Original Article

Investigation of the relationship between colonoscopy insertion difficulty factors and endoscope shape using an endoscopic position detection unit

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In this study, we investigated the relationship between the cecal intubation time (CIT) and the form and method used for passing through the sigmoid/descending colon junction (SDJ) and the hepatic flexure using an endoscopic position detection unit (UPD), with reference to various factors [age, sex, body mass index (BMI), history of abdominal and pelvic surgery, and diverticulum]. A total of 152 patients underwent colonoscopy with UPD. The mean age was 66.9 ± 12.4 years, and the male to female ratio was 3.6:1. The average CIT time was 14.3 ± 8.2 min. Age, number of experienced endoscopies, history of abdominal and pelvic surgery, BMI, and diverticulum were associated with prolonged CIT; SDJ passage pattern was straight: 8.6 ± 5.0, alpha loop: 11.8 ± 5.6, puzzle ring-like loop: 20.2 ± 5.0, reverse alpha loop: 22.4 ± 9.7, and other loop: 24.7 ± 10.5. The hepatic flexure passing method was in the following order: right rotation maneuver: 12.6 ± 6.6, push maneuver: 15.1 ± 5.9, and right rotation with positional change maneuver: 20.5 ± 7.2. In conclusion, colonoscopy with UPD revealed an association between CIT and SDJ passage pattern and hepatic flexure passing method.

***Key Words*: endoscopic position detection unit, colonoscopy, colonoscopy screening, colonoscopy insertion difficulty factors**

As of 2021, colorectal cancer (CRC) deaths are the second leading cause of cancer deaths in Japan overall, the second leading cause in men, and the leading cause in women, and many patients are dying from CRC.[1] A large cohort study conducted in the United States showed an approximately 70% reduction in deaths from CRC following the introduction of screening colonoscopy.[2] Furthermore, in the National Polyp Study, a randomized controlled trial, deaths from CRC were reduced by approximately 50% after resection of all neoplastic polyps in the colon.[3] In addition, the results of cost-effectiveness analyses using simulation models in CRC screening have shown that the implementation of CRC screening using some form of total colonoscopy is more cost-effective than no screening.[4–6] Colonoscopy screening tests have been emphasized in national and international guidelines to reduce colorectal cancer mortality.[7,8]

The adenoma detection rate (ADR) is the percentage of patients with at least one histologically proven adenoma or cancer.[9] It is a validated predictor of interval CRC and is currently the quality indicator of choice for colonoscopy. The ADR is over 30% for men and over 20% for women.[10] Kaminski *et al.*[11] reported that endoscopists with an ADR of less than 20% have a 10-fold higher risk of CRC after CS than endoscopists with an ADR of 20% or greater. Furthermore, various image-enhanced endoscopies have been reported to improve the visibility of tumors, especially ADRs, by colonoscopy. In a meta-analysis, narrow band imaging (NBI) was reported to have a higher ADR than conventional white light imaging (WLI), and linked color imaging (LCI) was reported to be the image-enhanced endoscopy with the best colorectal lesion visibility among LCI, BLI, and WLI.[12–14] On the other hand, endoscopic devices equipped with artificial intelligence (AI) have appeared in recent years and have attracted much attention. The AI currently installed in colonoscopes is reported to be capable of automatically recognizing minute lesions in real time and predicting even the histological image of the lesion, and the influence of AI is expected to grow in colonoscopy in the future.[15–17]

Along with the ADR, the cecal intubation rate and bowel cleansing rate have been reported as quality indicators of colonoscopy.[18–20] A longer CIT has also been reported to be associated with decreased detection of adenomas and advanced adenomas and may be an indicator of a difficult examination, as longer insertion times require longer removal times to ensure adequate examination and adenoma detection.[21] The cecal intubation rate and time are persistent issues in colonoscopy. Until now, only the CIT has been used as an only indicator of cecal insertion difficulty. The authors have reported that the form and method used for passing through the sigmoid/descending colon junction (SDJ) and the hepatic flexure are important in colonoscopy insertion using an endoscopic position detection unit (UPD).[22] The authors have also reported that the same pattern of colonoscopy insertion was reported in the same patient at multiple times.[22] In this study, we investigated the relationship between the CIT and the form and method used for passing through the SDJ and the hepatic flexure using an endoscopic position detection unit (UPD), with reference to various factors (age, sex, body mass index (BMI), history of open surgery, and SDJ diverticulum).

Participants and Methods

This study was a retrospective trial conducted at Tokyo Medical University Hospital to investigate the efficacy of UPD for colonoscopy insertion in patients who had received

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colonoscopy for screening and surveillance. The study protocol adhered to the ethical principles of the Declaration of Helsinki and was approved by the institutional review board of Tokyo Medical University (T2020-0158). Because this study was conducted under a retrospective design and written informed consent was not obtained from each enrolled patient, a document describing an opt-out policy through which potential patients and/or relatives could refuse inclusion was uploaded on the Tokyo Medical University Hospital website.

The subjects were 152 patients who underwent colonoscopy with UPD for colorectal screening and surveillance between April 1, 2022 and December 31, 2022. The mean age was 66.9 ± 12.4 years, and the male-to-female ratio was 3.6:1. Four physicians, two trainees (TK, KY) who had performed 1,000 to 2,000 colonoscopies and two expert (EI, MH) who had performed more than 20,000 colonoscopies were involved in the study. Patients with CRC stenosis that rendered the cecum unreachable were excluded. Patients who had undergone surgery for CRC were also excluded. Exclusion criteria were also lack of clear endoscopic UPD images to evaluate endoscopic findings.

Endoscopes and peripheral equipment. This study used PCF-190DI and PCF-290DI colonoscopes (Olympus Medical Systems, Tokyo, Japan). Both colonoscopes are equipped with passive bending, high force transmission, and variable stiffness for responsive insertion technology. The optical source was an EVIS EXERAIII190 system and EVIS X1 system (Olympus Medical Systems). UPD uses a magnetic field to enable real-time visualization of three-dimensional (3D) images of the insertion shape and location of the colonoscope.

