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Impact of pediatric versus adult colonoscope on terminal ileum intubation: a retrospective study

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Abstract

Background Various possible predictors of successful terminal ileal intubation (TII) have been explored but the role of the type of colonoscope is unclear.

Methods We carried out a retrospective review of a prospectively collected database of all colonoscopies performed at a single endoscopy unit between May 2015 and July 2020. The primary outcome measure was successful TII in patients with specific indications for ileal examination. The primary predictor was the type of endoscope, pediatric or adult, used during the procedure. Univariate and multivariate analyses were performed.

Results In 5845 colonoscopies fulfilling the study criteria, the overall TII rate was 67.8%. In univariate analysis, the use of a pediatric colonoscope was associated with a higher TII rate (72.1% vs. 58.8%, P<0.001). Other variables associated with successful TII based on univariate analysis included the patient's age, male sex, body mass index, endoscopists' specialty, place of training, shorter colonoscope insertion time, shorter duration of the procedure, longer withdrawal time, procedures performed in the afternoon, type of sedation administered during colonoscopy, and cleanliness of the colon. Multivariate analysis yielded an adjusted odds ratio (OR) of 1.40 (95% confidence interval [CI] 1.21-1.62) for the use of a pediatric colonoscope. Propensity score-matching analysis also showed superiority of the pediatric colonoscope in achieving TII compared to an adult colonoscope, OR 1.35 (95%CI 1.17-1.57).

Conclusions Pediatric colonoscope increases the success of TII during colonoscopy. For endoscopists performing colonoscopy with intent to examine the terminal ileum, it is recommended to choose a pediatric colonoscope to maximize the success rate.

Keywords Terminal ileum, colonoscope, colonoscopy, pediatric, scope

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Introduction

Ileal intubation is technically feasible in almost all patients undergoing colonoscopy [1-4]. It serves as a reliable confirmatory step of a complete colonoscopic examination [5]. Moreover, examination of the terminal ileum is an important step during colonoscopy performed in specific clinical scenarios, such as excluding inflammatory bowel disease (IBD) [6,7]. Therefore, several techniques have been described to enhance the likelihood of terminal ileal intubation (TII) [8-10]. However, there is a paucity of data evaluating the impact of endoscope type on the likelihood of achieving ileal intubation.

Our aim was to explore the differences in TII rate with pediatric and adult colonoscopes among the subset of patients undergoing colonoscopy with clinical indications for terminal ileum examination. Additionally, our secondary goal was to identify other factors predictive of TII.

Patients and methods

We conducted a retrospective review of a prospectively collected database of all colonoscopies performed at a single

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tertiary-care referral endoscopy unit from May 2015 to July 2020. We restricted our sample to patients who underwent colonoscopy with specific clinical indications necessitating TII. These indications included suspicion of IBD, established IBD, abnormal imaging studies of the gastrointestinal tract suggesting IBD, abdominal pain, gastrointestinal bleeding, perirectal fistula, anemia, weight loss, and chronic diarrhea. Other exclusion criteria included incomplete procedures (i.e., those without documentation of cecal intubation), patients younger than 18 years of age, procedures during which different types of endoscopes were utilized, those performed with endoscopes other than either adult or pediatric colonoscopes, and patients with a history of right hemicolectomy.

The primary outcome measure was TII, as documented in the colonoscopy report. The main predictor evaluated was the type of colonoscope, adult vs. pediatric.

Data collected included patients' age, sex, body mass index (BMI), endoscopists' names, specialty (gastroenterologist vs. surgeon), location of endoscopy training (North America, Europe, Australia, and others), quality of colon preparation (poor or unsatisfactory prep in the right side of the colon or in the entire colon vs. others), total procedure time, scope insertion time (cecal intubation time) and withdrawal time, timing of the procedure (morning, 8 am-12 pm, vs. afternoon, after 12 pm), and the type of colonoscope utilized (pediatric vs. adult). All the included procedures were performed using either a pediatric colonoscope with a working length of 1680 mm (OLYMPUS EVIS EXERA III Colonovideoscope, PCF-PH190L) or an adult colonoscope with a working length of 1680 mm (OLYMPUS EVIS EXERA III Colonovideoscope, CF-HQ 190L).

