subcutaneous fat area, derived from preoperative CT scans seem to be better predictors of surgical site infections than body mass index [13]. Therefore, we hypothesized that body metrics derived from preoperative CT scans could predict the development of PSH. In our study, waist circumference, abdominal adipose tissue volume ratio, and total muscle mass density were significantly related to the development of PSH on univariate analysis. However, none of these CT-based body metrics emerged as independent predictors of PSH on multivariate analysis. This result could be related to the correlations (although predominantly weak to moderate) that exist between these CT-based body metrics and the diameter of the abdominal wall defect at the ostomy site.

The PSH prevalence reported in the literature varies between 30% and 65% [2, 3], with the highest prevalence in patients with end colostomy (approximately 50%) [4]. In our study, the prevalence of PSH was 46% after 1 year of follow-up, which is comparable with the prevalence reported in the literature. Of the patients in whom PSH developed, 40% experienced PSH-related symptoms.

Our finding that COPD is an independent predictor of PSH development is in line with previous work [7] and could be explained by chronic coughing, which results in increased abdominal pressure. In addition, patients with COPD often use glucocorticoids

TABLE 3: Univariate and Multivariate Analysis of Predictive Factors of Parastomal Hernia Development

Variable	Parastomal Hernia		*p*		
	Yes (*n* = 30)	No (*n* = 35)	Univariate	Multivariate	HR (95% CI)
Chronic obstructive pulmonary disease			0.01[a]	0.003	6.4 (1.9–22.0)
No	25 (83)	34 (97)			
Yes	5 (17)	1 (3)			
Sex			0.72	—	—
Male	15 (50)	21 (60)			
Female	15 (50)	14 (40)			
Abdominal wall or inguinal hernia at preoperative CT or in medical history			0.02[a]	NS	—
No	12 (40)	22 (63)			
Yes	18 (60)	13 (37)			
Operation time (min)			0.01[a]	0.005	3.9 (1.5–10.0)
≤ 395	11 (37)	20 (57)			
> 395	19 (63)	15 (43)			
Body mass index[b]			0.08[a]	NS	—
≤ 25	9 (31)	18 (51)			
> 25	20 (69)	17 (49)			
Age at preoperative CT (y)			0.09[a]	NS	—
≤ 62	12 (40)	19 (54)			
> 62	18 (60)	16 (46)			
Waist circumference at preoperative CT (cm)			0.07[a]	NS	—
≤ 98	11 (37)	20 (57)			
> 98	19 (63)	15 (43)			
Total amount of visceral adipose tissue at preoperative CT (cm^3)			0.19	—	—
≤ 3195	12 (40)	20 (57)			
> 3195	18 (60)	15 (43)			
Total amount of subcutaneous adipose tissue at preoperative CT (cm^3)			0.40	—	—
≤ 4390	13 (43)	19 (54)			
> 4390	17 (57)	16 (46)			
Abdominal adipose tissue volume ratio (%)[c]			0.09[a]	NS	—
≤ 42	11 (37)	20 (57)			
> 42	19 (63)	15 (43)			
Maximum diameter of colostomy in ventral abdominal wall (mm)			< 0.001[a]	< 0.001	5.2 (2.1–12.7)
≤ 34	7 (23)	26 (74)			
> 34	23 (77)	9 (26)			
Rectus muscle diameter (mm)			0.56	—	—
≤ 9	16 (53)	16 (46)			
> 9	14 (47)	19 (54)			
Diameter of rectus muscle diastasis (mm)			0.13	—	—
≤ 23	17 (57)	14 (40)			
> 23	13 (43)	21 (60)			

(Table 3 continues on next page)

TABLE 3: Univariate and Multivariate Analysis of Predictive Factors of Parastomal Hernia Development (continued)

