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ORIGINAL ARTICLE

Atrophic change of the abdominal rectus muscle significantly influences the onset of parastomal hernias beyond existing risk factors after end colostomy

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Abstract

Purpose To investigate optimal risk factors, including atrophy of the abdominal rectus muscle (ARM) for postoperative parastomal hernia (PH) in patients who underwent end colostomy at left lower quadrant.

Methods This single-institution retrospective study included 91 patients who underwent end colostomy between April 2004 and December 2015. The surgical and long-term outcomes among patients with or without PH were collected and compared.

Results Altogether, 22 (24.2%) patients had a PH including 15 (68.2%) patients with a simultaneous incisional hernia. Univariate analysis showed that older patients (71 ± 11.9 vs. 64 ± 12.2 years, $p = 0.03$) and those with higher body mass index (BMI) (23.8 ± 3.8 vs. 20.9 ± 3.3 kg/m^2, $p < 0.001$) had a statistically significant relation with having PHs. Relative atrophy of left abdominal rectus muscle was more frequently found in patients with PH (ratio of left side/right side; caudal level and medial side: 0.66 vs. 0.92, $p < 0.01$, caudal level and lateral side: 0.95 vs. 1.03, $p = 0.04$). Multivariate analysis revealed that BMI > 25 kg/m^2 [odds ratio (OR) 9.05, 95% confidence interval (CI) 2.06–39.76, $p = 0.003$] and atrophy of the left lower medial portion of the abdominal rectus muscle (OR 12.85, 95% CI 2.49–66.39, $p = 0.002$) were independent risk factors for PHs. Neither the laparoscopic approach nor the extraperitoneal route of the colostomy was proven to correlate with a lower rate of PHs.

Conclusions High BMI and atrophic change of ARM were significantly associated with PH development. Surgical techniques for prevention of atrophic change of ARM are expected to reduce the incidence of PHs.

Keywords Parastomal hernia · Colostomy · Abdominal rectus muscle · Muscle atrophy

Introduction

Herniation at the incisional scar—i.e., an incisional hernia (IH)—is encountered commonly as a postoperative complication of abdominal surgery [1–3]. IHs are attributed to patient-related factors such as obesity [3], increasing age, abdominal surgical history, history of diabetes [3], and chronic obstructive pulmonary disease [2, 4, 5]. Surgical factors such as the suturing technique, ligature thread, surgical-site infection, and wound dehiscence can be also related to IH formation [2, 4, 5]. Parastomal hernia (PH), a ventral IH attached to a stoma, has a wide range of incidence of 4–48% after stoma construction [6]. Technical factors—including stoma size, location, stomal aperture, route of stoma creation, fixation to fascia, and postoperative complications—are suggested to be importantly involved in PH formation [6]. Although surgical techniques to prevent the development of PH have been considered, including mesh placement [7] and creation of a colostomy via an extraperitoneal route [8], no procedure has been proven to be significantly effective. Timmermans et al. found that patients with a PH also had IH, and 55% of all IHs developed at the same level as the colostomy [9]. They indicated that the midline incision would move in the opposite direction due to reduced restraining forces at the site of the colostomy because of atrophy of the abdominal rectus muscle (ARM) [10]. ARMs are mostly involved in ventral flexion of the spine, and their blood supply is mainly from the superior and inferior epigastric arteries, which are connected [11]. Innervation of

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the ARM is mostly by T7–T12 intercostal nerves. Several nerves distribute to lower portion of the ARM along with the lateral intercostal vessels at the lateral side of the inferior epigastric artery [12]. Stoma is usually created through the lateral ARM which is directly divided or split along its muscle fibers. During the stoma construction, dividing the ARM may injure muscle fibers, vessels, and nerves, subsequently causing ARM atrophy and disruption of its function and strength. Therefore, we hypothesized that atrophy of the ARM induced by colostomy creation strongly influences PH development.

To provide further information about PH in patients who underwent end colostomy, we conducted a single-institution retrospective study and reported our experience with 91 cases, investigating the clinicopathological features including quantitative measurements of patients with PH. We also analyzed the optimal risk factors, including atrophic change of the ARM, for postoperative PH to assess the relationship between atrophic change of ARM and PH formation.