Point and interval estimates were reported for all descriptive data and presented as mean ± standard deviation. Frequencies (n) and percentages (%) were used to report summaries of categorical variables. Student's *t*-test was used to compare means and Pearson's chi-square test or Fisher's exact test (when expected frequencies were less than 5) to compare categorical variables in unadjusted analyses. These unadjusted univariate analyses were used to examine variables associated with type of colonoscope and successful TII.

We then used multivariate analysis to explore the association between the type of colonoscope and successful TII, adjusting for potential confounding variables. Because of the clustering or lack of independence of the outcome (successful TII) at the endoscopist level, because endoscopists performed several procedures, we used a mixed-effects logistic regression utilizing the command melogit in STATA 15.1. Mixed-effects logistic regression provides a fixed effect estimate of the odds ratio for the association between type of colonoscope and successful TII, adjusting for the additional covariates, and accounting for clustering by including a random effect at the endoscopist level. A directed acyclic graph was used to guide the choice of covariates and potential confounders included in the multivariate analysis.

We performed the mixed-effects logistic regression using available case analysis. Although the amount of missing data was modest, as a sensitivity analysis, we used multiple imputation (with 10 imputations) to impute the missing covariates—insertion time, timing of the procedure (morning vs. afternoon) and BMI—using the mi impute and mi estimate commands in STATA version 15.1. The intubation of the ileum, patients' age and sex, type of colonoscope used during the procedure, quality of the colon preparation, and the endoscopists who performed colonoscopy, were included as predictors in the imputation model.

In addition, in a complementary analysis of the association between type of colonoscope and successful TII, we decided to use propensity score methods to match patients by type of colonoscope (pediatric vs. adult), because there were small differences in observable characteristics between individuals who underwent colonoscopy by pediatric colonoscope compared to adult colonoscope.

Statistical analysis

Initially, we estimated a logistic regression model predicting the probability of undergoing colonoscopy using a pediatric colonoscope, adjusting for patients' clinical and demographic characteristics. The predicted probability for undergoing colonoscopy using pediatric colonoscope from this model was each individual's propensity score. Subsequently, we performed matching using the psmatch2 package in STATA (version 15.1). Individuals who underwent colonoscopy using pediatric colonoscopy were matched to patients who underwent colonoscopy using an adult colonoscope applying the nearest neighbor algorithm without replacement and with a 1:1 ratio and a caliper of 0.02. Matches were formed such that their propensity scores differed by at most 0.2 standard deviations (the caliper width). It has been shown that calipers derived from this rule can result in a reduction of more than 90% in the bias due to observable differences between the 2 groups [11]. Statistical significance was defined as a P-value <0.05. All statistical analyses were performed using STATA version 15.1 (Stata Corp., College Station, TX). The study protocol was approved by the institutional review board of Cleveland Clinic Abu Dhabi.

Results

A total of 13361 colonoscopy reports were reviewed electronically: 753 incomplete colonoscopies were excluded, while 5845 fulfilled all the other study criteria. A total of 32 endoscopists performed the procedures. They represented a heterogeneous cohort, comprising 23 gastroenterologists and 9 surgeons, with a wide range of endoscopic training backgrounds (16 from the USA, 2 from Canada, 6 from Europe, 2 from Australia and 6 from Asia and Africa).

Of the total procedures, 48.26% were performed in males and 51.74% in females. The age of patients undergoing colonoscopy ranged from 18-116 years (44.0±15.3 years, median 42 years).

The 116-year-old patient underwent colonoscopy to investigate iron deficiency anemia.