Variable	Parastomal Hernia		*p*		
	Yes (*n* = 30)	No (*n* = 35)	Univariate	Multivariate	HR (95% CI)
Total muscle index (cm²/m²)			0.98	—	—
≤ 45	15 (54)	18 (51)			
> 45	13 (46)	17 (49)			
Total abdominal wall muscle index (cm²/m²)			0.90	—	—
≤ 39	15 (54)	17 (49)			
> 39	13 (46)	18 (51)			
Right psoas muscle index (cm²/m²)			0.86	—	—
≤ 3	16 (53)	17 (49)			
> 3	14 (47)	18 (51)			
Left psoas muscle index (cm²/m²)			0.95	—	—
≤ 3	16 (53)	17 (49)			
> 3	14 (47)	18 (51)			
Total muscle mass attenuation (HU)			0.07[a]	NS	—
≤ 40	19 (63)	14 (40)			
> 40	11 (37)	21 (60)			
Right abdominal wall muscle index (cm²/m²)			0.70	—	—
≤ 19	14 (48)	18 (51)			
> 19	15 (52)	17 (49)			
Left abdominal wall muscle index (cm²/m²)			0.90	—	—
≤ 20	13 (46)	19 (54)			
> 20	15 (54)	16 (46)			

Note—Values are the number (percentage) unless otherwise indicated; for continuous variables, medians were used as cutoff values. Dash (—) indicates data not applicable. HR = hazard ratio, NS = not significant.
[a]Variables entered in the logistic regression model (multivariate analysis).
[b]Weight in kilograms divided by the square of height in meters.
[c]Calculated as [visceral adipose tissue / (visceral + subcutaneous adipose tissue)] × 100%.

TABLE 4: Correlation of CT-Based Body Metrics That Were Significant Predictors of PSH Development on Univariate Analysis Only With Variables That Were Also Significant Predictors on Multivariate Analysis

Variable Significant[a] on Univariate but not Multivariate Analysis	Variable Significant on Univariate and Multivariate Analysis		
	COPD[b]	Operation Time[c]	Maximum Diameter of Colostomy in Abdominal Wall[d]
Waist circumference at preoperative CT	0.17	0.21	0.37[c]
Abdominal adipose tissue volume ratio	0.06	0.16	0.38[c]
Total muscle mass attenuation	−0.32	−0.011	0.03

[a]Significance was set at $p \leq 0.10$.
[b]Kendall tau correlation coefficient.
[c]Pearson correlation coefficient.
[d]$p < 0.05$.

either as maintenance therapy or during exacerbations related to COPD; this type of treatment has been suggested to lead to weakening of the abdominal wall tissue, which increases the risk of developing abdominal wall hernias, including PSHs [14]. Patients with COPD also have a higher risk of malnutrition, which might contribute to PSH development [14].

To our knowledge, our study is the first to identify operation time as an independent predictor of the development of PSH. This finding might be explained by the surgeon's decreased focus at the end of a long and difficult operation, when the stoma is created. In addition, the end colostomy might be created by a less experienced physician, because a fellow or last-year resident

might perform this part of the surgery without supervision of the surgeon, which would probably influence the quality of the colostomy site. However, other unidentified intrinsic patient factors also may influence both operation time and PSH development.

In our study, larger diameter of the abdominal wall defect at the end colostomy site emerged as an independent predictor of PSH development, which seems plausible. An abdominal wall defect diameter of 3 cm or more at the stoma site has been reported to be associated with an increased risk of PSH development, and the risk increases 10% for every millimeter increase in aperture size [15]. Hotouras et al. [9] evaluated the aperture diameter at postoperative CT and reported a significantly higher aperture diameter in patients with PSH (median, 35 mm) compared with patients without PSH (median, 22 mm; $p < 0.0001$). In that study, none of the patients had a PSH when the aperture diameter was below 25 mm [9]. To our knowledge, no further evidence exists regarding the predictive value of aperture size as measured on postoperative CT scans. In our study, PSH developed in all patients with an abdominal wall defect surface area larger than 10 cm^2 ($n = 13$) or diameter larger than 50 mm in the largest dimension ($n = 9$). Instrumentation, such as a template, that can help create an aperture less than 10 cm^2 or less than 50 mm in the largest dimension may reduce the frequency of PSH. Colostomy trephines increase over time [16], so the intraoperatively created aperture size should be significantly smaller than 10 cm2 or 50 mm in the largest dimension. Furthermore, prophylactic mesh placement may help reduce the frequency of PSH development when a relatively large abdominal wall defect at the colostomy site cannot be prevented, such as in patients with an ileus of the colon.

