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Prospective comparison of an adult, an intermediate pediatric and a long pediatric colonoscope in the training process of gastrointestinal fellows to achieve high-quality practice in colonoscopy

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Abstract

Background Few data are available on the influence of colonoscope type on the training process and quality of colonoscopy. We conducted this prospective observational cohort study to investigate scope suitability for starting colonoscopy training, in relation to technical competence, quality indicators, and the patient's comfort during diagnostic colonoscopy.

Methods A total of 126 consecutive patients were enrolled in the study and assigned to one of 3 groups: adult colonoscope ([AC], n=41); intermediate pediatric colonoscope ([IPC], n=43); and long pediatric colonoscope ([LPC], n=42). Primary outcomes were completeness of the examination and minutes to the cecum. Secondary outcomes included patient tolerance, position change, use of abdominal compression, loop formation, kind of loop, and overall difficulty of the procedure.

Results Cecal intubation rates were not statistically different between the groups: AC/87.8%; IPC/81.4%; and LPC/92.8%. Terminal ileal intubation rate differed significantly among the 3 groups (P=0.015) with LPC having the higher rate (66.7% vs. 60.9%/AC and 37.2%/IPC). There were significant differences in positional changes (fewer with LPC/1.36 vs. AC/2.15 and IPC/2.09, P=0.027) and midazolam administered doses (lower with LPC/0.52 vs. AC/1.07 and IPC/0.93, P=0.032). Loop formation with subsequent resolution was significantly associated with more pain for the patient with all of the 3 colonoscope types.

Conclusions The LPC performs better in trainee hands than AC and IPC in terms of reaching competency, and quality indicators show less discomfort for the patients during colonoscopic procedures (lower midazolam dose and fewer positional changes). It could be considered the most suitable scope for starting high-quality colonoscopy training.

Keywords Colonoscopy, pediatric colonoscope, training, adult colonoscope

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Introduction

Colonoscopy has become a valuable diagnostic and therapeutic procedure used in gastroenterology, but there is a risk of potential complications; thus, the quality of endoscopy has been identified as a major priority. Competence in colonoscopy is ensured by appropriate training and assessment of the endoscopist. The technical skills ensure that a safe, painless and complete procedure provides the information which, along with the endoscopist's cognitive skills, will lead to accurate diagnosis and appropriate therapy. Guidelines and assessment tools for establishing colonoscopy standards for specialists and trainees have been developed [1-5]. Subsequently, expertise in colonoscopy can be judged by indicators such as the total number of procedures [6], adenoma detection rate (ADR), cecal intubation rate (CIR), cecal intubation time (CIT), and complication rate, including patient's discomfort [7]. A high cecum and terminal ileum intubation rate are of crucial

importance for sparing time for the diagnostic colonoscope withdrawal without missing any pathologic lesions [8]. A prolonged procedural time is also associated with abdominal discomfort, sedation-related hypoxia, and perforation. In addition, preprocedural assessment regarding sedation, bowel preparation and technical skills, including loop prevention, transabdominal pressure and body position change, are basic aspects of training programs. However, there is still a paucity of evidence about the association between colonoscope type and colonoscopy quality indicators in gastroenterology fellows. Clinical experience suggests that there is no concern about "running out of scope" before examination completion when using a long colonoscope, given the ability of pushing through the loops [9]. On the other hand, although the flexibility of a pediatric colonoscope enables an effortless and painless passage through a narrowed and angulated colon, it is vulnerable to loop formation [10]. Up to now, the data support that the intermediate adult colonoscope (AC) achieves a significantly higher and faster CIR compared to the conventional long AC, favorable for the ileum intubation rate [11]. In this study, in a prospective, comparative manner, we investigated an AC, an intermediate pediatric colonoscope (IPC), and a long pediatric colonoscope (LPC) in the training process of gastrointestinal fellows with a view to achieving high-quality practice in colonoscopy.

