Effect of 3-Dimensional Imaging Device on Polyp and Adenoma Detection During Colonoscopy: A Randomized Controlled Trial

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To evaluate the effect of 3-dimensional (3D) imaging device on polyp and adenoma detection during colonoscopy.

In a single-blind, randomized controlled trial, participants aged 18–70 years who underwent diagnostic or screening colonoscopy were consecutively enrolled between August 2019 and May 2022. Each participant was randomized in a 1:1 ratio to undergo either 2-dimensional (2D-3D) colonoscopy or 3D-2D colonoscopy through computer-generated random numbers. Primary outcome included polyp detection rate (PDR) and adenoma detection rate (ADR), defined as the proportion of individuals with at least 1 polyp or adenoma detected during colonoscopy. The primary analysis was intention-to-treat.

Of 1,196 participants recruited, 571 in 2D-3D group and 583 in 3D-2D group were finally included after excluding those who met the exclusion criteria. The PDR between 2D and 3D groups was separately 39.6% and 40.5% during phase 1 (odds ratio [OR] = 0.96, 95% confidence interval [CI]: 0.76–1.22, P = 0.801), whereas PDR was significantly higher in 3D group (27.7%) than that of 2D group (19.9%) during phase 2, with a 1.54-fold increase (1.17–2.02, P = 0.002). Similarly, the ADR during phase 1 between 2D (24.7%) and 3D (23.8%) groups was not significant (OR = 1.05, 0.80–1.37, P = 0.788), while ADR was significantly higher in 3D group (13.8%) than that of 2D group (9.9%) during phase 2, with a 1.45-fold increase (1.01–2.08, P = 0.041). Further subgroup analysis confirmed significantly higher PDR and ADR of 3D group during phase 2, particularly in midlevel and junior endoscopists.

The 3D imaging device could improve overall PDR and ADR during colonoscopy, particularly in midlevel and junior endoscopists. Trial number: ChiCTR1900025000.

As one of the leading causes of cancer-related death, colorectal cancer (CRC) is a pressing target for population screening worldwide (1). Colonoscopy has been considered as the gold standard for screening CRC, which has been shown to effectively reduce the incidence and mortality of CRC using the detection and removal of adenomas and polyps (2,3). Previous evidence indicated that per 1% increase of adenoma detection rate (ADR) was associated with 3% decrease of incident CRC (4). However, missed polyps or adenomas remain a significant problem during colonoscopy. Recent studies demonstrated approximately 27% of polyps and 9% of advanced adenomas missed, particularly for small and flat lesions (5,6). In addition to inspection time and bowel preparation, size and morphology of polyp/adenoma lesions as well as endoscopist experience are all critical factors contributing to these unrecognized polyps or adenomas (4,7,8).

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A good visualization is essential to increase the detection rate of polyps and adenomas. The current standard technique of endoscopic visualization is using a 2-dimensional (2D) imaging on the screen. A recent development technique of 3-dimensional (3D) endoscopes provides a 3D imaging, which theoretically achieves additional realistic information in depth, anatomical details as well as orientation of polyps during the colonoscopy procedure.

To address this important issue, we developed a simple, feasible, and cost-effective 3D imaging device to assist colonoscopy procedure, to improve the detection rate of polyps and adenomas. Therefore, the aim of this study was to investigate whether the 3D imaging device can increase the detection rate of polyps and adenomas than conventional 2D colonoscopy in real clinical practice. In addition, we also aimed to assess the efficacy of 3D device in detection of small and flat polyps as well as in endoscopists of different levels and experiences.

Three-dimensional imaging device

The 3D imaging device used in this trial was postmarketing (Type: 3DVS-S100A, Suzhou Scivita Medical Technology). Simply, the image processing device synthesizes the output image signal and converts it into a 3D signal displayed on the monitor, thereby achieving synchronous and real-time conversion of 2D endoscopic images into 3D images (Figure 1). The operator needs to wear 3D glasses to observe 3D images.

The detailed principle of monocular 3D imaging device was as follows (see Supplementary Figure S1, http://links.lww.com/AJG/C990). Based on the single-lens image, the perspective projection operation is used to generate the initial binocular image. After performing color gamut conversion, image concatenation, signal convolution, and network reconstruction, the resolution of binocular images would be enhanced. Subsequently, grayscale depth maps would be generated using the process of Sobel edge filtering, gradient detection, and depth extraction. Finally, based on the virtual reality theory, the 3D image would be reconstructed by combining the aforementioned grayscale depth map, vergence angle, and equivalent disparity.

Study design and participants

This was a multicenter, cross-over randomized controlled trial. The study protocol was approved by the Medical Ethics Committee of Beijing Friendship Hospital, Capital Medical University (approval number 2019-P2-143-01), and the institutional review boards at each participating center and was registered at Chinese Clinical Trial Registry (ChiCTR1900025000). Written informed consent was obtained from each participant before randomization. The study was conducted in accordance with protocol and principles of the Declaration of Helsinki. All authors had access to the study data and reviewed and approved the final manuscript.

Participants aged 18–70 years who underwent a diagnostic or screening colonoscopy were consecutively enrolled between August 2019 and May 2022. Participants with history of inflammatory bowel disease, CRC, colorectal resection, or Peutz-Jeghers syndrome and a contradiction for biopsy were excluded. Those participants with severe cardiopulmonary insufficiency, mental illness, or poor bowel preparation who could not cooperate with the colonoscopy procedure were also excluded.