According to the European Hernia Society guidelines, high-quality evidence supports the use of a prophylactic mesh during construction of a permanent end colostomy in elective surgery to reduce the incidence of PSH development [2]. Additionally, Figel et al. [17] reported that a prophylactic bioprosthetic mesh would be cost-effective if at least 39% of patients would need subsequent surgical correction of a PSH after creation of an end colostomy. However, Figel et al. conducted a small study that did not consider the additional operation time related to the mesh placement, and the authors used a biologic mesh. Lee et al. [18] conducted a systematic review analyzing the cost-effectiveness of prophylactic mesh placement in patients who underwent APR with permanent colostomy and concluded that mesh prophylaxis, compared with no mesh placement, might be less costly and more effective in preventing PSH in patients with stage I–III rectal cancer and cost-effective in patients with stage IV rectal cancer. However, they only considered mesh infection in their model, although other complications related to the use of a mesh can occur. In addition, no subanalyses were performed among patients who have greater risk of PSH. A more accurate prediction of patients who are at risk would probably render mesh prophylaxis more cost-effective. Moreover, better prediction of PSH development could prevent complications due to the mesh in patients with a low risk of PSH development because use of a mesh can be omitted in these patients. Therefore, prophylactic mesh use only in patients with one or more of the predictive factors identified in the current study, such as patients with COPD, those who underwent a long operation, and those with an (inadvertently) large abdominal wall defect at the ostomy site, could be beneficial. However, this should be the subject of further research.

Our study had several limitations. First, we conducted a retrospective study, and some patients had to be excluded because of inadequate quality of the CT scans, which were obtained in referring hospitals. Second, because our hospital is a tertiary referral center for colorectal malignancies, our patient population consisted of a relatively high number of patients with more advanced disease and more comorbidities, which could have influenced our results. For example, the high proportion of patients with advanced locoregional disease could explain the relatively long operation time related to more difficult surgical procedures. However, the prevalence of PSH in our study population was comparable with that reported in the literature.

In conclusion, COPD as a comorbidity, a longer operation time, and a larger size of the abdominal wall defect at the ostomy site were identified as independent predictors of PSH development in patients who underwent end colostomy. Moreover, intraoperative creation of an ostomy opening more than 34 mm in diameter in the abdominal wall should be avoided.

References

1. Muysoms F, Campanelli G, Champault GG, et al. EuraHS: the development of an international online platform for registration and outcome measurement of ventral abdominal wall hernia repair. *Hernia* 2012; 16:239–250
2. Antoniou SA, Agresta F, Garcia Alamino JM, et al. European Hernia Society guidelines on prevention and treatment of parastomal hernias. *Hernia* 2018; 22:183–198
3. Ripoche J, Basurko C, Fabbro-Perray P, Prudhomme M. Parastomal hernia: a study of the French Federation of Ostomy Patients. *J Visc Surg* 2011; 148:e435–e441
4. Carne PW, Robertson GM, Frizelle FA. Parastomal hernia. *Br J Surg* 2003; 90:784–793
5. Kald A, Juul KN, Hjortsvang H, Sjödahl RI. Quality of life is impaired in patients with peristomal bulging of a sigmoid colostomy. *Scand J Gastroenterol* 2008; 43:627–633
6. Randall J, Lord B, FulhAm J, Soin B. Parastomal hernias as the predominant stoma complication after laparoscopic colorectal surgery. *Surg Laparosc Endosc Percutan Tech* 2012; 22:420–423
7. Aquina CT, Iannuzzi JC, Probst CP, et al. Parastomal hernia: a growing problem with new solutions. *Dig Surg* 2014; 31:366–376
8. Hotouras A, Murphy J, Thaha M, Chan CL. The persistent challenge of parastomal herniation: a review of the literature and future developments. *Colorectal Dis* 2013; 15:e202–e214
9. Hotouras A, Murphy J, Power N, Williams NS, Chan CL. Radiological incidence of parastomal herniation in cancer patients with permanent colostomy: what is the ideal size of the surgical aperture? *Int J Surg* 2013; 11:425–427
10. Gillern S, Bleier JI. Parastomal hernia repair and reinforcement: the role of biologic and synthetic materials. *Clin Colon Rectal Surg* 2014; 27:162–171
11. Zwart AT, van der Hoorn A, van Ooijen PMA, Steenbakkers RJHM, de Bock GH, Halmos GB. CT-measured skeletal muscle mass used to assess frailty in patients with head and neck cancer. *J Cachexia Sarcopenia Muscle* 2019; 10:1060–1069
12. Xiao J, Cain A, Purcell SA, et al. Sarcopenic obesity and health outcomes in patients seeking weight loss treatment. *Clin Nutr ESPEN* 2018; 23:79–83
13. Levi B, Zhang P, Lisiecki J, et al. Use of morphometric assessment of body composition to quantify risk of surgical-site infection in patients undergoing component separation ventral hernia repair. *Plast Reconstr Surg* 2014; 133:559e–566e