The colonoscopies analyzed in this study were performed with UPD-3 (Olympus Medical Systems). PCF-190DI and PCF-290DI are insertion-type colonoscopes with an integrated magnetic coil. The magnetic field from the magnetic coil is received by the antenna of the UPD, and the strength of the magnetic field received is analyzed by a computer and rendered as a 3D image that is displayed as a picture-in-picture on the colonoscopy screen. The UPD image allows the operator to check the status of the scope (e.g., location, bend) while simultaneously observing the colonoscopy images.

Colon insertion technique. The left hemicolon from the anus to the splenic flexure was inserted using the right turn shortening technique. Positional changes were used when necessary.

Study. During colonoscopy insertion, UPD and endoscopic images were recorded in all cases. The recorded videos were reviewed for each examination. The time from the anus to the cecum, the time from the anus to the splenic flexure (anorectal-splenic flexure time), and the time from the splenic flexure to the cecum (splenic flexure-cecum time) were also measured separately from the UPD images. In the left hemicolon, the passive pattern of the SDJ observed on UPD graphic images was classified into (1) straight, (2) N-loop, (3) α-loop, (4) reverse α-loop, (5) γ-loop, (6) puzzle ring-like loop, and (7) others (Fig. 1). On the other hand, in the right hemicolon, we recorded whether the pattern of the hepatic flexure observed in the UPD graphic image was inserted into the ascending colon by (1) right rotation operation, (2) right rotation operation with positional change, or (3) push operation (Fig. 2).

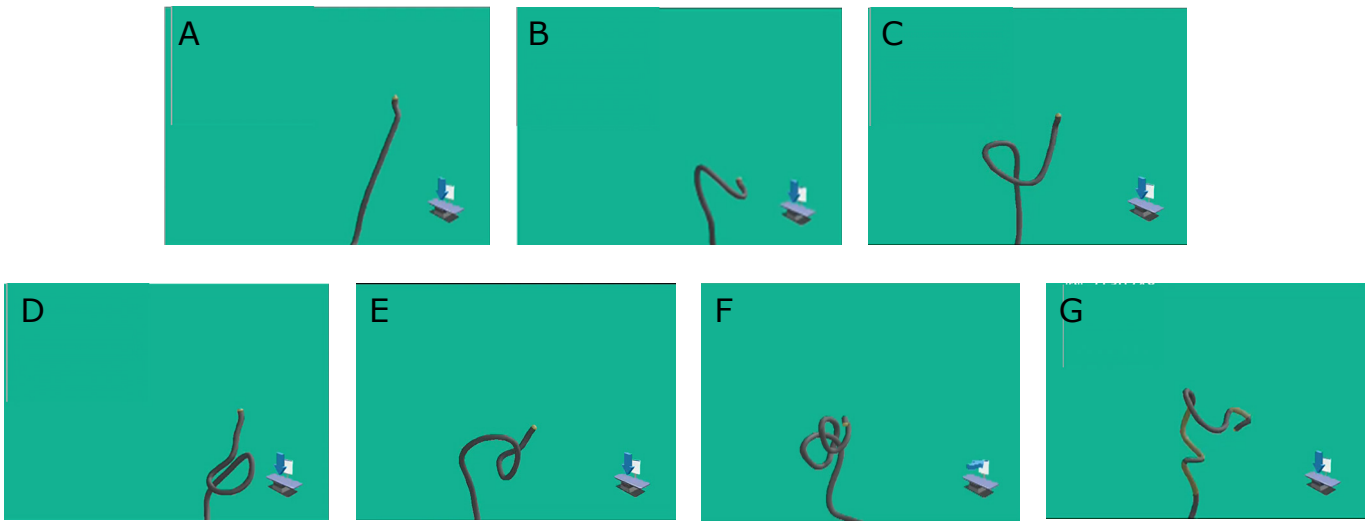

Fig. 1. Endoscopic position detection unit (UPD) graphic image of passage patterns for the sigmoid/descending colon junction. (A) straight; (B) N-loop; (C) α-loop; (D) reverse α-loop; (E) γ-loop; (F) puzzle ring-like loop; (G) other.

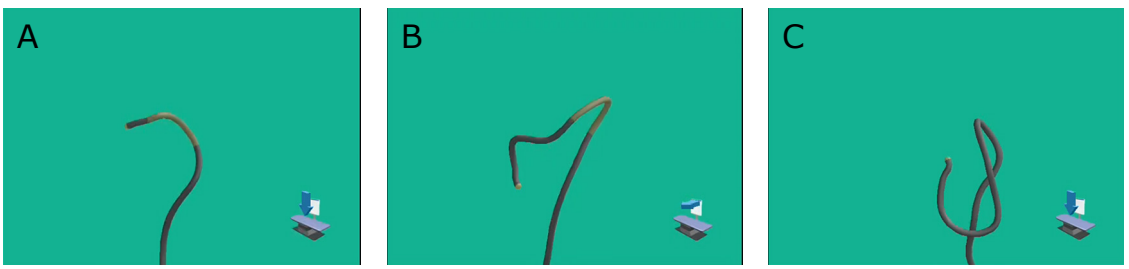

Fig. 2. Endoscopic position detection unit (UPD) graphic image of passage methods for the hepatic flexure. (A) right rotation maneuver; (B) right rotation with positional change maneuver; (C) push maneuver.

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Table 1. Cecal intubation time and various factors

		Cecal intubation time		*p* value	Anorectal-splenic flexure time		*p* value	Splenic flexure-cecum time		*p* value
Age	65< vs 65≥	12.2 ± 6.7	15.5 ± 8.7	0.013	6.8 ± 4.1	9.4 ± 7.1	0.014	5.3 ± 4.9	6.1 ± 4.9	0.338
NEE	trainee vs expert	16.8 ± 8.2	11.3 ± 7.0	<0.001	7.6 ± 6.5	5.8 ± 4.9	0.121	7.7 ± 5.4	3.7 ± 3.0	<0.001
Gender	male vs female	14.2 ± 8.3	14.6 ± 7.8	0.775	8.2 ± 6.3	9.1 ± 6.1	0.471	5.9 ± 5.2	5.5 ± 3.9	0.654
HAPS	negative vs positive	13.6 ± 7.8	15.3 ± 8.6	0.207	7.5 ± 5.9	9.9 ± 6.6	0.025	6.1 ± 5.1	5.5 ± 4.3	0.453
BMI	25< vs 25≥	14.8 ± 8.8	13.5 ± 7.1	0.337	9.0 ± 6.7	7.5 ± 5.5	0.153	5.8 ± 5.0	6.0 ± 4.8	0.82
SDJD	negative vs positive	14.1 ± 8.2	16.2 ± 8.3	0.368	8.3 ± 6.2	9.9 ± 6.9	0.375	5.8 ± 6.0	6.3 ± 3.6	0.716

NEE, number of experienced endoscopy cases; HAPS, history of abdominal and pelvic surgery; BMI, body mass index; SDJD, sigmoid/decending colon junction diverticulum.