A pediatric colonoscope was used in 3940 procedures, accounting for 67.4% of all cases, while the remaining 1905 (32.6%) were performed using an adult colonoscope. Table 1 lists the main characteristics of the 2 cohorts, pediatric and adult colonoscope, before and after propensity score matching. Fig. 1 illustrates the standardized percentage bias across the covariates for the unmatched and the matched cohorts. The patients who underwent colonoscopy using a pediatric colonoscope were younger (43.5±15.6 vs. 45.2±14.6 years), more likely to be female (56.1% vs. 42.6%), with lower BMI (28.1±5.8 vs. 29.4±7.0 kg/m^2), more likely to have the procedure performed by endoscopists trained in North America (78.1% vs. 76.4%) or Asia or Africa (10.4% vs. 5.4%), with faster colonoscope insertion (6.1±4.6 vs. 6.5±5.0 min), a longer withdrawal time (12.3±6.2 vs. 11.5±6.7 min), a greater proportion of afternoon cases (60.8% vs. 52.4%) and were more likely to have the procedure performed with anesthesia-administered sedation (97.6% vs. 95.3%) (Table 1).

Table 1 Comparison of the characteristics of patients, physicians and procedures by type of colonoscope used before and after propensity score matching

Characteristics	Before matching pediatric scope N=3940	Before matching adult scope N=1905	P-value	After matching pediatric scope N=1516	After matching adult scope N=1516	P-value
Age (years), mean±SD	43.5±15.6	45.2±14.6	<0.001	44.8±15.5	44.7±14.3	0.817
Sex, female (%)	2123 (56.1%)	811 (42.6%)	<0.001	880 (58.0%)	842 (55.5%)	0.164
BMI, mean±SD	28.1±5.8	29.4±7.0	<0.001	29.4±6.0	29.0±5.5	0.132
GI physicians n (%)	3696 (93.8)	1789 (93.9)	0.877	1418 (93.5%)	1423 (93.9%)	0.709
Surgery physicians n (%)	244 (6.2)	116 (6.1)		98 (6.5%)	93 (6.1%)	
Training						
North America n (%)	3077 (78.1)	1456 (76.4)	<0.001	1191 (78.6)	1192 (78.6)	0.809
Europe n (%)	249 (6.3)	243 (12.8)		181 (11.9)	168 (11.1)	
Australia n (%)	204 (5.2)	104 (5.5)		52 (3.4)	56 (3.7)	
Others n (%)	410 (10.4)	102 (5.4)		92 (6.1)	100 (6.6)	
Procedure duration (min) mean ± (SD)	18.9±8.4	18.8±9.1	0.744	19.1±9.1	18.7±8.8	0.145
Insertion duration (min) mean ± (SD)	6.1±4.6	6.5±5.0	0.001	6.3±5.3	6.4±4.9	0.919
Withdrawal (min) mean±SD	12.3±6.2	11.5±6.7	<0.001	12.4±6.9	11.7±6.6	0.002
AM procedure n (%)	1537 (39.2)	906 (47.6)	<0.001	704 (46.4)	695 (45.8)	0.743
PM procedure n (%)	2385 (60.8)*	999 (52.4)		812 (53.6)	821 (54.2)	
Adequate prep n (%)	3377 (85.7)	1639 (86.0)	0.738	1296 (85.5)	1305 (86.1)	0.640
Sedation						
No sedation n (%)	7 (0.18)	3 (0.16)	0.001	0 (0)	2 (0.1)	0.606
Conscious sedation n (%)	87 (2.2)	87 (4.6)		40 (2.6)	40 (2.6)	
Deep sedation n (%)	3846 (97.6)	1815 (95.3)		1476 (97.4)	1474 (97.2)	

* Missing data for 18 procedures

BMI, body mass index; GI, gastroenterology; SD, standard deviation

Overall, successful TII was accomplished in 67.8% of procedures with variable rates among endoscopists (0-100%) (Fig. 2). Once endoscopists who contributed less than 20 colonoscopies to the study analysis were excluded, the successful TII rate ranged from 23.0-91.8%. The bubble chart (Fig. 2) illustrates the clustering effect, the heterogeneity of ileal intubation rate among endoscopists, and crudely the higher success rate of ileal intubation when a pediatric colonoscope was used. Overall, there are more blue dots (pediatric colonoscopes) that are higher than orange dots (adult colonoscope), reflecting the overall higher success rate of ileal intubation when a pediatric colonoscope was used. TII was achieved more often with a pediatric colonoscope than with an adult colonoscope (72.1% vs. 58.8%, P<0.001)