14. Gea J, Pascual S, Casadevall C, Orozco-Levi M, Barreiro E. Muscle dysfunction in chronic obstructive pulmonary disease: update on causes and biological findings. *J Thorac Dis* 2015; 7:E418–E438
15. Pilgrim CH, McIntyre R, Bailey M. Prospective audit of parastomal hernia: prevalence and associated comorbidities. *Dis Colon Rectum* 2010; 53:71–76
16. Ho KK, Economou T, Smart NJ, Daniels IR. Radiological progression of end colostomy trephine diameter and area. *BJS Open* 2018; 3:112–118
17. Figel NA, Rostas JW, Ellis CN. Outcomes using a bioprosthetic mesh at the time of permanent stoma creation in preventing a parastomal hernia: a value analysis. *Am J Surg* 2012; 203:323–326; discussion, 326
18. Lee L, Saleem A, Landry T, Latimer E, Chaudhury P, Feldman LS. Cost effectiveness of mesh prophylaxis to prevent parastomal hernia in patients undergoing permanent colostomy for rectal cancer. *J Am Coll Surg* 2014; 218:82–91

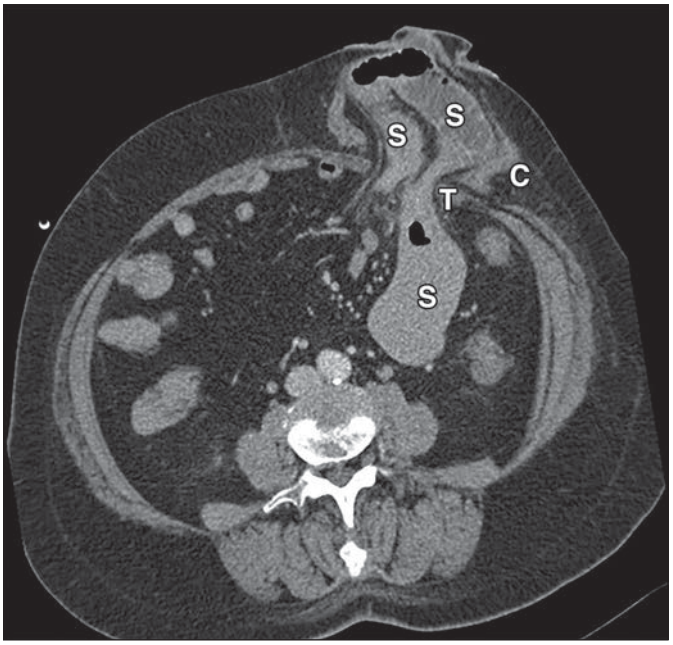


Fig. 1—66-year-old woman with parastomal hernia (PSH). Abdominal CT scan obtained at follow-up 19 months after abdominoperineal resection for rectal cancer shows herniation of small-bowel loop (S) into PSH with transition point (T) in proximal loop when entering PSH, causing small-bowel obstruction. Maximum size of abdominal wall defect at ostomy site is 46 mm. Diameter of descending colon (C) proximal to end colostomy site is normal. At laparotomy, small-bowel herniation was confirmed, and lysis of adhesive band in PSH was performed to relieve small-bowel obstruction.