Table 2. Characteristics in this study

		Total	Trainee	Expert	*p* value
n		152	82	70	
Age		66.9 ± 12.4	70.0 ± 9.3	63.2 ± 14.5	<0.001
Gender	male/female	116/32	67/15	49/21	0.091
BMI		24.1 ± 3.7	24.2 ± 3.4	24.0 ± 4.0	0.658
HAPS	negative/positive	92/60	50/32	42/28	0.902
SDJPP	S/N/α/Rα/γ/PR/O	31/80/19/2/3/8/9	17/43/11/2/2/4/3	14/37/8/0/1/4/6	0.728
HFPM	RRO/RRO + PC/PO	99/23/30	52/18/12	47/5/18	0.019
SDJD	negative/positive	139/18	73/9	66/4	0.248
Cecal intubation time	min	14.3 ± 8.2	16.8 ± 8.2	11.3 ± 7.0	<0.001
Anorectal-splenic flexure time	min	8.4 ± 6.3	9.2 ± 6.1	7.6 ± 6.5	0.121
Splenic flexure-cecum time	min	5.8 ± 4.9	7.7 ± 5.4	3.7 ± 3.0	<0.001

BMI, body mass index; HAPS, history of abdominal and pelvic surgery; SDJPP, sigmoid/decending colon junction passage pattern. (S) straight, (N) N-loop, (α) α-loop, (Rα) reverse α-loop, (γ) γ-loop, (PR) puzzle ring-like loop, (O) others. HFPM, hepatic flexure passage method. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum.

Statistical analysis. The analysis software SPSS, ver. 27.0 (IBM Japan, Tokyo, Japan) was used. Age, BMI, and time to cecum were expressed as the mean ± SD, and comparisons by insertion method and endoscopic experience were analyzed by *t* test or one-way ANOVA. Categorical variables were expressed as *n* numbers, and contingency table analysis (*chi*-square test) was used to examine differences between groups. A risk rate of less than 5% was considered statistically significant, and all *p* values were two-tailed.

Results

The average CIT was 14.3 ± 8.2 min, the anorectal-splenic flexure time was 8.4 ± 6.3 min, and the splenic flexure-cecum time was another 5.8 ± 4.9 min. Table 1 shows the relationship between the CIT and various factors (the number of experienced colonoscopies, age, sex, BMI, and presence of SDJ diverticulum). Older age (65 years or older), trainee, abdominal and pelvic surgery, BMI less than 25, and SDJ diverticulum were associated with a longer CIT, with significant differences, especially in the number of experienced endoscopy cases (Expert and Trainee) and age. We further divided the CIT into anorectal-splenic flexure time and splenic flexure-cecum time. The anorectal-splenic flexure time was significantly longer in patients over 65 years of age, with trainee, female, BMI less than 25, and with SDJ diverticulum, and significantly different in patients over 65 years of age and with a history of abdominal and pelvic surgery. On the other hand, the splenic flexure-cecum time was significantly longer in patients aged 65 years or older and trainees.

Relationships among several factors and the number of experienced endoscopy cases (trainee and expert) (Table 2). The average age of subjects in the expert group was significantly younger than that of trainees. The CIT was significantly longer in trainees. The anorectal-splenic flexure time was prolonged in trainees but not significantly different from that in experts, and the splenic flexure-cecum time was significantly shorter in experts than in trainees. There was no difference in sex, BMI, history of abdominal and pelvic surgery, or SDJ transit pattern, but there was a significant difference in hepatic flexure passage pattern. The fact that there was no difference in the SDJ transit pattern between trainees and experts suggests that colonoscopic insertion is performed without affecting the skill of the operating surgeon.

The relationship between each SDJ passage pattern and various factors was examined (Table 3). There was a significant association with CIT, and by pattern, straight: 8.6 ± 5.0, the shortest time, followed by α loop: 11.8 ± 5.6; conversely, a longer time was observed for puzzle ring-like loop: 20.2 ± 5.0, reverse α loop: 22.4 ± 9.7, and other loop: 24.7 ± 10.5. BMI was also significantly associated with the puzzle ring-like loop: 21.1 ± 2.8, the lowest value, followed by other loops: 21.4 ± 2.9, and conversely, the γ loop: 28.5 ± 5.0, the highest value. There was a significant association with the hepatic flexure passage pattern. Not surprisingly, there was a significant difference in antral-splenic flexure time.

The relationship between the pattern of hepatic flexure passage and various factors is shown in Table 4. There was a significant association with CIT, with 12.6 ± 6.6, 20.5 ± 7.2, and 15.1 ± 5.9 for right rotation, right rotation and position change, and pushing, respectively. A significant association was also observed in patients with a history of abdominal and pelvic surgery. In patients with a history of surgery, more cases passed through the hepatic flexure by pushing.