Patients and methods

This prospective study was conducted in the endoscopy unit of a large tertiary referral hospital (Linköping University Hospital, Linköping, Sweden) over a 6-month period, from January to June, 2018. Patients were eligible to participate if they were scheduled to undergo a colonoscopy for screening, surveillance in follow up of previous polypectomy, surveillance in inflammatory bowel disease, or diagnostic workup. Patients with prior colon resection, fulminant colitis, acute colonic pseudo-obstruction, known obstructive lesions, severe hematochezia, those younger than 18 years old, those meant to undergo partial colonoscopy or examination with a specific endoscope, and those unwilling to provide written informed consent, were excluded. Demographic data and history of previous colonoscopy prior to the procedure were obtained. Body mass index (BMI) was calculated as body weight divided by body height squared (kg/m^2). The examinations were performed by 4 fellows in gastroenterology under the supervision of an attending consultant. None of the trainees had reached a high level of experience (200 diagnostic procedures + 50 therapeutic procedures = 250 in total) according to the national guidelines for a trainee with confidence in the technique of colonoscopy (CIR 90%, terminal ileum intubation rate 70%, polypectomy of pedunculated and flat polyps up to 20 mm, therapeutic hemostasis) [12]. Patients were enrolled and assigned based upon colonoscope availability into 3 groups, depending on the type of colonoscope: AC group, the conventional adult size, full length 1680 mm CF-HQ190L; IPC group, the pediatric size, intermediate length 1330 mm PCF-H190DI colonoscope; and LPC group, the pediatric-size, full-length 1680 mm PCF-H190DL. Specifications of these endoscopes are summarized in Table 1. The position and the configuration of the endoscope inside the colon in all the instruments used during the procedures were provided by a ScopeGuide 3D-image-navigation system (Olympus Medical Devices, Japan). The patients were unaware of the colonoscope type, while the fellow, the attending endoscopist and the gastroenterology assistant were not blinded to instrument allocation. Colon preparation was accomplished by asking the patients to ingest 4 L of a polyethylene glycol electrolyte solution over a 12-h period before the procedure and was assessed by the attending specialist gastroenterologist using the Boston Bowel Preparation Scale [13]. All procedures were performed using conscious sedation and analgesia with intravenous midazolam and alfentanil, titrated as required. Patients, endoscopists and nurses assessed the pain score with the pain assessment tool on a visual analog scale (VAS), where 0 involved no pain and 10 involved the worst pain possible, and all were blind to the others' scoring. When insertion of the colonoscope was hampered by endoscope looping, manual abdominal pressure was applied by the assistant nurse and, in case of pressure failure, the posture of the patient was also changed.

Complete colonoscopy was defined as cecum or terminal ileum intubation by visualization of the appendiceal orifice and ileum mucus, respectively. The CIT was defined as the time required to reach the cecum and total procedural time as the time until the endoscope was removed from the anus. The assistant endoscopist replaced the trainee and finished the examination if the procedure became time-consuming or the trainee asked for help. The primary outcomes recorded were the completeness of the examination and the CIT. Secondary outcomes included total procedural time, adenomas and polyps detected, number and kind of loop formation, use of manual abdominal compression, positional change, loop resolution, "through-the-loop" endoscopy, patient tolerance, sedation and analgesia dose, examination completion by the attending endoscopist, and overall difficulty of the procedure using the global assessment score. All patients provided written informed consent and the study was approved by the hospital ethics committee according to the Declaration of Helsinki.

Statistical analysis

This was a quantitative, correlational study, investigating the association between colonoscope type, CIR, and terminal intubation rate, and the relationship between colonoscope type and a number of independent variables concerning the procedure of colonoscopy. Descriptives and frequencies were used, as appropriate. Loop resolution differences in the 3 pain scores (physician's, patient's, and nurse's), measured with the VAS scale, were examined using the independent samples' *t*-test. Differences between the 3 types of colonoscope, AC, IPC and LPC, in terms of the numeric variables of the sample were examined using one-way analysis of variance (ANOVA). Significant differences between pairs were calculated with the