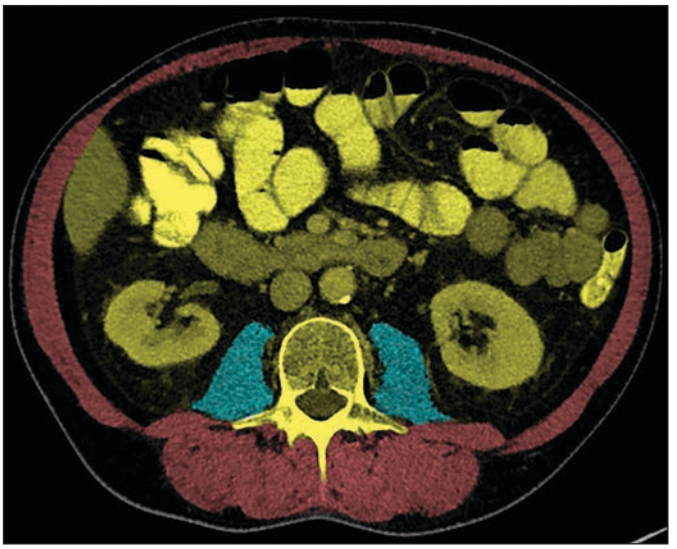


Fig. 2—63-year-old man who underwent follow-up abdominal CT after treatment of rectal cancer. Abdominal CT scan shows example of preoperative muscle status assessment. Psoas major muscles (*blue*), abdominal wall and back muscles (*red*), and intraabdominal structures (*yellow*) are seen.

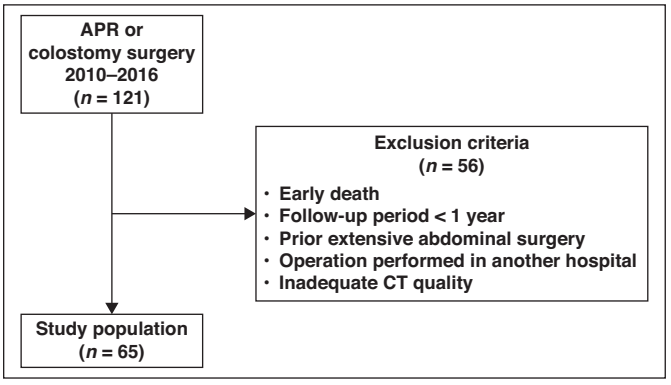
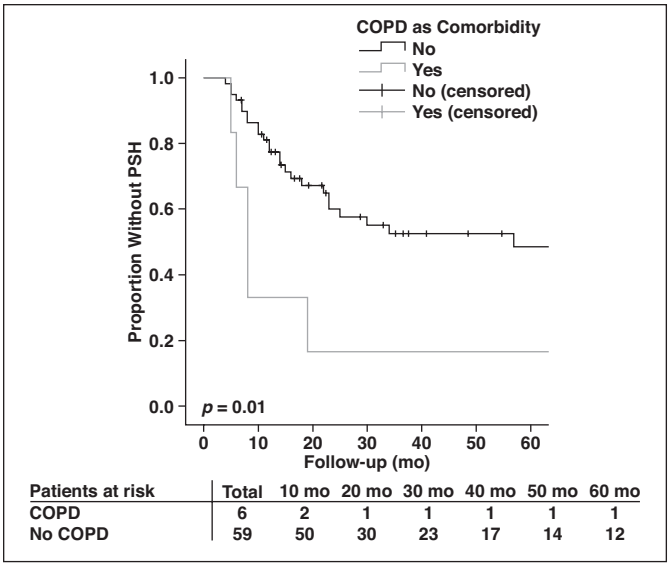
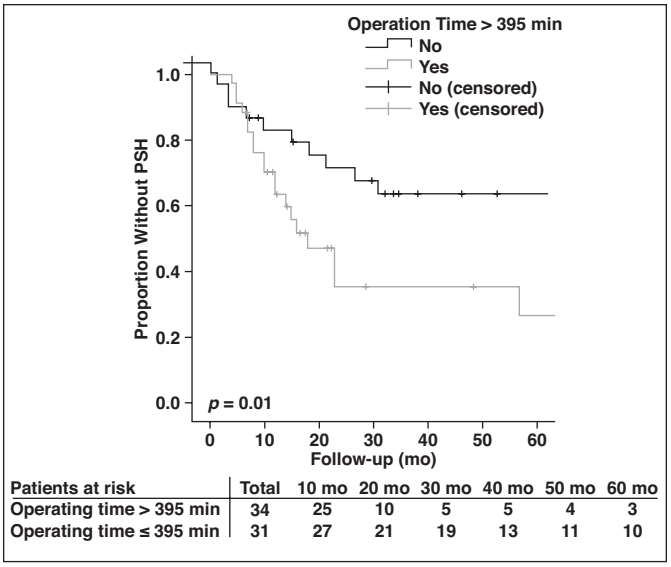


Fig. 3—Flowchart shows exclusion criteria and number of patients included in study population. APR = abdominoperineal resection.