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Table 3. Sigmoid/Decending colon junction passage pattern in this study

		Total	Straght	N-loop	α-loop	Reverse alpha-loop	γ-loop	Puzzle ring-like loop	Others	*p* value
n		152	31	80	19	2	3	8	9	
Age		66.9 ± 12.4	65.6 ± 13.0	66.1 ± 12.5	68.8 ± 14.3	66.5 ± 2.1	59.0 ± 8.0	72.8 ± 9.4	71.8 ± 9.1	0.484
Gender	male/female	116/36	25/6	60/20	17/2	1/1	3/0	3/5	7/2	0.102
BMI		24.1 ± 3.7	24.3 ± 2.4	24.3 ± 4.1	24.5 ± 2.7	24.6 ± 1.5	28.5 ± 5.0	21.1 ± 2.8	21.4 ± 2.9	0.017
HAPS	negative/positive	92/60	19/12	49/31	15/4	1/1	3/0	3/5	2/7	0.06
HFPM	RRO/RRO + PC/PO	99/23/30	21/2/8	53/12/15	15/3/1	0/0/2	2/1/0	1/4/3	7/1/1	0.011
SDJD	negative/positive	139/13	28/3	72/8	19/0	2/0	2/1	8/0	8/1	0.493
NEE	trainee/expert	82/70	17/11	43/37	11/8	2/0	2/1	4/4	3/6	0.728
Cecal intubation time	min	14.3 ± 8.2	8.6 ± 5.0	15.0 ± 8.0	11.8 ± 5.6	22.4 ± 9.7	15.3 ± 1.7	20.2 ± 5.0	24.7 ± 10.5	<0.001
Anorectal-splenic flexure time	min	8.4 ± 6.3	4.2 ± 2.3	8.8 ± 5.7	6.5 ± 2.6	8.5 ± 5.6	5.9 ± 1.3	13.6 ± 3.6	20.3 ± 10.4	<0.001
Splenic flexure-cecum time	min	5.8 ± 4.9	4.4 ± 4.0	6.3 ± 5.3	5.4 ± 5.0	13.9 ± 3.6	9.4 ± 2.4	6.6 ± 3.1	4.4 ± 2.9	0.075

BMI, body mass index; HAPS, history of abdominal and pelvic surgery; HFPM, hepatic flexure passage method. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum; NEE, number of experienced endoscopy cases.

Table 4. Heptic flecture passage method in this study

		total	RRO	RRO + PC	PO	*p* value
n		152	99	23	30	
Age		66.9 ± 12.4	66.2 ± 13.5	66.4 ± 10.5	69.3 ± 9.7	0.483
Gender	male/female	116/36	78/21	19/4	19/11	0.162
BMI		24.1 ± 3.7	23.7 ± 3.5	24.3 ± 4.4	25.2 ± 3.7	0.147
HAPS	negative/positive	92/60	61/38	18/5	rota	0.034
SDJPP	S/N/α/Rα/γ/PR/O	31/80/19//2/3/8/9	21/53/15/0/2/1/7	2/12/3/0/1/4/1	8/15/1/2/0/3/1	0.011
SDJD	negative/positive	139/13	88/11	23/0	28/2	0.211
NEE	trainee/expert	82/70	52/47	18/5	12/18	0.019
Cecal intubation time	min	14.3 ± 8.2	12.6 ± 8.3	20.5 ± 7.2	15.1 ± 5.9	<0.001
Anorectal-splenic flexure time	min	8.4 ± 6.3	8.3 ± 6.6	10.3 ± 7.0	7.3 ± 4.2	0.221
Splenic flexure-cecum time	min	5.8 ± 4.9	4.2 ± 4.0	10.2 ± 5.6	7.8 ± 4.2	<0.001

BMI, body mass index; HAPS, history of abdominal and pelvic surgery; SDJPP, sigmoid/decending colon junction passage pattern. (S) straight, (N) N-loop, (α) α-loop, (Rα) reverse α-loop, (γ) γ-loop, (PR) puzzle ring-like loop, (O) others. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum; NEE, number of experienced endoscopy cases.

Risk factor analysis of CIT over 10 and 15 min revealed significant differences (Table 5) in age, number of experienced endoscopy cases, SDJ passage pattern (N-loop and α-loop), and hepatic flexure passage pattern (positional change and push maneuver) at 10 min. On the other hand, the number of experienced endoscopy cases, N-loops and γ-loops, positional change, and push maneuvering were significantly different in the 15-min period. In addition, sub analysis of various factors related to anorectal-splenic flexure times of 5 and 10 min or longer was performed (Table 6). Factors related to the time at 5 min were N-loop and α-loop, while factors related to the time at 10 min were BMI, history of abdominal and pelvic surgery, and puzzle ring-like loop of SDJ passage pattern (Table 6). On the other hand, various factors related to the splenic flexure-cecum time of 5 min and more than 10 min were analyzed (Table 7). The factors that showed significant differences at 5 min were age, number of experienced endoscopy cases, position change of the pattern of passage through the hepatic flexure, and push operation (Table 7), while the factors that showed significant differences at 10 min were number of experienced endoscopy cases, history of abdominal and pelvic surgery, γ loop in the pattern of passage through the SDJ, and position change of the pattern of passage through the hepatic flexure.

Discussion

Endoscopic UPD is used in Europe as magnetic endoscope imaging (MEI); UPD is a device that, in combination with a special scope with a built-in magnetic coil, can display the insertion geometry of the scope in three dimensions in real time. The Danish National Board of Health's manual on colorectal screening recommends that UPD be used for CRC screening because UPD provides the same information as confirming scope insertion geometry with X-rays.[23] Shah *et al.*[24] reported that MEI significantly improves the performance of colonoscopy, particularly when used by trainees or by experts in technically difficult cases; loops were Jess *et al.*[25] also reported that MEI imaging methods significantly reduce examination time, particularly in They reported that it is always available for colonoscopy to identify the exact location of colorectal lesions. The authors[26] and Sato *et al.*[27] also reported that the use of UPD can reduce patient distress during the examination.

A cohort study of patients with difficulty or inability to reach the cecum reported a significantly lower rate of ileal appendectomy in elderly patients, women, and patients with a history of abdominal and pelvic surgery, and a meta-analysis revealed that elderly patients, women, low BMI, and poor pretreatment were

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Table 5. Risk factors taking more than 10 min for Cecum intubation time: univariate analysis