Table 1 Specifications of the 3 types of colonoscope used during the procedures

Type	Specifications	Insertion tube (mm)	Distal end (mm)	Channel ID (mm)	Bending (up/down)	Bending (left/right)	Working length (mm)	Field of view	Depth of field (mm)
Adult colonoscope	OLYMPUS CF-HQ190L	12.8	13.2	3.7	180°/180°	160°/160°	1680	170°	5-100
Intermediate pediatric colonoscope	OLYMPUS PCF-H190DL	11.8	11.7	3.2	180°/180°	160°/160°	1680	170°	2-100
Long pediatric colonoscope	OLYMPUS PCF-H190Dl	11.8	11.7	3.2	180°/180°	160°/160°	1330	170°	2-100

ID, internal diameter

use of the Bonferroni criterion. In addition, the chi-square test was used to examine potential differences between the 3 types of colonoscope with regard to the CIR and the terminal ileum intubation rate, as well the other categorical independent variables of the sample. Statistical significance for all tests was set at 0.05. Statistical analysis was performed using the statistical package SPSS 24 for Windows.

Results

During the study period, a total of 142 consecutive patients were eligible to be recruited. After 16 patients had been excluded (11 with colon resection, 2 with severe hematochezia, 2 with obstructive lesions, 1 with fulminant colitis), a total of 126 patients were included in the final analysis and allocated into 3 groups: 41/AC group, 43/IPC group, and 42/LPC group. A summary of the baseline characteristics of all subjects is shown in Table 2. When the 3 groups were compared there were no significant differences in age, sex, experience of previous colonoscopy, BMI, quality of bowel preparation or indication for the examination (Table 2). Tables 3-5 summarize the major outcomes in the 3 groups. Successful cecal intubation was achieved in 110 of the 126 patients (87.3%). There was no difference in success in intubating the cecum: 36 of 41 (87.8%) cases for the AC colonoscope; 35 of 43 (81.4%) for the IPC; and 39 of 42 (92.8%) cases for the LPC (P=0.282). The terminal ileum intubation rate for all study procedures was 54.7% (69/126). There was a statistical difference in the terminal ileum intubation rates between the 3 groups (P=0.015). *Post hoc* analysis revealed that the AC and the LPC achieved significantly higher intubation rates compared to the IPC (P=0.050 and 0.018 respectively), while no statistically significant difference was observed between the AC and LPC groups. The mean total procedural time was 36.69 minutes. The time required to complete the total procedure differed significantly among the 3 groups (P=0.009). The LPC and the IPC were significantly faster than the AC (P=0.012 and 0.045 respectively), while the LPC and the IPC were not statistically different. The mean midazolam dose was 0.84 mg. The sedation dose was significantly different among the 3 groups (P=0.032); in particular, according to the *post hoc* analysis, the LPC needed less midazolam administration compared to the AC for pain control (P=0.036). The number of position changes required for the completion of the procedure was significantly different among the 3 groups (P=0.027) and with further subgroup analysis it was found that the AC group needed more posture changes than the LPC (P=0.05). There was no statistically significant difference in the CIT, the adenoma and polyp detection rates, the pain scores, the alfentanil doses, the manual pressures, the number and type of loop formation, the "through-the-loop endoscopy" or the endoscopists' global assessment of procedure difficulty.

Discussion

The optimal colonoscope, which would facilitate safe, fast and comfortable insertion to the ileum in all cases, is determined by several features. In particular, the colonoscope should be characterized by easy, but steady, maneuverability, a thin insertion tube diameter to pass narrow segments, and at the same time ideal length and stiffness to prevent loop formation and pain. For instance, a small-diameter colonoscope may, on the one hand, diminish patients' pain and perform better in angulated colons; but on the other hand, it may contribute to loop formation.

According to previous studies, the pediatric colonoscope has been compared extensively as an alternative to the AC in routine colonoscopy [14-17]. It was concluded that the switch to a pediatric instrument could be beneficial when colonoscopy could not be completed with the standard instrument. Although the different colonoscope types seem to be equal in the hands of specialist endoscopists, information is not available regarding the ideal endoscope when it refers to inexperienced fellows beginning their "hands-on" training.