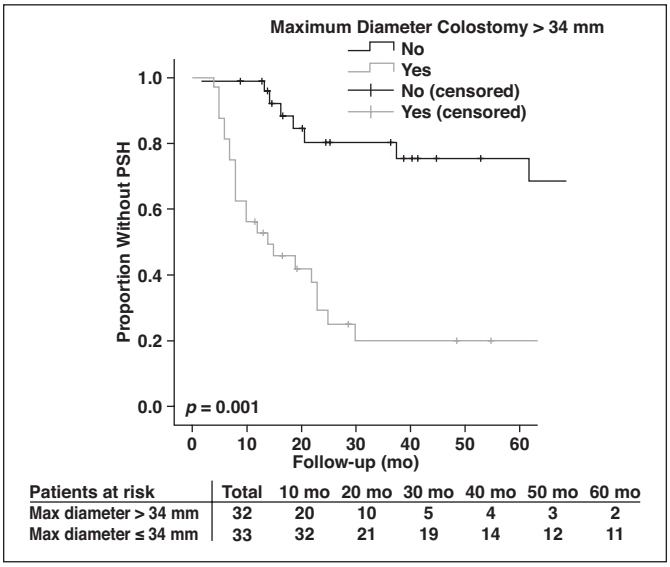
Patients at risk	Total	10 mo	20 mo	30 mo	40 mo	50 mo	60 mo
COPD	6	2	1	1	1	1	1
No COPD	59	50	30	23	17	14	12

A



Patients at risk	Total	10 mo	20 mo	30 mo	40 mo	50 mo	60 mo
Operating time > 395 min	34	25	10	5	5	4	3
Operating time ≤ 395 min	31	27	21	19	13	11	10

B



Patients at risk	Total	10 mo	20 mo	30 mo	40 mo	50 mo	60 mo
Max diameter > 34 mm	32	20	10	5	4	3	2
Max diameter ≤ 34 mm	33	32	21	19	14	12	11

C

Fig. 4—Kaplan-Meier curves illustrating influence of predictive factors on occurrence of parastomal hernia (PSH).
A, Graph shows chronic obstructive pulmonary disease (COPD) as predictor for PSH.
B, Graph shows operation time of over 395 minutes as predictor for PSH.
C, Graph shows maximum diameter of abdominal wall defect at end colostomy > 34 mm as predictor for PSH.