		10 min			15 min		
		OR	95% CI	*p* value	OR	95% CI	*p* value
Age		1.029	1.001–1.058	0.041	1.029	0.000–1.060	0.057
NEE	expert (vs trainee)	0.293	0.144–0.597	<0.001	0.260	0.127–0.532	<0.001
Gender	female (vs male)	1.151	0.514–2.580	0.732	1.463	0.685–3.128	0.326
BMI		0.973	0.888–1.067	0.561	0.921	0.838–1.012	0.086
HAPS	positive (vs negative)	1.425	0.699–2.863	0.335	1.339	0.686–2.615	0.392
SDJPP	N (vs S)	9.230	3.551–23.991	<0.001	5.905	1.654–21.085	0.006
	α (vs S)	4.929	1.439–16.884	0.011	2.489	0.491–12.614	0.271
	Rα (vs S)	—			—		
	γ (vs S)	—			18.667	1.280–272.127	0.032
	PR (vs S)	—			—		
HFPM	RRO + PC (vs RRO)	17.600	2.282–135.741	0.006	14.844	4.597–47.927	<0.001
	PO (vs RRO)	4.000	1.416–11.303	0.009	2.734	1.166–6.410	0.021
SDJD	positive (vs negative)	1.703	0.447–6.485	0.435	2.077	0.661–6.520	0.211
Anorectal-splenic flexure time	min	2.281	1.718–3.027	<0.001	1.462	1.279–1.672	<0.001
Splenic flexure-cecum time	min	2.106	1.609–2.758	<0.001	1.625	1.384–1.909	<0.001

NEE, number of experienced endoscopy cases; BMI, body mass index; HAPS, history of abdominal and pelvic surgery; SDJPP, sigmoid/decending colon junction passage pattern. (S) straight, (N) N-loop, (α) α-loop, (Rα) reverse α-loop, (γ) γ-loop, (PR) puzzle ring-like loop, (O) others. HFPM, hepatic flexure passage method. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum.

Table 6. Risk factors for left hemicoeliac insertion time: univariate analysis

		5 min			10 min			15 min		
		OR	95% CI	*p* value	OR	95% CI	*p* value	OR	95% CI	*p* value
Age		1.020	0.992–1.048	0.162	1.033	0.998–1.070	0.063	1.033	0.984–1.085	0.192
NEE	expert (vs trainee)	0.514	0.256–1.031	0.061	0.700	0.331–1.477	0.349	0.322	0.100–1.037	0.058
Gender	female (vs male)	1.462	0.626–3.413	0.381	1.000	0.422–2.372	1	1.392	0.457–4.274	0.557
BMI		0.911	0.829–1.002	0.055	0.891	0.799–0.995	0.040	0.783	0.658–0.933	0.006
HAPS	positive (vs negative)	1.838	0.882–3.831	0.104	2.750	1.296–5.837	0.008	2.429	0.870–6.783	0.09
SDJPP	N (vs S)	9.059	3.530–23.249	<0.001	10.678	1.370–83.250	0.24	—		
	α (vs S)	5.296	1.533–18.299	0.008	1.667	0.098–28.320	0.724	—		
	Rα (vs S)	2.444	0.137–43.470	0.543	30.000	0.988–911.200	0.051	—		
	γ (vs S)	4.889	0.392–60.922	0.218	—			—		
	PR (vs S)	—			210.000	11.656–3783,596	<0.001	—		
HFPM	RRO + PC (vs RRO)	2.165	0.680–6.900	0.191	2.250	0.860–5.889	0.099	2.472	0.754–8.102	0.135
	PO (vs RRO)	0.684	0.294–1.592	0.378	1.065	0.404–2.809	0.898	0.636	0.131–3.075	0.573
SDJD	positive (vs negative)	1.008	0.294–3.453	0.99	1.373	0.397–4.741	0.617	2.679	0.658–10.900	0.169
Cecum intubation time	min	1.299	1.177–1.433	<0.001	1.259	1.167–1.359	<0.001	1.410	1.210–1.621	<0.001
Splenic flexure-cecum time	min	1.053	0.973–1.139	0.204	1.021	0.950–1.098	0.572	1.029	0.936–1.132	0.549

NEE, number of experienced endoscopy cases; BMI, body mass index; HAPS, history of abdominal and pelvic surgery; SDJPP, sigmoid/decending colon junction passage pattern. (S) straight, (N) N-loop, (α) α-loop, (Rα) reverse α-loop, (γ) γ-loop, (PR) puzzle ring-like loop, (O) others. HFPM, hepatic flexure passage method. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum.

risk factors for prolonged ileal appendectomy time.[28,29]

For improvement of ileal access, it is important to collect sufficient information, including predictive factors for difficult or impossible cecal access, before performing a full colonoscopy. The use of an endoscope with variable stiffness functions and an ultrathin-diameter endoscope is recommended, especially for women and other patients with predictive factors for difficult insertion.[30–33] In addition, the use of CO_2 and colonoscope distal attachment has been reported to be useful in shortening colonoscopy insertion time.[34–36] It has also been reported that water-assisted colonoscopy can shorten the time to reach the ileum.[37] However, there have been few detailed studies on what factors or causes of difficulty prolong the CIT. In the present study, the authors objectively examined how the shape and form of the scope inserted into the ileocecal area contributed to the prolongation of CIT using UPD graphic images.

Park *et al.*[38], Krishnan *et al.*[39], and Nagata *et al.*[40] reported that trainee physicians' low technical competence was linked to the time to reach the cecum. The authors reported that trainee physicians' low technical competence leads to CIT. In the present study, based on UPD graphic images, we found a significant difference in time to reach the cecum, especially from the splenic

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Table 7. Risk factors for right hemicoeliac insertion time: univariate analysis

		5 min			10 min		
		OR	95% CI	*p* value	OR	95% CI	*p* value
Age		1.037	1.008–1.068	0.013	1.027	0.986–1.069	0.205
NEE	expert (vs trainee)	0.176	0.086–0.357	<0.001	0.080	0.018–0.355	<0.001
Gender	female (vs male)	1.424	0.673–3.016	0.355	0.411	0.115–1.469	0.171
BMI		1.039	0.952–1.134	0.392	1.028	0.914–1.156	0.641
HAPS	positive (vs negative)	0.932	0.485–1.791	0.833	0.349	0.123–0.994	0.049
SDJPP	N (vs S)	2.325	0.954–5.667	0.063	1.647	0.431–6.287	0.465
	α (vs S)	1.778	0.538–5.880	0.346	2.489	0.491–12.614	0.271
	Rα (vs S)	—			—		
	γ (vs S)	—			18.667	1.280–272.127	0.032
	PR (vs S)	4.074	0.800–20.751	0.091	1.333	0.120–14.845	0.815
HFPM	RRO + PC (vs RRO)	12.045	3.762–38.558	<0.001	10.427	3.500–31.065	<0.001
	PO (vs RRO)	8.332	3.214–21.595	<0.001	2.275	0.684–7.567	0.18
SDJD	positive (vs negative)	1.987	0.619–6.379	0.249	0.967	0.200–4.666	
Cecum intubation time	min	1.217	1.136–1.304	<0.001	1.172	1.100–1.248	<0.001
Anorectal-splenic flexure time	min	1.043	0,988–1.100	0.126	1.002	0.935–1.073	0.96