Patients and methods

We retrospectively enrolled 91 patients who had undergone end colostomy, exteriorized through the ARM at the left lower quadrant of the abdomen, as surgical treatment for colorectal cancer at the Department of Surgery and Oncology, Kyushu University, Fukuoka, Japan between April 2004 and December 2015. The clinicopathological characteristics of the patients were determined from clinical and histopathological reports. Patients' demographics and clinical features at diagnosis included their sex, age, body mass index (BMI), smoking status, history of diabetes, operative findings (e.g., emergency surgery, surgical approach, procedure, duration of operation, hemorrhage), route of the colostomy, postoperative morbidity, and mortality. None of the patients in our series had a past history of connective tissue disorders or steroid treatment. Postoperative complications were evaluated according to the Clavien–Dindo grading system for the classification of surgical complications, version 2.0 [13]. All patients were followed up by regular examinations, including office visits and computed tomography (CT) scan every 6 months for the first 5 years to monitor possible recurrence of cancer. The number of patients lost to cancer-related death was 23 (24.1%). The number of patients lost for periodic CT scan every 6 months was two, although they had CT scan at least once a year during regular examination. Patients were excluded from the study if they had an ileostomy instead of a colostomy or transposition of the ARM. Patients with multiple stoma creations were not excluded. The median follow-up period of these patients was 36.9 months (range 10.2–87.8 months).

The Kyushu University Hospital Human Research Ethics Committee approved this study (No. 26–239).

Definitions and measurements

Ventral hernia, including PH and IH, was defined as any abdominal wall gap with or without a bulge in a postoperative incisional site that was detectable or palpable by clinical examination and/or imaging [14]. PH was defined as any palpable defect or bulge adjacent to the stoma when the patient was straining the abdomen while in a supine position. Ventral hernia was diagnosed by examination conducted by two physicians experienced in hernia investigations and by postoperative follow-up CT [15]. ARM measurements were performed at eight points on one-third of the medial side and one-third of the lateral side of both the right and left ARMs. Each of the measurements was obtained at a site 10 mm cranial and caudal from the colostomy edge (Fig. 1).

Statistical analysis

Univariate and multivariate analyses were conducted to compare patients with and without PH. All statistical analyses

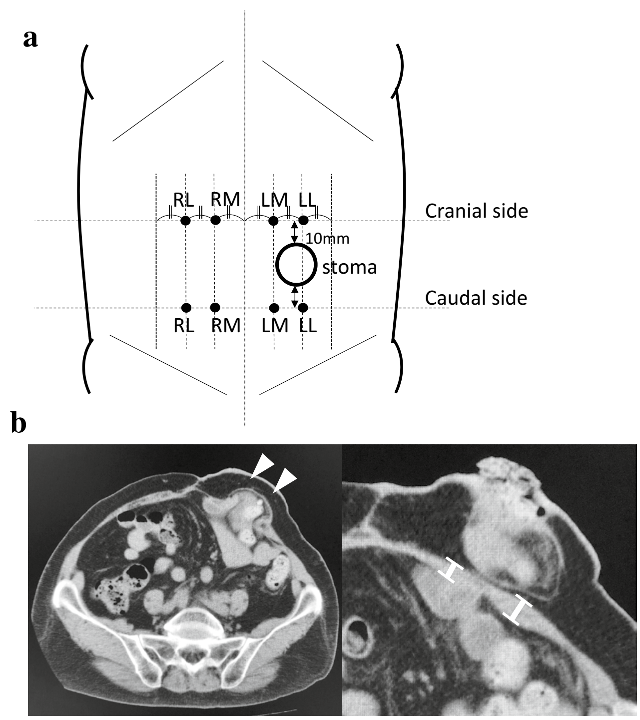

Fig. 1 **a** Eight points on one-third of the medial side and one-third of the lateral side of both right and left abdominal rectus muscles. Each of the measurements was performed 10 mm cranial and caudal to the colostomy. **b** Enhanced computed tomography scan reveals a parastomal hernia (white arrowheads). Thickness of the abdominal rectus muscle was measured in an axial section at each of the eight points (white bar)

were performed using JMP version 13.0.0 software (SAS Institute, Cary, NC, USA). Clinical and demographic characteristics were analyzed using the $\chi 2$ test for categorical variables. Differences in age, BMI, and measurements of thickness of the ARM were compared using the Wilcoxon rank-sum test. One-way analysis of variance test was used to compare the other continuous variables. Logistic regression analysis was used to determine independent risk factors for PH. In the multivariate analysis of all patients, all variables were included in a backward stepwise multiple logistic regression to identify significant risk factors for PH. The final model included age, BMI, surgical approach, route of the stoma, presence of an IH, and thickness of the ARM. The fitness of model was evaluated by likelihood ratio test that showed $p<0.001$. Values of $p<0.05$ were considered to indicate statistical significance.