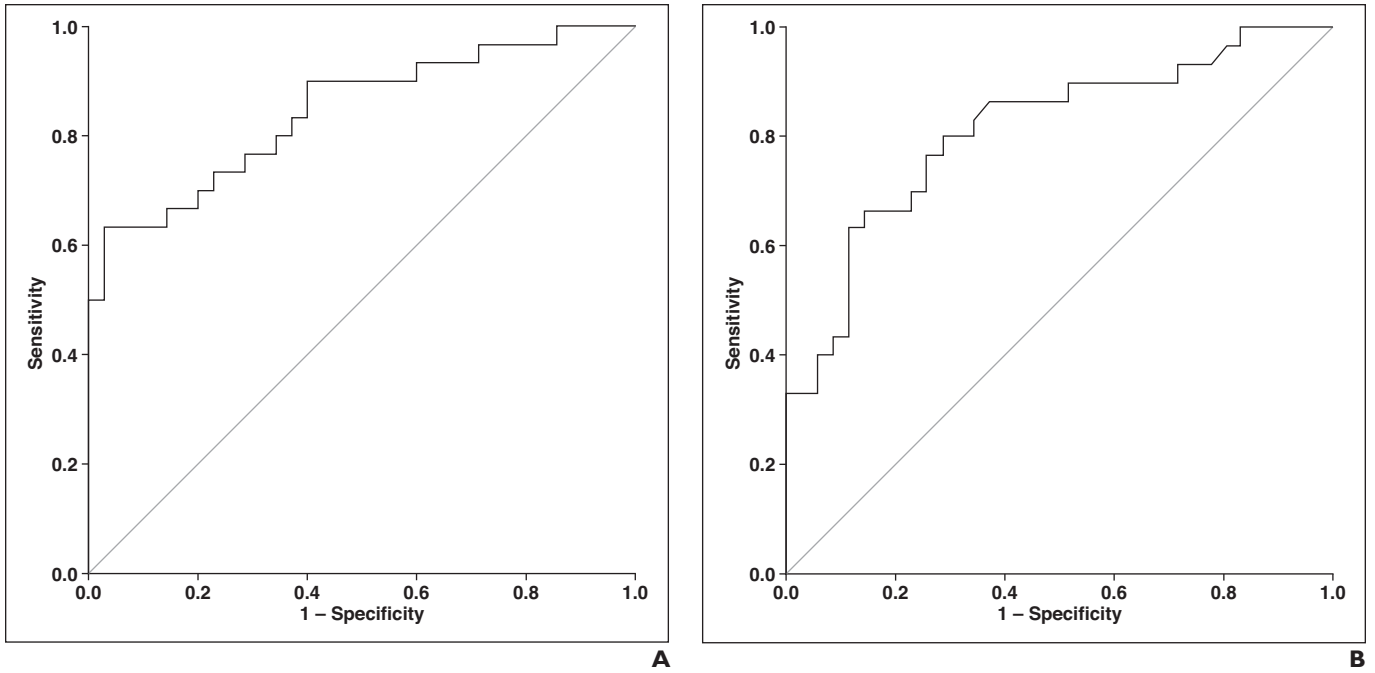


Fig. 5—Diagnostic value of cutoff points.
A and **B,** ROC curves illustrate sensitivity and specificity of cutoff points for total colostomy surface area (**A**) and largest diameter of anterior abdominal wall defect (**B**) in relation to parastomal hernia development. Diagonal line indicates indicates line of no discrimination.

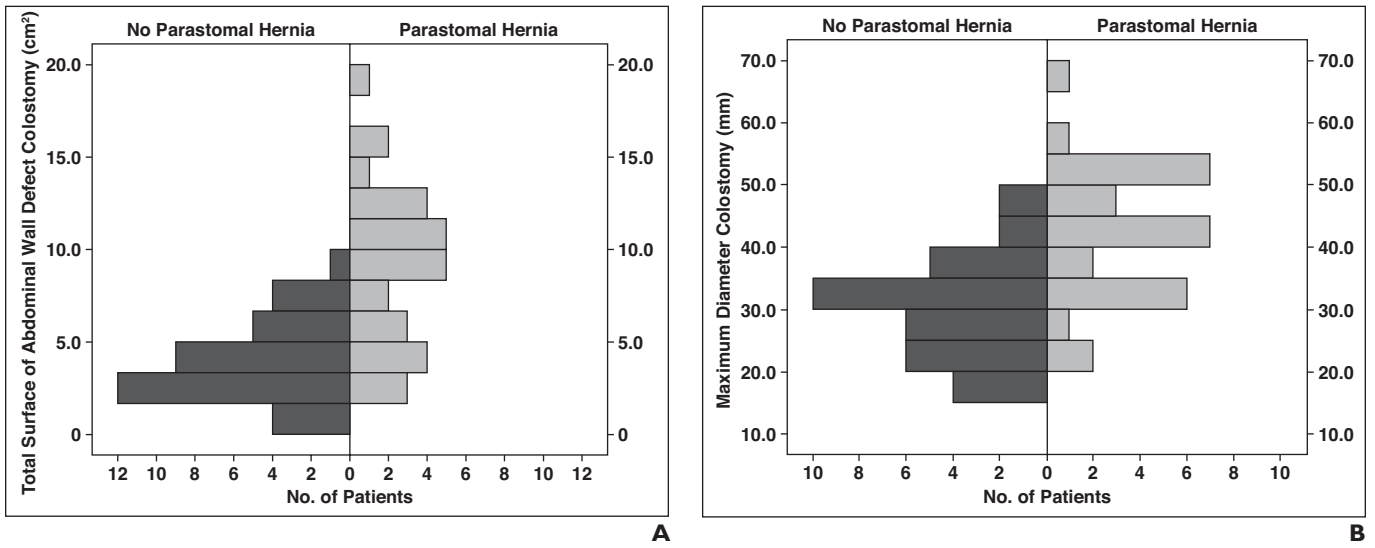


Fig. 6—Distribution of parastomal hernias.
A and **B,** Bar graphs show number of patients with parastomal hernias according to surface area (**A**) and largest diameter of abdominal wall defect at end colostomy site (**B**).