NEE, number of experienced endoscopy cases; BMI, body mass index; HAPS, history of abdominal and pelvic surgery; SDJPP, sigmoid/decending colon junction passage pattern. (S) straight, (N) N-loop, (α) α-loop, (Rα) reverse α-loop, (γ) γ-loop, (PR) puzzle ring-like loop, (O) others. HFPM, hepatic flexure passage method. (RRO) right rotation operation, (RRO + PC) right rotation operation with positional change, (PO) push operation. SDJD, sigmoid/decending colon junction diverticulum.

flexure, and no significant difference in time from the anus to the splenic flexure. Furthermore, the fact that there was no difference in the pattern of SDJ passage between the trainee and the expert suggests that the same pattern of SDJ insertion is performed at the SDJ without affecting the skill of the performing physician. On the other hand, in each of the patterns of hepatic flexure passage, significantly more cases were inserted into the hepatic flexure by pushing to the expert. The most important factor is that the expert physicians have higher endoscopic operability skills than the trainee physicians, and they are able to instantly judge that push is the shortest way to pass the hepatic flexure. In the future, we would like to instruct trainees on how to pass through the hepatic flexure with an endovascular technique, which may lead to an improvement in insertion time.

In terms of CIT by gender, there was no significant difference in the present study: 14.2 ± 8.3 for males and 14.6 ± 7.8 for females. Many reports have indicated that women are one of the factors that make insertion difficult.[41–44] The ratio of total patterns of SDJ passage was 78.4% for males and 83.3% for females, as reported by Rowland RS, but this did not lead to a significant prolongation of the time, but did not lead to a significant prolongation of time.[45] On the other hand, the time to reach the splenic flexure-cecum was 5.9 ± 5.2 for males and 5.5 ± 3.9 for females, which was slightly shorter for females.

The time to reach the cecum according to age was significantly prolonged in patients aged 65 years and older: 15.5 ± 8.7 and 12.2 ± 6.7 in those aged <65 years. In particular, the anorectal-splenic flexure time was 9.4 ± 7.1 for patients aged 65 years and older and 6.8 ± 4.1 for patients aged <65 years, showing no significant difference between age and SDJ transit pattern. However, the age of puzzle ring-like loops was 72.8 ± 9.4, and the age of other loops was 71.8 ± 9.1, which may be related to reports of increased colon length with age using CT and barium enema, as well as reports of loops forming more easily during colonoscopy in elderly patients because of their more elastic and lax mesentery.[46–48]

There were no significant differences between the history of abdominal/pelvic surgery and CIT. Lee *et al.*[49] and Nagata *et al.*[40] reported that colonoscopy is considered difficult in patients with a history of abdominal/pelvic surgery due to post-operative adhesions and anatomic changes. In this study, a significant difference in anorectal-splenic flexure time was found: yes: 9.9 ± 6.6, no: 7.5 ± 5.9. Furthermore, although there was no significant difference between the history of abdominal/pelvic surgery and the pattern of SDJ passage, the ratio of patients with a history of abdominal/pelvic surgery was higher in the puzzle ring-like loop and other loops. Patients with a history of abdominal/pelvic surgery may have difficulty passing the SDJ due to adhesions or anatomical changes. A significant association was found between the pattern of passage through the hepatic flexure and history of abdominal/pelvic surgery. By recording the UPD, we found that the reason for the difficulty of insertion in patients with a history of abdominal/pelvic surgery was that the pattern of passage through the hepatic flexure was often pushed.

There were no significant differences between BMI and CIT in the study. However, the difference in anorectal-splenic flexure time was 9.0 ± 6.7 for <25 and 7.5 ± 6.7 for ≥25, indicating a significant difference between the two groups. Patients with obesity tend to have a shorter colon, which may allow for more rapid cecal intubation.[50–54] It is also possible that low BMI may result in less intra-abdominal fat, which may facilitate the formation of loops.

In the present study, we examined the time to reach the cecum in SDJ diverticula. The results were 16.2 ± 8.2 for yes and 14.1 ± 8.2 for no, although there was no significant difference. Studies suggest that diverticulosis makes the colon more spastic, makes insufflation more difficult, makes adequate bowel preparation more difficult, makes it more difficult to find the lumen, and increases the likelihood that colonoscopy will be difficult.[49]

Risk factor analysis was performed for cecum arrival times of 10 and 15 min or longer. Kawasato *et al.*[55] analyzed 813 CS cases in total and reported that physicians may find it useful to select CS cases based on sex, age, and BMI. The authors reported that it may be useful for physicians to select CS cases based on sex, age, and BMI. The authors have previously reported that when the same patient underwent two CSs, the same SDJ transit format pattern and hepatic flexure passage pattern were inserted in most cases. The results of the present study suggest that in patients who have undergone TCS with UPD once, it may be possible for trainees to select patients who are under 65 years of

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age, have a straight SDJ transit pattern, and a right-turn rotation in the hepatic flexure passage pattern when performing the next and subsequent TCSs. It will be possible in the future to stratify the difficulty level of colorectal insertion according to the skill of the physician.

Patients who had undergone two examinations with PCF-H190DI and PCF-H290DI combined with UPD were included for reproducibility of colonoscopy insertion and the possibility of tailor-made insertion. We have reported that colonoscopies were inserted in almost the same pattern on both occasions. In the present study, we further examined the factors that influence the cecum arrival time and examined the relationship between the influencing factors and the SDJ passage pattern and the hepatic flexure passage pattern using UPD. The results of this study showed that a patient who was less than 65 years old had a straight SDJ pattern and could insert the colonoscope with a right-handed rotation was suitable for a trainee endoscopist to perform a colonoscopy. To further promote colonoscopy in Japan, it is necessary to provide appropriate training for endoscopists, and it may be possible to stratify the difficulty of colonoscopy insertion in individual patients by keeping and analyzing endoscopy records using the UPD.