Results

Clinical characteristics of patients with an end colostomy

Overall, 22 (24.2%) of 91 patients who underwent end colostomy developed a PH and 23 (25.3%) developed an IH. The median period between diagnosing PH and its surgical repair was 17.2 months (range 5.7–60.9 months). Abdominoperineal resection was performed in 63 patients (65.0%), Hartmann's operation in 27 patients (27.8%), and other procedures including total pelvic exenteration in 7 patients (7.2%). Approximately half of all the patients underwent laparoscopic surgery (42.3%) and the others had a colostomy via an extraperitoneal route (52.6%) (Table 1).

Table 1 Clinical characteristics of 91 patients with an end colostomy

Characteristic	Value
Age, median, years (range)	65 (36–90)
Sex	
Male	56 (57.1%)
Female	42 (42.8%)
BMI, median, kg/m^2 (range)	21.8 (13.4–31.6)
Surgical procedure	
APR	63 (65.0%)
Hartmann	27 (27.8%)
Others	7 (7.2%)
Type of surgery	
Elective	87 (89.7%)
Emergency	10 (10.3%)
Surgical approach	
Laparotomy	56 (57.7%)
Laparoscopy	41 (42.3%)
Colostomy lesion	
Sigmoid colon	69 (71.1%)
Descending colon	18 (18.6%)
Transverse colon	10 (10.3%)
SP mobilization	
Not performed	79 (81.4%)
Performed	18 (18.6%)
Colostomy route	
Transabdominal	46 (47.4%)
Extraperitoneal	51 (52.6%)

APR abdominoperineal resection, *BMI* body mass index, *SP* splenic flexure

Comparison of clinical features and surgical outcomes

Table 2 compares clinical features and surgical outcomes between the patients with and without PH. Older patients (71 ± 11.9 vs. 64 ± 12.2 years, $p=0.03$) and higher BMI patients (23.8 ± 3.8 vs. 20.9 ± 3.3 kg/m^2, $p<0.001$) developed PH significantly more often. PH was detected significantly more frequent in patients who underwent laparoscopic surgery than in those who underwent laparotomy (63.6% vs. 36.4%, $p=0.02$). The route of colostomy was not a significant factor since the incidence of PH did not differ much between patients with the colostomy performed via the transabdominal route and those via or the extraperitoneal route (59.1% vs. 40.9%, $p=0.20$). Postoperative IH was coincidently observed with PH (68.2% vs. 31.8%, $p=0.04$). There were no significant differences in the clinical features, including sex, smoking status, history of diabetes, surgical procedure, emergency surgery, and postoperative complications (including surgical-site infection) between the patients with and without PH.

Comparison of ARM thickness measurements

To investigate the correlation between the incidence of PH and ARM atrophy, we measured the thickness of ARM at eight points (Fig. 1a). Table 3 compares those measurements between patients with and without PH. At the cranial level of the colostomy, all four points, including the right lateral point (RL), right medial point (RM), left medial point (LM), and left lateral point (LL) of the ARM did not differ in the two groups. At the caudal level of the colostomy, however, the RL point of the ARM became significantly thicker (8.95 ± 5.1 vs. 7.96 ± 5.4 mm, $p=0.05$), whereas the LM point of ARM became significantly thinner (7.05 ± 2.7 vs. 8.31 ± 2.4 mm, $p=0.05$) in patients with PH than in those without PH. According to the left/right ARM ratio, the left ARM became more atrophic than the right ARM at the caudal level in patients with PH than in those without PH on the

Table 2 Clinical characteristics of patients with and without a parastomal hernia

Characteristic	Parastomal hernia		p value
	Present ($n=22$)	Absent ($n=69$)	
Age, median, years (range)	71 (43–90)	64 (36–90)	0.03*
Sex			
Male	14 (63.6%)	41 (59.4%)	0.72
Female	8 (36.4%)	28 (40.6%)	
BMI, median, kg/m^2 (range)	23.8 (14.6–30.5)	20.9 (13.4–31.6)	< 0.001*
Smoking			
Present	3 (13.6%)	11 (15.9%)	0.79
Absent	19 (86.3%)	58 (84.1%)	
History of diabetes			
Present	2 (9.1%)	7 (10.1%)	0.88
Absent	20 (90.9%)	62 (89.9%)	
Surgical procedure			
APR	14 (63.6%)	48 (69.6%)	0.87
Hartmann's	6 (27.3%)	16 (23.2%)	
Others	2 (9.1%)	5 (7.2%)	
Type of surgery			
Elective	19 (86.4%)	63 (91.3%)	0.51
Emergency	3 (13.6%)	6 (8.7%)	
Surgical approach			
Laparotomy	8 (36.4%)	44 (63.7%)	0.02*
Laparoscopy	14 (63.6%)	25 (36.2%)	
SP mobilization			
Done	6 (27.3%)	11 (15.9%)	0.25
Not done	16 (72.7%)	58 (84.1%)	
Route of stoma creation			
Transabdominal	13 (59.1%)	30 (43.5%)	0.20
Extraperitoneal	9 (40.9%)	39 (56.5%)	
Postoperative complication			
Present	15 (68.2%)	35 (50.7%)	0.15
Absent	7 (31.8%)	34 (49.3%)	
Stoma-related complication			
Present	1 (4.6%)	3 (4.35%)	0.97
Absent	21 (94.5%)	66 (95.7%)	
Incisional hernia			
Present	15 (68.2%)	8 (11.6%)	0.04*
Absent	7 (31.8%)	61 (88.4%)	