Univariate analysis identified the following variables as being associated with successful TII: younger patient age (41.2±14.4 vs. 50.0±15.4 years), lower BMI (28.0±5.6 vs. 29.7±7.3 kg/m^2), shorter insertion time (5.6±4.1 vs. 7.7±5.7 min), longer withdrawal time (12.4±6.1 vs. 11.1±6.9 min), and shorter duration of the procedure (18.6±7.9 vs. 19.4±10.0 min). The success rate of TII was associated with the patient's sex (male 69.3% vs. female 66.4%), the endoscopists' specialty (gastroenterology 69.2% vs. surgery 46.1%), place of training, type of sedation administered during colonoscopy, procedures performed in the afternoon (69.8% vs. 65.5%), cleanliness of the colon (70.7% vs. 50.1%), and the type of colonoscope (pediatric 72.1% vs. adult 58.8%, P<0.001) (Table 2).

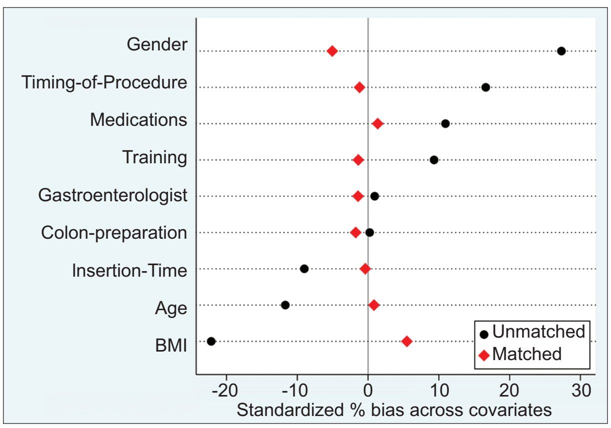

Figure 1 Standardized percentage bias across the covariates for the unmatched and the matched groups

In multivariable analysis, mixed-effects logistic regression of the imputed data yielded an adjusted odds ratio (OR) for the use of a pediatric colonoscope of 1.40 (95% confidence interval [CI] 1.21-1.62; P<0.001). That is, the adjusted odds of successful TII were approximately 40% higher when a pediatric colonoscope was used. This analysis also indicated that younger age (OR 1.04, 95%CI 1.037-1.046; P<0.001), lower BMI (OR 1.04, 95%CI 1.03-1.05; P<0.001), shorter insertion time (OR 1.07, 95%CI 1.05-1.9; P<0.001) at least adequate quality of right colon preparation (OR 3.05, 95%CI 2.53-3.66; P<0.001), procedures performed by gastroenterologists (OR 5.26, 95%CI 1.56-11.71; P=0.005), and in the afternoon shift (OR 1.36, 95%CI 1.18-1.56; P<0.001) were associated with successful TII (Table 3).

We noted that only 0.61% of the data were missing. There were no missing data for the outcome or the primary predictor, type of colonoscope, because both are mandatory fields in the software used to create the colonoscopy report. When analysis was restricted to those procedures with complete data on all variables, this yielded very similar results for the association of interest (adjusted OR for pediatric colonoscope to achieve TII compared to adult colonoscope, 1.45, 95%CI 1.25-1.68; P<0.001).