Limitations

This study has a few limitations. First, it was a single-center retrospective study. Second, it was not possible to determine the stratification of patients eligible for beginners, trainees, and experts by UPD.

Author Contributions

Study concept and design: TK; methodology: TK and MS; software: TK and MS; investigation: TK, KY, YA, MH, EI, and NN; formal analysis: TK and MS; drafting of the manuscript: TK and MS; critical revision of the manuscript: MS and TK; supervision: TI and TK; project administration: TK.

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Conflict of Interest

No potential conflicts of interest were disclosed.

References

1 Cancer registration and statistics. Cancer Information Service at National Cancer Research Center. http://ganjoho.jp/reg_stat. Accessed 4 Oct 2023.
2 Nishihara R, Wu K, Lochhead P, *et al*. Long-term colorectal-cancer incidence and mortality after lower endoscopy. *N Engl J Med* 2013; **369**: 1095–1105.
3 Zauber AG, Winawer SJ, O'Brien MJ, *et al*. Colonoscopic polypectomy and long-term prevention of colorectal-cancer deaths. *N Engl J Med* 2012; **366**: 687–696.
4 Sekiguchi M, Igarashi A, Matsuda T, *et al*. Optimal use of colonoscopy and fecal immunochemical test for population-based colorectal cancer screening: a cost-effectiveness analysis using Japanese data. *Jpn J Clin Oncol* 2016; **46**: 116–125.
5 Sonnenberg A, Delcò F, Inadomi JM. Cost-effectiveness of colonoscopy in screening for colorectal cancer. *Ann Intern Med* 2000; **133**: 573–584.
6 Frazier AL, Colditz GA, Fuchs CS, Kuntz KM. Cost-effectiveness of screening for colorectal cancer in the general population. *JAMA* 2000; **284**: 1954–1961.
7 Rex DK, Boland CR, Dominitz JA, *et al*. Colorectal cancer screening: recommendations for physicians and patients from the U.S. Multi-Society Task Force on Colorectal Cancer. *Gastroenterology* 2017; **153**: 307–323.
8 Saito Y, Oka S, Kawamura T, *et al*. Colonoscopy screening and surveillance guidelines. *Dig Endosc* 2021; **33**: 486–519.
9 Corley DA, Jensen CD, Marks AR, *et al*. Adenoma detection rate and risk of colorectal cancer and death. *N Engl J Med* 2014; **370**: 1298–1306.
10 Rex DK, Schoenfeld PS, Cohen J, *et al*. Quality indicators for colonoscopy. *Gastrointest Endosc* 2015; **81**: 31–53.
11 Kaminski MF, Regula J, Kraszewska E, *et al*. Quality indicators for colonoscopy and the risk of interval cancer. *N Engl J Med* 2010; **362**: 1795–1803.
12 Atkinson NSS, Ket S, Bassett P, *et al*. Narrow-Band Imaging for detection of neoplasia at colonoscopy: a meta-404 analysis of data from individual patients in randomized controlled trials. *Gastroenterology* 2019; **157**: 462–471.
13 Yoshida N, Hisabe T, Ikematsu H, *et al*. Comparison between linked color imaging and blue laser imaging for improving the 408 visibility of flat colorectal polyps: a multicenter pilot study. *Dig Dis Sci* 2020; **65**: 2054–2062.
14 Shinozaki S, Kobayashi Y, Hayashi Y, *et al*. Colon polyp detection using linked color imaging compared to white light imaging: systematic review and meta-analysis. *Dig Endosc* 2020; **32**: 874–881.
15 Weigt J, Repici A, Antonelli G, *et al*. Performance of a new integrated computer-assisted system (CADe/CADx) for detection and characterization of colorectal neoplasia. *Endoscopy* 2022; **54**: 180–184.
16 Hassan C, Spadaccini M, Iannone A, *et al*. Performance of artificial intelligence in colonoscopy for adenoma and polyp detection: a systematic review and meta-analysis. *Gastrointest Endosc* 2021; **93**: 77–85.
17 Repici A, Spadaccini M, Antonelli G, *et al*. Artificial intelligence and colonoscopy experience: lessons from two randomised trials. *Gut* 2022; **71**: 757–765.
18 Baxter NN, Sutradhar R, Forbes SS, Paszat LF, Saskin R, Rabeneck L. Analysis of administrative data finds endoscopist quality measures associated with postcolonoscopy colorectal cancer. *Gastroenterology* 2011; **140**: 65–72.
19 Baxter NN, Goldwasser MA, Paszat LF, Saskin R, Urbach DR, Rabeneck L. Association of colonoscopy and death from colo-rectal cancer. *Ann Intern Med* 2009; **150**: 1–8.
20 Clark BT, Protiva P, Nagar A, *et al*. Quantification of adequate bowel preparation for screening or surveillance colonoscopy in men. *Gastroenterology* 2016; **150**: 396–405.
21 von Renteln D, Robertson DJ, Bensen S, Pohl H. Prolonged cecal insertion time is associated with decreased adenoma detection *Gastrointest Endosc* 2017; **85**: 574–580.
22 Kawai T, Kawai Y, Akimoto Y, *et al*. Investigation of the new advantages of colonoscope insertion with an endoscopic position detection unit. *Diagnostics (Basel)* 2022; **12**: 2610.
23 Anbefalinger vedrørende screening for tyk- og endetarmskræft. Sundhedsstyrelsen. https://www.sst.dk/da/udgivelser/2012/anbefalinger-vedroerende-screening-for-tyk--og-endetarmskraeft Accessed 3 Sep 2012.
24 Shah SG, Brooker JC, Williams CB, Thapar C, Saunders BP. Effect of magnetic endoscope imaging on colonoscopy performance: a randomised controlled trial. *Lancet* 2000; **356**: 1718–1722.
25 Jess P, Bulut O, Almasi A, Waaddegaard P. The usefulness of a magnetic endoscope locating device in colonoscopy in daily practice: a prospective case-controlled study. *Surg Endosc* 2009; **23**: 1353–1355.
26 Fukuzawa M, Uematsu J, Kono S, *et al*. Clinical impact of endoscopy position detecting unit (UPD-3) for a non-sedated colonoscopy. *World J Gastroenterol* 2015; **21**: 4903–4910.
27 Sato K, Fujinuma S, Sakai Y. Evaluation of the looping formation and pain during insertion into the cecum in colonoscopy. *Dig Endosc* 2006; **18**: 181–187.
28 Shah HA, Paszat LF, Saskin R, Stukel TA, Rabeneck L. Factors associated with incomplete colonoscopy: a population based study. *Gastroenterology* 2007; **132**: 2297–2303.
29 Jaruvongvanich V, Sempokuya T, Laoveeravat P, Ungprasert P. Risk factors associated with longer cecal intubation time: a systematic review and meta-analysis. *Int J Colorectal Dis* 2018; **33**: 359–365.
30 Xie Q, Chen B, Liu L, Gan H. Does the variable-stiffness colonoscope makes colonoscopy easier? A meta-analysis of the efficacy of the variable stiffness colonoscope compared with the standard adult colonoscope. *BMC*