APR abdominoperineal resection, *BMI* body mass index, *SP* splenic flexure

medial side (0.66 vs. 0.92, $p<0.01$; Fig. 2) and on the lateral side (0.95 vs. 1.03, $p=0.04$; Fig. 2).

Multivariate analysis to evaluate risk factors for the PH

The multivariate logistic regression analysis revealed that BMI > 25 kg/m^2 [odds ratio (OR) 9.05, 95% confidence interval (CI) 2.06–39.76, $p=0.003$] and atrophy at the LM point of ARM at the caudal level (OR 12.85, 95% CI 2.49–66.39, $p=0.002$) were independent risk factors associated with PH in patients who underwent end-colostomy surgery (Table 4). IH was suggested as a risk factor for PH, although it was not significant. In addition, neither the laparoscopic approach nor the transabdominal route of the colostomy was confirmed as a risk factor (Table 4).

Table 3 Measurements of the abdominal rectus muscle in patients with and without a parastomal hernia

Measurement site	Parastomal hernia		p value
	Present ($n=22$)	Absent ($n=69$)	
Cranial level: median, mm (range)			
Right medial point (RM)	8.48 (4.44–11.06)	8.41 (4.32–13.57)	0.30
Right lateral point (RL)	7.26 (5.12–11.05)	7.25 (4.46–10.87)	0.85
Left medial point (LM)	6.69 (3.72–12.14)	8.03 (4.62–4.63)	0.06
Left lateral point (LL)	7.57 (4.42–13.09)	8.04 (4.62–12.58)	0.43
Caudal level: median, mm (range)			
Right medial point (RM)	10.0 (4.49–18.3)	9.47 (3.01–15.49)	0.12
Right lateral point (RL)	8.95 (4.42–18.82)	7.96 (3.55–12.89)	0.05*
Left medial point (LM)	7.50 (2.71–11.1)	8.31 (3.93–14.55)	0.05*
Left lateral point (LL)	8.59 (2.01–16.5)	7.96 (2.24–14.36)	0.32

*Statistically significant ($p<0.05$)