Finally, exploring the relationship between TII and the type of colonoscope using a propensity score-matching analysis

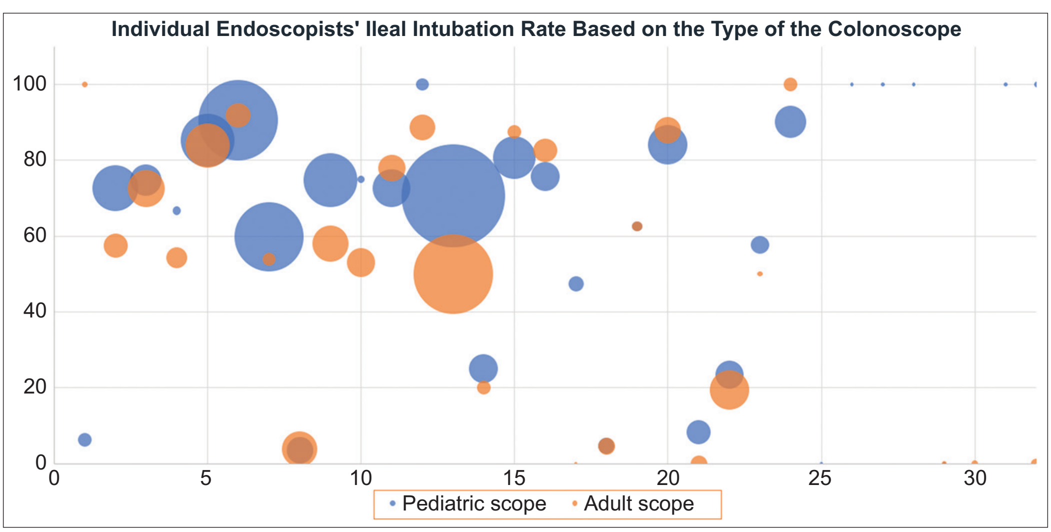

Figure 2 Bubble chart summarizing the unadjusted relationship between ileal intubation rate among different endoscopists. The horizontal axis represents different endoscopists (1-32). The vertical axis represents the rate of successful ileal intubation. The size of the dot reflects the number of colonoscopies performed by a particular endoscopist. Finally, the color of the dot reflects the type of the colonoscope (blue: pediatric colonoscope vs. orange: adult colonoscope)

Table 2 Univariate analysis of variables associated with successful ileal intubation

Variable	Cecum N=1884	Terminal ileum N=3961	P-value
Age (years), mean±SD	50.0±15.4	41.2±14.4	<0.001
Sex, female (%)	1017 (54.0%)	2007 (50.7%)	0.018
BMI, mean±SD	29.7±7.3	28.0±5.6)	<0.001
Specialty:			
GI physicians n (%)	1690 (89.7)	3795 (95.8)	<0.001
Surgery physicians n (%)	194 (10.3)	166 (4.2)	
Training:			
North America	1433 (76.1)	3100 (78.3)	<0.001
Europe	246 (13.1)	246 (6.2)	
Australia	75 (4.0)	233 (5.9)	
Others	130 (6.9)	382 (9.6)	
Procedure duration (min), mean±SD	19.4±10.0	18.6±7.9	<0.001
Insertion duration (min), mean±SD	7.7±5.7	5.6±4.1	<0.001
Withdrawal (min), mean±SD	11.1±6.9	12.4±6.1	<0.001
Timing of the procedure:			
AM procedure n (%)	844 (45.2)	1599 (40.4)	<0.001
PM procedure n (%)	1022 (54.8)*	2362 (59.6)	
Adequate prep n (%)	1470 (78.0)	3546 (89.5)	<0.001
Type of sedation:			
No sedation n (%)	4 (0.21)	6 (0.15)	0.036
Conscious sedation n (%)	68 (3.6)	106 (2.7)	
Deep sedation n (%)	1812 (96.2)	3849 (97.2)	
Type of colonoscope:			<0.001
Pediatric scope n (%)	1099 (58.3)	2841 (71.7)	
Adult scope n (%)	785 (41.7)	1120 (28.8)	

* Missing data for 18 procedures

BMI, body mass index; GI, gastroenterology; SD, standard deviation

reached a similar conclusion. The OR for achieving TII using a pediatric scope compared to an adult scope was 1.35 (95%CI 1.17-1.57; P<0.001). The slightly different estimated OR under the propensity score-matching analysis compared to the mixed-effects logistic regression may be partially explained by the lack of adjustment for clustering in the propensity score-matching analysis. An attempt to run a propensity score-matching analysis, matching observations with a cluster (physician), resulted in a very substantial reduction in sample size that would have significantly diminished the generalizability of the results.