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Gastroenterol 2012; **12**: 151.
31 Othman MO, Bradley AG, Choudhary A, Hoffman RM, Roy PK. Variable stiffness colonoscope versus regular adult colonoscope: meta-analysis of randomized controlled trials. *Endoscopy* 2009; **41**: 17–24.
32 Sofi AA, Nawras A, Khan MA, Howden CW, Lee WM. Meta-analysis of the performance of ultrathin vs. standard colonoscopes. *Endoscopy* 2017; **49**: 351–358.
33 Sato K, Ito S, Shigiyama F, *et al*. A prospective randomized study on the benefits of a new small-caliber colonoscope. *Endoscopy* 2012; **44**: 746–753.
34 Memon MA, Memon B, Yunus RM, Khan S. Carbon dioxide versus air insufflation for elective colonoscopy: a meta-analysis and systematic review of randomized controlled trials. *Surg Laparosc Endosc Percutan Tech* 2016; **26**: 102–116.
35 Wu J, Hu B. The role of carbon dioxide insufflation in colonoscopy: a systematic review and meta-analysis. *Endoscopy* 2012; **44**: 128–136.
36 Kondo S, Yamaji Y, Watabe H, *et al*. A randomized controlled trial evaluating the usefulness of a transparent hood attached to the tip of the colonoscope. *Am J Gastroenterol* 2007; **102**: 75–81.
37 Mizukami T, Yokoyama A, Imaeda H, Kumai K. Collapse-submergence method: simple colonoscopic technique combining water infusion with comolete air removal from rectosigmind colon. *Dig Endosc* 2007; **19**: 43–48.
38 Park HJ, Hong JH, Kim HS, *et al*. Predictive factors affecting cecal intubation failure in colonoscopy trainees. *BMC Med Educ* 2013; **13**: 5.
39 Krishnan P, Sofi AA, Dempsey R, Alaradi O, Nawras A. Body mass index predicts cecal insertion time: the higher, the better. *Dig Endosc* 2012; **24**: 439–442.
40 Nagata N, Sakamoto K, Arai T, *et al*. Predictors for cecal insertion time: the impact of abdominal visceral fat measured by computed tomography. *Dis Colon Rectum* 2014; **57**: 1213–1219.
41 Anderson JC, Gonzalez JD, Messina CR, Pollack BJ. Factors that predict incomplete colonoscopy: thinner is not always better. *Am J Gastroenterol* 2000; **95**: 2784–2787.
42 Bernstein C, Thorn M, Monsees K, Spell R, O'Connor JB. A prospective study of factors that determine cecal intubation time at colonoscopy. *Gastrointest Endosc* 2005; **61**: 72–75.
43 Hsieh YH, Kuo CS, Tseng KC, Lin HJ. Factors that predict cecal insertion time during sedated colonoscopy: the role of waist circumference. *J Gastroenterol Hepatol* 2008; **23**: 215–217.
44 Liang CM, Chiu YC, Wu KL, *et al*. Impact factors for difficult cecal intubation during colonoscopy. *Surg Laparosc Endosc Percutan Tech* 2012; **22**: 443–446.
45 Rowland RS, Bell GD, Dogramadzi S, Allen C. Colonoscopy aided by magnetic 3D imaging: is the technique sufficiently sensitive to detect differences between men and women? *Med Biol Eng Comput* 1999; **37**: 673–679.
46 Khashab MA, Pickhardt PJ, Kim DH, Rex DK. Colorectal anatomy in adults at computed tomography colonography: normal distribution and the effect of age, sex, and body mass index. *Endoscopy* 2009; **41**: 674–678.
47 Sadahiro S, Ohmura T, Yamada Y, Saito T, Taki Y. Analysis of length and surface area of each segment of the large intestine according to age, sex and physique. *Surg Radiol Anat* 1992; **14**: 251–257.
48 Waye JD. Difficult colonoscopy. *Gastroenterol Hepatol (NY)* 2013; **9**: 676–678.
49 Lee SK, Kim TI, Shin SJ, Kim BC, Kim WH. Impact of prior abdominal or pelvic surgery on colonoscopy outcomes. *J Clin Gastroenterol* 2006; **40**: 711–716.
50 Witte TN, Enns R. The difficult colonoscopy. *Can J Gastroenterol* 2007; **21**: 487–490.
51 Yoong KK, Heymann T. Colonoscopy in the very old: why bother? *Postgrad Med J* 2005; **81**: 196–197.
52 Uddin FS, Iqbal R, Harford WV, *et al*. Prone positioning of obese patients for colonoscopy results in shortened cecal intubation times: a randomized trial. *Dig Dis Sci* 2013; **58**: 782–787.
53 Jain D, Goyal A, Uribe J. Obesity and Cecal Intubation Time. *Clin Endosc* 2016; **49**: 187–190.
54 Saunders BP, Fukumoto M, Halligan S, *et al*. Why is colonoscopy more difficult in women? *Gastrointest Endosc* 1996; **43(2 Pt 1)**: 124–126.
55 Kawasato R, Hashimoto S, Shirasawa T, *et al*. Correlation between obesity and metabolic syndrome-related factors and cecal intubation time during colonoscopy. *Clin Exp Gastroenterol* 2017; **10**: 1–7.

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