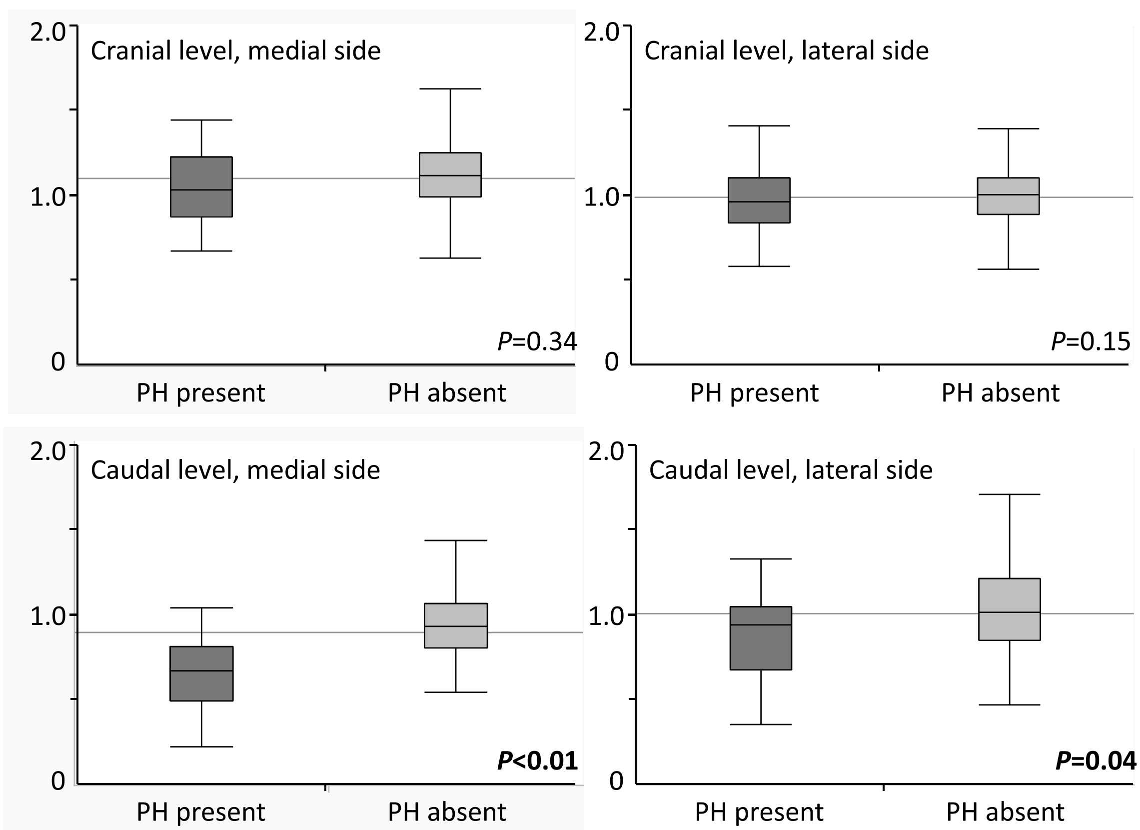

Fig. 2 Comparisons of the left/right abdominal rectus muscle ratio between patients with and without a parastomal hernia

Discussion

This study uniquely showed that atrophic change of ARM was significantly associated with PH formation. The study highlighted that both high BMI and atrophy at the LM portion of the ARM caudal level to the colostomy site were independent risk factors for PH in patients who underwent end-colostomy surgery. Neither the laparoscopic approach nor the extraperitoneal colostomy route was correlated with a lower rate of PH appearance.

Development of PHs was related to both general patient factors and technical factors. General patient factors, including obesity, increasing age, a history of surgery, and diabetes mellitus, were similar to those for IH [16, 17]. Several studies have revealed that obesity was also strongly associated

Table 4 Risk factors for parastomal hernias

Risk factors	Multivariate analysis Odds ratio (95% CI)	*p* value
Age: high/low	1.84 (0.49–6.88)	0.36
BMI: high/low	9.05 (2.06–39.76)	0.003*
Surgical approach: laparoscopy/laparotomy	2.53 (0.60–10.65)	0.21
Route: transabdominal/extraperitoneal	1.75 (0.47–6.47)	0.40
Incisional hernia: present/absent	4.93 (0.91–26.78)	0.06
Caudal LLM of ARM atrophy: present/absent	12.85 (2.49–6.39)	0.002*

LLM left lower medial side, *ARM* abdominal rectus muscle

*Statistically significant ($p < 0.05$)

with PH [18, 19]. Obese patients have greater intraabdominal pressure, which usually resulted from elevated BMI, as compared to the normal-weight population [19, 20]. The high intra-abdominal pressure in obese patients is due to the increased visceral fat, which causes greater tangential force on the visceral wall. Therefore, obese patients are suggested to be at a high risk for PH development [18]. Our study revealed that relatively high BMI (> 25 kg/m^2) was significantly associated with PH formation. In general, Asian populations have lower BMIs compared to non-Asian populations, although the visceral fat volume is suggested to be greater than in non-Asian populations [21]. Considering the difference in obesity definitions between Western countries and Japan, the BMI cutoff value in this study, 25 kg/m^2, was appropriate as the cutoff value for the risk factor of PH in the Japanese population.

Technical factors for PH seemed to be different from those associated with IH. Laparoscopic surgery, including stoma creation, is being increasingly being used for colorectal surgery in Japan [22]. Many recent studies revealed that laparoscopic surgery can contribute to reducing the incidence of IH [23]. Compared with the conventional open approach, the surgical wound after laparoscopic approach is smaller, resulting in a reduced risk for IH. However, single-incision laparoscopic surgery has been suggested to be associated with three-times higher risk for IH than multi-port laparoscopic surgery [24]. The mini-laparotomy site of single-incision laparoscopic surgery is likely to be more damaged during a surgical procedure than the incision sites of multi-port laparoscopic surgery. Such damage can lead to delayed wound healing and can cause surgical site infection—possibly resulting in hernia formation.

Laparoscopic surgery is more likely than laparotomy to result in a PH, in contrast to IH [18, 25]. Our results also suggested little benefit of laparoscopic surgery for preventing PH, because PH was diagnosed at a significantly higher rate in patients who underwent laparoscopic surgery than in those who underwent laparotomy. As suggested previously, high abdominal pressure is one of the possible causes of PHs. Obese patients with a large aperture caused by a large abdominal wall radius and high abdominal pressure are suggested to be at greater risk of a PH [18]. Among patients who undergo laparoscopic surgery that includes colostomy, abdominal pressure is mostly exerted on the stoma site because it is the largest wound. Although there were no patients who had connective tissue disorders or underwent treatment with glucocorticoids in our series, when other factors associated with tissue fragility around the stoma site are present, such as in patients who have had long-term exposure to glucocorticoids [26], PH is likely to occur.