Saiffudin *et al* [17] compared 150 colonoscopies performed by a specialist endoscopist using either an IPC or a long AC. The 2 endoscopes did not differ statistically significantly in terms of any of the outcomes measured, and the authors concluded that a pediatric colonoscope is suitable for routine colonoscopy in adults. In a subgroup analysis, there was a trend for women with a prior history of hysterectomy to benefit from the use of the IPC, but this also did not reach statistical significance.

Table 2 Baseline characteristics of subjects

Characteristics	AC	IPC	LPC	P-value
Age (years)*	55.7±14.9	57.0±16.3	55.6±15.1	0.661
Sex, No. (%)**				0.744
Male	20/41 (48.8%)	22/43 (51.2%)	22/42 (52.4%)	
Female	21/41 (51.2%)	21/43 (48.8%)	20/42 (48.6%)	
BMI (kg/m^2) ±0.74	23.9±3.1	24.1±3.1	23.8±3.1	0.324
Experience of previous colonoscopy, No. (%)**				0.142
Yes	19/41 (46.3%)	22/43 (51.1%)	18/42 (42.8%)	
No	22/41 (53.7%)	21/43 (48.9%)	24/42 (57.2%)	
Boston bowel preparation scale*	8.2±0.72	8.1±0.74	8.0±0.68	0.423
Indication, No. (%)**				0.536
Screening	24/41 (59%)	27/43 (63%)	24/42 (57%)	
Polyp surveillance	10/41 (24%)	9/43 (21%)	9/42 (22%)	
IBD surveillance	2/41 (5%)	3/43 (7%)	3/42 (7%)	
Diagnostic work-up	5/41 (12%)	4/43 (9%)	6/42 (14%)	

Data are represented as mean ± SD or number (%), as appropriate

Differences are considered significant if P-value <0.05

*Mean (SD) values were compared with one-way ANOVA

**Percentages of cases within each group were compared with chi-square tests

AC, adult colonoscope; IPC, intermediate pediatric colonoscope; LPC, long pediatric colonoscope; BMI, body mass index; SD, standard deviation; IBD, inflammatory bowel disease

Table 3 Comparison of various quality procedural factors according to colonoscope type

Factors	AC	IPC	LPC	P-value
Cecal intubation rate (Y/T, %)*	36/41 (87.8%)	35/43 (81.4%)	39/42 (92.9%)	0.282
Terminal ileum intubation rate (Y/T, %)*	25/41 (61.0%)	16/43 (37.2%)	28/42 (66.7%)	0.014
Cecal intubation time (min)**	14.05±8.98	14.74±9.95	14.76±8.09	0.920
Total procedural time (min)**	41.32±14.09	35.07±11.85	33.83±8.19	0.009
Adenomas detected**	0.61±1.46	0.47±0.80	0.52±0.86	0.827
Polyps detected **	1.46±2.26	1.14±2.50	1.05±1.19	0.631

Data are expressed as mean ± SD or number (%), as appropriate

Differences are considered significant if P-value <0.05

*Percentages of cases within each group were compared with chi-square tests. Test value refers to $\chi 2$

**Mean (SD) values were compared with one-way ANOVA; test value refers to F

AC, adult colonoscope; IPC, intermediate pediatric colonoscope; LPC, long pediatric colonoscope; SD, standard deviation; Y/T, XXX

Table 4 Comparisons of factors associated with the comfort of the procedure according to colonoscope type

Factors	AC	IPC	LPC	P-value
Pain score (using VAS)				
Assessed by physicians	4.22±2.03	3.51±2.26	3.62±1.56	0.216
Assessed by patients	4.37±2.00	3.54±2.45	3.60±1.84	0.141
Assessed by nurses	4.15±1.88	3.51±2.37	3.38±1.45	0.163
Midazolam dose (mg)	1.07±1.17	0.93±0.96	0.52±0.77	0.032
Alfentanil dose (mg)	0.62±1.09	0.48±0.39	0.60±1.29	0.786

Data are expressed as mean±SD

Differences are considered significant if P-value <0.05

Mean (SD) values were compared with one-way ANOVA

AC, adult colonoscope; IPC, intermediate pediatric colonoscope; LPC, long pediatric colonoscope; VAS, visual analog scale