Discussion

Despite expert opinion recommending routine ileal intubation to preserve this endoscopic skill [12-15], the practice of TII during colonoscopy varies widely among endoscopists, ranging from 12-96% in the literature [2,3,6,16-19]. Therefore, different methods have been described to facilitate this potentially challenging step during colonoscopy. Procedural factors reported to facilitate TII in prior studies included patient's position [8], administration of hyoscine butyl bromide [20], endoscopist experience (trainee vs. attending physician) [13] and use of longer endoscopes [21]. In our study population, all procedures were performed by attending physicians without trainee involvement, the default position was left lateral, and hyoscine butyl bromide was not used to facilitate ileal intubation.

There are scant data addressing the impact of endoscope type on TII. One previous study showed no difference in cecal intubation rates with the use of variable-stiffness pediatric, pediatric and adult colonoscopes [22,23]. Vemulapalli *et al* conducted a prospective study of 204 patients who underwent colonoscopy with and without Endocuff Vision. The univariate analysis for procedures performed without Endocuff Vision showed no difference between pediatric and adult colonoscopes in reaching the terminal ileum [24]. However, the study sample was small (55 colonoscopies without the use of Endocuff vision) and the study was not powered to detect the difference between the 2 types of scopes in achieving ileal intubation. Furthermore, the authors acknowledged that the decision to choose a pediatric rather than an adult colonoscope

Table 3 Multivariate analysis: OR for successful intubation of the terminal ileum

Variable	OR	Lower 95%	Upper 95%	P-value
Type of colonoscope				
Adult colonoscope	1 (Ref)			
Pediatric colonoscope	1.40	1.21	1.62	<0.001
Age	0.960	0.956	0.964	<0.001
Sex				
Male (reference)	1 (Ref)			
Female	0.90	0.79	1.04	0.147
Body mass index	0 .962	0.951	0.973	<0.001
Specialty				
Surgery physicians	1 (Ref)			
GI physicians	5.26	1.56	11.71	0.005
Training				
North America	1 (Ref)			
Europe	0.95	0.32	2.81	0.921
Australia	2.49	0.53	11.66	0.248
Others	0.90	0.26	3.11	0.872
Insertion duration	0.935	0.921	0.949	<0.001
Time of procedure				
AM procedure	1 (Ref)			
PM procedure	1.36	1.18	1.56	<0.001
Quality of prep				
Poor prep	1(Ref)			
Adequate prep or better	3.05	2.53	3.66	<0.001
Type of sedation				
No sedation	1 (Ref)			
Conscious sedation	1.43	0.27	7.57	0.668
Deep sedation	1.64	0.32	8.23	0.872

OR, odds ratio; GI, gastroenterology

was influenced by the patient's age and prior knowledge of the presence of severe diverticular disease.

Our study found that use of a pediatric colonoscope was associated with a higher rate of TII compared to an adult colonoscope, after adjusting for an array of confounders and covariates (OR 1.40, P<0.001). We hypothesize that the smaller diameter and greater flexibility of pediatric compared to adult colonoscopes assist in ileocecal negotiation to achieve TII, regardless of valve position or anatomic variations.

There are conflicting data regarding the association between age and likelihood of successful TII [2,19,25]. For example, lower TII rates among elderly patients have been previously observed in studies that included patients undergoing colonoscopy for non-screening indications [2,19]. On the other hand, 2 large retrospective studies concluded that age was not associated with a higher likelihood of TII [25,26]. Our study found that younger patients were more likely to have successful TII. One possible explanation is that older patients may have a more flaccid colon, increasing the overall difficulty of the procedure. Furthermore, it is possible that endoscopists are more willing to attempt ileal intubation in younger patients because of their lower prevalence of comorbidities.