Previous studies revealed that the extraperitoneal approach for the stoma route significantly reduced the incidence of PH formation compared with the transabdominal approach [8, 27]. Using the extraperitoneal approach, the colon is led toward the stoma through the lateral extraperitoneal space, resulting in strengthening of the lateral space of the stoma. It has been proposed that the higher intraabdominal pressure pushes the lateral to the stoma, thus extraperitoneal colostomy prevents intraabdominal contents from herniating through the stoma site [26]. Nevertheless, our results showed that 18.8% of patients who underwent stoma creation via the extraperitoneal approach developed PH after surgery. Among these patients, the LM ARM at the caudal side became thinner in patients with a PH than those without a PH. Most of the PH patients after colostomy via the extraperitoneal approach had herniation on the medial side of the stoma. Thus, the extraperitoneal approach plays an auxiliary protective role but not enough to prevent PH by itself. Our data indicated that muscular atrophy in the medial side of the stoma mainly led to PH formation, even though the extraperitoneal approach partly strengthens the lateral side of the stoma.

Colostomy is usually created on the anterior abdominal wall by splitting the muscle fibers of the ARM. The ARM's blood supply is mainly from the superior and inferior epigastric arteries, which are connected. Fahim et al. investigated the most substantial and most frequently identified nerves running into the anterolateral abdominal musculature [28]. The eleventh and twelfth intercostal nerves appear to play an important role in its insertions into the ARM and external oblique muscle. Yamada et al. reported using paramedian incisions for access to the aorta, incising the anterior and posterior sheaths of the ARM, and separating the ARM from the sheaths, which resulted in much more atrophy of the ARM than flank incisions [29]. These previous studies suggested that direct trauma or transection of the eleventh and twelfth intercostal nerves when opening the abdominal wall would lead to denervation and subsequent atrophy of the ARM rather than reduction of the blood supply.

ARM atrophy after colostomy creation and subsequent midline shift are considered frequent causes of IH formation [10]. A correlation between PH formation and IH formation is suggested in patients with end colostomy [9]. Our study also demonstrated that IH was significantly found in PH patients despite the fact that none of the patients have connective functional issues, this suggests that atrophic change of the ARM may lead to midline shift and influence both of IH and PH formation. Interestingly, a previous study indicated that progressive decrease of skeletal muscle mass—so-called sarcopenia—is not clearly related to IH development [30]. In our study, atrophic change of the left lower ARM was significantly associated with PH formation, beyond existing risk factors such as obesity, the surgical approach, and coexistence of IH. The right lower ARM did not develop atrophic change in patients diagnosed with PH who had atrophic change of the left lower ARM. Disproportional contraction of the ARM (i.e., induced by one-sided atrophy) leads to enlargement of the gap between the stoma and the ARM, resulting in herniation, irrelevant to the whole-body skeletal muscle mass decrease. Our study also showed that atrophic change was found only in some area of the ARM. We suggested that damage of peripheral nerve or vessels, which supply the distal muscle, is caused by anatomical and technical factors during stoma creation and it is involved in partial atrophic change of the ARM in the caudal side of the damaged areas. Therefore, we should be more conscious of the importance of a precise surgical technique for preserving the ARM, the peripheral blood vessels, and the peripheral lower thoracic nerves, especially the eleventh and twelfth intercostal nerves. It may be important to pay particular attention to avoid injuring these nerves while creating a stoma aperture, being particularly aware that the eleventh and twelfth intercostal nerves pass below the umbilicus in the direction of the contralateral inguinal ligament and pelvic tubercle.

We are aware that our research may have several limitations. This study was designed to be a retrospective, single-institution trial. Because the patient population was too small for us to draw firm conclusions, additional prospective, controlled studies are warranted. There were other risk factors associated with PH that were not included in our study. We should consider that other clinical risk factors could contribute to onset of PH. Although PHs mostly develop during the first few years after surgery, the risk of hernia formation extends to more than a decade [6]. We should, therefore, collect further data during a long follow-up period.

Atrophic change of the ARM is associated with the development of PH in patients with an end colostomy over the long term. With the association of any other risk factors, avoiding ARM injury during stoma construction could help reduce PH formation. Surgeons should carefully separate the ARM, identifying and preserving vessels and nerves with the aim of preventing PH, which may result in a better quality of life postoperatively for patients with an end colostomy.

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Compliance with ethical standards

Conflict of interest The authors have declared no conflicts of interest.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Kyushu University Hospital Human Research Ethics Committee (No. 26–239).