Table 5 Comparison of factors associated with the technical completeness of the procedure according to colonoscope type

Factors	AC	IPC	LPC	P-value
No of manual pressures*	1.44±1.32	1.09±1.23	1.21±1.07	0.419
No of positional changes*	2.15±1.88	2.09±1.36	1.36±1.12	0.027
Loop formation (Y/T, %)**	26/41 63.4%	20/43 46.5%	20/42 47.6%	0.226
Multiple loops (Y/T, %)**	2/41 4.9%	0/43 0%	2/42 4.8%	0.355
Kind of 1st loop**				0.172
Alpha "α"	9/41 (22.0%)	7/43 (16.3%)	9/42 (21.4%)	
Spiral "N"	10/41 (24.4%)	4/43 (9.3%)	6/42 (14.3%)	
Reversed alpha "α"	6/41 (14.6)	3/43 (7.0 %)	2/42 (4.8%)	
Deep transverse	1/41 (2.4%)	6/43 (14%)	2/42 (4.8%)	
Gamma "γ"	0/41 (0%)	0/43 (0%)	1/42 (2.3%)	
Loop resolution (Y/T, %)**	17/41 41.5%	13/43 30.2%	10/42 23.8%	0.217
"Through-the-loop" endoscopy (Y/T, %)**	7/41 17.1%	4/43 9.3%	11/42 26.2%	0.122
Att. endoscopist complete examination (Y/T, %)**	7/41 17.1%	7/43 16.3%	4/42 14.3%	0.555
Global assessment score*	4.46±2.16	3.91±2.48	3.67 ± 1.37	0.200

Data are expressed as mean ± SD or number (%), as appropriate

Differences are considered significant if P-value <0.05

*Mean (SD) values were compared with one-way ANOVA; test value refers to F

**Percentages of cases within each group were compared with chi-square tests; test value refers to χ^2

AC, adult colonoscope; IPC, intermediate pediatric colonoscope; LPC, long pediatric colonoscope; Y/T, XXX

In the same context, it has been shown that CIT was shorter in patients examined with an intermediate AC compared to a LPC, particularly in the subgroups of men and those below the age of 50 years [18].

Furthermore, a study that compared a variable-stiffness, a pediatric and an AC concluded that, although the variable-stiffness one performed well, it did not appear to offer any distinct advantages over the other endoscopes. In this trial, the colonoscopies were performed by either an attending gastroenterologist or a training fellow under direct supervision [19]. It would be interesting, though, to know if there was any difference between the endoscopists.

On the other hand, Barthel *et al* [20] showed that gastroenterology fellows using the intermediate AC managed to complete the colonoscopy faster and in a more painless manner for the patients compared to the long AC, although the latter achieved a higher CIR. It has been suggested that a long colonoscope best guarantees insertion to the cecum, whereas an intermediate colonoscope permits fast but limited examination.

There are only a few trials investigating, separately, either the usefulness of pediatric colonoscopes in the hands of a specialist, or the different ACs in the hands of trainees. In our study, we aimed to compare in a prospective, non-randomized manner an AC, an IPC, and a LPC in the training process of gastrointestinal fellows.

A significant number of correlations were found in this study, which might have implications in colonoscopy education. To begin with, the terminal ileum intubation rate was higher with the long endoscopes, whether the AC or the pediatric one, compared to the intermediate length (LPC vs. IPC P=0.018; and AC vs. IPC P=0.05). This observation agrees with the results of Kim *et al* [21], where the long colonoscope also appeared to offer a higher success rate for terminal ileal intubation. Even when expert endoscopists attempt to prevent colonic loops, it is extremely rare to have no loop formation. As a result, when using an intermediate endoscope, the length of uninserted endoscope may not be sufficient to push through the loops and intubate the terminal ileum successfully, whereas long endoscopes with the additional spared length may achieve higher intubation rates. In addition, in order not to miss pathologic lesions, especially in areas such as the terminal ileum and proximal colon, it is important to achieve a high rate of cecal and terminal ileal intubation. In short, the LPC might be a useful aid for trainees in their first attempts at intubating the ileum.