Interestingly, patients with lower BMI were more likely to undergo successful ileal intubation. Our finding is in line with a large retrospective study that reported that, for every unit increase in BMI, the odds of TII dropped by 4% [25].

Not surprisingly, prolonged insertion time of the scope was associated with lower likelihood of successful TII. Again, our finding is similar to what was observed by Lieman *et al*, who reported shorter cecal intubation time when TII is attempted. They reported median cecal intubation time of 6 vs. 5 min (P<0.001) [25]. Insertion time may be a surrogate marker of technical difficulty of the procedure. Moreover, with longer procedure time, endoscopists may be less willing to invest additional time to intubate the terminal ileum due to scheduling pressure.

Also not surprisingly, poor preparation of the right colon was associated with a lower likelihood of TII. The presence of a significant right colonic fecal load may hinder TII and dissuade endoscopists from attempting the maneuver. This has also been demonstrated in a prior prospective study [27]. However, a large retrospective cohort study reached a different conclusion, reporting no difference in TII based on the quality of the colon preparation [26].

In our cohort, there was a difference in the unadjusted TII rates between gastroenterologists and surgeons (69.2%

vs. 46.1%, P<0.001). Moreover, when we accounted for clustering and used multivariate analysis (mixed-effect logistic regression), the difference attenuated but continued to be statistically significant. The variation in TII rates between gastroenterologists and surgeons could be attributed to their training background and the nature of practices for each group. Finally, the place of endoscopy training did not influence TII.

Prior studies have demonstrated variations in colonoscopy quality indicators, namely polyp detection rate and adenoma detection rate, between procedures performed in the morning and afternoon shifts [28]. This variation has been attributed to different factors, including endoscopist fatigue and endoscopists rushing to finish the procedure at the end of the working day [29,30]. However, in our study, the likelihood of successful TII was significantly higher in the afternoon. The result of our study is discordant with a previous study that revealed no relationship between TII and procedure timing [25].

The overall success rate of TII in our study was 67.8%, significantly lower than what has been previously reported. However, several studies that reported higher TII rates were either small or represented the experience of just a few endoscopists [1]. Larger studies (i.e., >1000 patients and/or >20 endoscopists) reported lower TII rates [13,19,26,31,32], capturing the variable rate of successful TII among a heterogeneous group of endoscopists.

To the best of our knowledge, this is the first study specifically addressing the impact of utilizing a pediatric vs. an adult colonoscope on the likelihood of TII. Our finding may have broader applicability, because it summarizes the results of endoscopists with a diverse range of international training backgrounds. Furthermore, the number of endoscopists who participated in the study is larger than that in most published studies that have addressed TII and probably helped to limit the impact of variations in skill set among individual endoscopists. Finally, we implemented robust statistical analyses to adjust for an array of confounders and to account for missing data and clustering effects.

The main limitation of the study is its retrospective design. Furthermore, the lack of clear guidelines regarding absolute and "soft" indications for TII may lead other researchers to disagree with the indications we adopted to determine that endoscopists should have performed TII in these cases.

In conclusion, a pediatric colonoscope should be preferentially considered if TII is clinically indicated, as it may have a higher level of success compared to an adult colonoscope. We acknowledge that endoscopists' practice and preference for type of endoscope may vary. Therefore, individual physicians may continue to prefer using adult colonoscopes to achieve higher level of intubation if they feel more comfortable with them. Further studies are needed to confirm our findings and identify other factors associated with successful TII.

Summary Box

What is already known:

- Different techniques are used to facilitate ileal intubation
- The predictors of ileal intubation during diagnostic colonoscopy are not completely known

What the new findings are:

- The use of a pediatric colonoscope was associated with a significantly higher likelihood of ileal intubation compared to an adult colonoscope
- Other factors associated with a higher success rate of ileal intubation included younger age, lower body mass index, gastroenterology training for the endoscopists, faster scope insertion, procedures performed in the afternoon, and adequate or good quality of preparation in the right colon
- In contrast, the success rate of ileal intubation did not appear to vary according to the patient's sex or the type of sedation used

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