Human and animal rights All procedures in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent For this type of study, formal consent is not required.

References

1. Mudge M, Hughes LE (1985) Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 72(1):70–71
2. Bosanquet DC, Ansell J, Abdelrahman T, Cornish J, Harries R, Stimpson A, Davies L, Glasbey JC, Frewer KA, Frewer NC, Russell D, Russell I, Torkington J (2015) Systematic review and meta-regression of factors affecting midline incisional hernia rates: analysis of 14,618 patients. PLoS One 10(9):e0138745. https://doi.org/10.1371/journal.pone.0138745
3. Nastro P, Knowles CH, McGrath A, Heyman B, Porrett TR, Lunniss PJ (2010) Complications of intestinal stomas. Br J Surg 97(12):1885–1889. https://doi.org/10.1002/bjs.7259
4. Yamada T, Okabayashi K, Hasegawa H, Tsuruta M, Abe Y, Ishida T, Matsui S, Kitagawa Y (2016) Age, preoperative subcutaneous fat area, and open laparotomy are risk factors for incisional hernia following colorectal cancer surgery. Ann Surg Oncol 23(Suppl 2):S236–241. https://doi.org/10.1245/s10434-015-4462-y
5. Sneiders D, Yurtkap Y, Kroese LF, Kleinrensink GJ, Lange JF, Gillion JF, Hernia-Club M (2019) Risk factors for incarceration in patients with primary abdominal wall and incisional hernias: a prospective study in 4472 patients. World J Surg. https://doi.org/10.1007/s00268-019-04989-x