Secondly, another interesting finding was that pediatric colonoscopes achieved a shorter total procedural time compared to the AC (LPC vs. AC P=0.008; and IPC vs. AC P=0.028). We believe the reason for this is that the pediatric colonoscopes are easier to handle than the AC during the initial training process, because of both the weight and the length of the portion not inserted during the procedure. It is well known that longer withdrawal times are crucial for detailed examination of the colon so that no lesions will be missed [8]. Nevertheless, a prolonged procedural time is associated with abdominal discomfort, sedation-related hypoxia and

perforation. Given that the ADRs and the polyp detection rates were not statistically different between the groups, we could assume that a shorter procedural time is in favor of a more comfortable and painless colonoscopy.

Third, we found that there was statistical significance in the mean sedative dosages and the number of positional changes: more specifically, the LPC group needed less midazolam and postural maneuvers than the AC (LPC vs. AC P=0.036; and PLC vs. AC P=0.031). Despite these valuable clinical correlations, differences in the pain scores assessed by the physicians, the patients and the nurses did not reach significance, as it is a common fact that pain perception is highly subjective and quantification of pain is difficult in clinical studies, even when individualizing it. Nonetheless, we could encourage fellows to begin their hands-on training with the LPC, considering the lower complication risk of sedation and the stress related to patient's positional changes, which both need some experience.

It is known that the primary source of discomfort during colonoscopy is looping, related to instrument length and technique [22]. Another interesting point is that we correlated the resolution of the loops with the pain score assessed by physicians, patients and nurses (P=0.009, P=0.002, and P=0.006, respectively), as summarized in Table 6. Loop formation with subsequent resolution was confirmed to be significantly associated with higher levels of pain for the patient with all of the 3 colonoscope types.

Despite the interesting results, our study has some limitations. It was not feasible to design a double-blinded study; thus, bias could not be completely eliminated. The trainees may have been overtired with a specific instrument over another one, and the non-objective pain scoring and the global assessment could have been biased, as they knew which colonoscope was being used, despite the fact that we introduced 3 individual pain scores. Moreover, the decision to terminate the procedure was at the discretion of the attending gastroenterologist and this could be a source of bias. All 4 trainees had a similar amount of experience, and we believe that bias caused by variations in experience of the techniques was minimized in this trial. Third, patients who had prior colon resection, fulminant colitis, acute colonic pseudo-obstruction, known obstructive lesions or severe hematochezia were excluded, and we believe that the AC would have an advantage over an intermediate colonoscope in such cases. Finally, the number of fellows included in the study was small and all of them were from a single fellowship program.

Table 6 Correlations between loop resolution and pain during the procedure

	Loop resolution	No	Mean	P-value
Pain VAS score physicians	Yes	40	4.45±2.09	0.009
	No	86	3.47±1.86	
Pain VAS score patients	Yes	40	4.68±2.15	0.002
	No	86	3.43±2.01	
Pain VAS score nurses	Yes	40	4.38±1.84	0.006
	No	86	3.35±1.93	

Data are expressed as mean ± SD

Differences are considered significant if P-value <0.05

Mean (SD) values were compared using the independent sample t-test

VAS, visual analog scale; SD, standard deviation

In conclusion, this prospective non-randomized trial demonstrated that the use of the LPC colonoscope in the trainees' hands was associated with a higher terminal ileum intubation rate, lower mean sedation dosage and less positional changes for the patient. We believe that these observations have implications for colonoscopy education and the LPC might thus be recommended for routine use as a first choice for trainees.

Summary Box

What is already known:

- Cecal and terminal ileum intubation rates and time are crucial quality indicators in diagnostic colonoscopy
- Expertise in colonoscopy can be judged by specific indicators
- There is a paucity of data regarding difference between colonoscope type and quality indicators in gastroenterology fellows during colonoscopy training

What the new findings are:

- The terminal ileum intubation rate was higher with the long pediatric and adult colonoscope in trainees
- Pediatric colonoscopes achieved a shorter total procedural time during colonoscopy training
- The long pediatric colonoscope might be recommended as the first choice for trainees to achieve high-quality practice in colonoscopy

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