6. Carne PW, Robertson GM, Frizelle FA (2003) Parastomal hernia. Br J Surg 90(7):784–793. https://doi.org/10.1002/bjs.4220
7. Lopez-Cano M, Lozoya-Trujillo R, Quiroga S, Sanchez JL, Vallribera F, Marti M, Jimenez LM, Armengol-Carrasco M, Espin E (2012) Use of a prosthetic mesh to prevent parastomal hernia during laparoscopic abdominoperineal resection: a randomized controlled trial. Hernia 16(6):661–667. https://doi.org/10.1007/s10029-012-0952-z
8. Lian L, Wu XR, He XS, Zou YF, Wu XJ, Lan P, Wang JP (2012) Extraperitoneal vs. intraperitoneal route for permanent colostomy: a meta-analysis of 1,071 patients. Int J Colorectal Dis 27(1):59–64. https://doi.org/10.1007/s00384-011-1293-6
9. Timmermans L, Deerenberg EB, Lamme B, Jeekel J, Lange JF (2014) Parastomal hernia is an independent risk factor for incisional hernia in patients with end colostomy. Surgery 155(1):178–183. https://doi.org/10.1016/j.surg.2013.06.014
10. Timmermans L, Deerenberg EB, van Dijk SM, Lamme B, Koning AH, Kleinrensink GJ, Jeekel J, Lange JF (2014) Abdominal rectus muscle atrophy and midline shift after colostomy creation. Surgery 155(4):696–701. https://doi.org/10.1016/j.surg.2013.12.033
11. Moon HK, Taylor GI (1988) The vascular anatomy of rectus abdominis musculocutaneous flaps based on the deep superior epigastric system. Plast Reconstr Surg 82(5):815–832
12. Hammond DC, Larson DL, Severinac RN, Marcias M (1995) Rectus abdominis muscle innervation: implications for TRAM flap elevation. Plast Reconstr Surg 96(1):105–110
13. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240(2):205–213
14. Muysoms FE, Miserez M, Berrevoet F, Campanelli G, Champault GG, Chelala E, Dietz UA, Eker HH, El Nakadi I, Hauters P, Hidalgo Pascual M, Hoeferlin A, Klinge U, Montgomery A, Simmermacher RK, Simons MP, Smietanski M, Sommeling C, Tollens T, Vierendeels T, Kingsnorth A (2009) Classification of primary and incisional abdominal wall hernias. Hernia 13(4):407–414. https://doi.org/10.1007/s10029-009-0518-x
15. Antoniou SA, Agresta F, Garcia Alamino JM, Berger D, Berrevoet F, Brandsma HT, Bury K, Conze J, Cuccurullo D, Dietz UA, Fortelny RH, Frei-Lanter C, Hansson B, Helgstrand F, Hotouras A, Janes A, Kroese LF, Lambrecht JR, Kyle-Leinhase I, Lopez-Cano M, Maggiori L, Mandala V, Miserez M, Montgomery A, Morales-Conde S, Prudhomme M, Rautio T, Smart N, Smietanski M, Szczepkowski M, Stabilini C, Muysoms FE (2018) European Hernia Society guidelines on prevention and treatment of parastomal hernias. Hernia 22(1):183–198. https://doi.org/10.1007/s10029-017-1697-5
16. Pilgrim CH, McIntyre R, Bailey M (2010) Prospective audit of parastomal hernia: prevalence and associated comorbidities. Dis Colon Rectum 53(1):71–76. https://doi.org/10.1007/DCR.0b013e3181bdee8c
17. Liu NW, Hackney JT, Gellhaus PT, Monn MF, Masterson TA, Bihrle R, Gardner TA, House MG, Koch MO (2014) Incidence and risk factors of parastomal hernia in patients undergoing radical cystectomy and ileal conduit diversion. J Urol 191(5):1313–1318. https://doi.org/10.1016/j.juro.2013.11.104
18. De Raet J, Delvaux G, Haentjens P, Van Nieuwenhove Y (2008) Waist circumference is an independent risk factor for the development of parastomal hernia after permanent colostomy. Dis Colon Rectum 51(12):1806–1809. https://doi.org/10.1007/s10350-008-9366-5
19. Sugerman H, Windsor A, Bessos M, Wolfe L (1997) Intra-abdominal pressure, sagittal abdominal diameter and obesity comorbidity. J Intern Med 241(1):71–79
20. Wilson A, Longhi J, Goldman C, McNatt S (2010) Intra-abdominal pressure and the morbidly obese patients: the effect of body mass index. J Trauma 69(1):78–83. https://doi.org/10.1097/TA.0b013e3181e05a79
21. Consultation WHOE (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363(9403):157–163. https://doi.org/10.1016/S0140-6736(03)15268-3
22. Shiroshita H, Inomata M, Bandoh T, Uchida H, Akira S, Hashizume M, Yamaguchi S, Eguchi S, Wada N, Takiguchi S, Ieiri S, Endo S, Iwazaki M, Tamaki Y, Tabata M, Kanayama H, Mimata H, Hasegawa T, Onishi K, Yanaga K, Morikawa T, Terachi T, Matsumoto S, Yamashita Y, Kitano S, Watanabe M (2019) Endoscopic surgery in Japan: the 13th national survey (2014–2015) by the Japan Society for Endoscopic Surgery. Asian J Endosc Surg 12(1):7–18. https://doi.org/10.1111/ases.12674
23. Mishra A, Keeler BD, Maxwell-Armstrong C, Simpson JA, Acheson AG (2014) The influence of laparoscopy on incisional hernia rates: a retrospective analysis of 1057 colorectal cancer resections. Colorectal Dis 16(10):815–821. https://doi.org/10.1111/codi.12687
24. Connell MB, Selvam R, Patel SV (2019) Incidence of incisional hernias following single-incision versus traditional laparoscopic surgery: a meta-analysis. Hernia 23(1):91–100. https://doi.org/10.1007/s10029-018-1853-6
25. Funahashi K, Suzuki T, Nagashima Y, Matsuda S, Koike J, Shiokawa H, Ushigome M, Arai K, Kaneko T, Kurihara A, Kaneko H (2014) Risk factors for parastomal hernia in Japanese patients with permanent colostomy. Surg Today 44(8):1465–1469. https://doi.org/10.1007/s00595-013-0721-3
26. Braun TP, Marks DL (2015) The regulation of muscle mass by endogenous glucocorticoids. Front Physiol 6:12. https://doi.org/10.3389/fphys.2015.00012
27. Kroese LF, de Smet GH, Jeekel J, Kleinrensink GJ, Lange JF (2016) Systematic review and meta-analysis of extraperitoneal versus transperitoneal colostomy for preventing parastomal hernia. Dis Colon Rectum 59(7):688–695. https://doi.org/10.1097/DCR.0000000000000605
28. Fahim DK, Kim SD, Cho D, Lee S, Kim DH (2011) Avoiding abdominal flank bulge after anterolateral approaches to the thoracolumbar spine: cadaveric study and electrophysiological investigation. J Neurosurg Spine 15(5):532–540. https://doi.org/10.3171/2011.7.SPINE10887
29. Yamada M, Maruta K, Shiojiri Y, Takeuchi S, Matsuo Y, Takaba T (2003) Atrophy of the abdominal wall muscles after extraperitoneal approach to the aorta. J Vasc Surg 38(2):346–353. https://doi.org/10.1016/s0741-5214(03)00119-8
30. van Rooijen MMJ, Kroese LF, van Vugt JLA, Lange JF (2019) Sarcomania? The inapplicability of sarcopenia measurement in predicting incisional hernia development. World J Surg 43(3):772–779. https://doi.org/10.1007/s00268-018-4837-x