Randomization and masking

All eligible participants were randomized in a 1:1 ratio to undergo either 2D-3D colonoscopy (first examined with 2D colonoscopy, followed by a second inspection with 3D colonoscopy) or 3D-2D colonoscopy (first examined with 3D colonoscopy, followed by a second inspection with 2D colonoscopy). We used computer-generated random numbers in block sizes of 6 using the Proc Plan procedure of the SAS software version 9.4. Participants' enrollment and group assignment were performed independently by the study team members of each center. Group assignments were con.(6.6(1Tf9730TD(

first experienced insertion with 2D and withdrawal with 3D (phase 1), then experienced insertion with 2D and withdrawal with 2D (phase 2). During each phase of both groups, the endoscopists were required to conduct cold forceps biopsy of the lesion with the assistance of nurses for histological analysis whenever a polyp was detected. The polyps' location, size, and morphological features according to the Paris classification were also recorded accordingly.

Baseline demographic and clinical characteristics were obtained from participants before colonoscopy, including age, sex, body mass index, family history of CRC and adenoma, comorbidity (diabetes, coronary heart disease), smoking and alcohol drinking status, medications (aspirin or other nonsteroidal anti-inflammatory drugs, folic acid, calcium, vitamin D), and indication for colonoscopy. Data collection regarding colonoscopy procedures for each participant included procedure time (insertion time, withdrawal time including or excluding biopsy time, total inspection time), BBPS, bubble score, and endoscope and endoscopist experience. Besides, any complication during the procedure was also recorded.

Outcomes

The primary outcomes were polyp detection rate (PDR) and ADR, defined as the proportion of individuals with at least 1 polyp or adenoma detected during colonoscopy. Secondary outcomes included miss rate of polyps or adenomas, defined as the number of polyps or adenomas detected in the second phase divided by total numbers of polyps or adenomas detected during the whole 2 phases.

Statistical analysis

To detect a 10% difference in PDR (20% vs 30%) or ADR (10% vs 20%) between the 2 groups with a 2-sided α of 0.05, at least 311 participants per study group (i.e., at least 622 participants in total) would be required to achieve a statistical power of 80%. Considering approximately 20% of potential exclusions or dropouts, a total of at least 778 participants would be required to enroll.

Modified intention-to-treat analysis was used to evaluate the primary outcome and secondary outcomes, which was defined as all participants randomized with completed colonoscopy procedure. Descriptive statistics were used to detail the baseline demographic and clinical characteristics. Mean with SD was used for continuous variables, and absolute number with percentage was used for categorical variables. For statistical inference between the 2 groups, a Student t test was conducted for continuous variables and a χ^2 or Fisher exact test was conducted for categorical variables. For PDR and ADR, odds ratio (OR) was calculated to measure the fold-change of detection rate between the 2 groups.

Furthermore, subgroup analysis was performed to investigate whether the difference of detection rate or miss rate between 2 groups varied by endoscopist experience (senior, midlevel, junior), polyp/adenoma size (0–5 mm, 5–10 mm, $\geq$10 mm), and morphological classifications (pedunculated, sessile, flat). Sensitivity analyses were conducted in participants who were with adequate bowel preparation and who aged 45 years or older.

A 2-tailed P value $<$ 0.05 was considered to be statistically signifi

total of 1,192 patients were enrolled and randomized, of whom 591 and 601 patients were assigned to the 2D-3D group and the 3D-2D group, respectively. After excluding patients with failed colonoscopy procedure or meeting other exclusion criteria, 571 patients in the 2D-3D group and 583 patients in the 3D-2D group were included in the intention-to-treat analysis (Figure 2). Baseline characteristics were similar between the 2 groups (mean age 52.3 years, male proportion 44.4%, Table 1). Of which, 529 (45.8%) underwent colonoscopy for screening. There was 93.1% of patients with adequate bowel preparation. Regarding the experience of the endoscopist, 647 (56.1%), 216 (18.7%), and 291(25.2%) patients underwent colonoscopy by junior, midlevel, and senior endoscopists, respectively. The first and second withdrawal times including biopsy were 7.26 and 6.82 minutes, respectively. A total of 1,047 biopsies were performed, with 537 and 510 biopsies in the 2D-3D group and the 3D-2D group, respectively. Overall, a total of 4 participants (0.3%) experienced bleeding during the procedure, while no other complications of the procedure were reported.

Polyp characteristics and detection/miss rate

Overall, 1,047 polyps were identified, with 544 (52.0%) adenomas, 2 (0.2%) sessile serrated adenomas/polyps, and 3 (0.3%) carcinomas. The polyps were generally small in size (mean size 5.0 [SD: 6.6] mm), with most (79.5%) less than 5.0 mm. Regarding morphological features, most polyps (69.0%) were flat, followed by sessile (26.9%). No statistically significant difference was detected between 2 groups regarding polyps' characteristics (Table 2, see Supplementary Table S1, http://links.lww.com/AJG/C990).

The PDRs between 2D and 3D groups during phase 1 were 39.6% and 40.5%, respectively (OR = 0.96, 95% confidence interval [CI]: 0.76–1.22, $P = 0.801$). Meanwhile, the PDR was significantly higher in the 3D group (27.7%) than that of the 2D group (19.9%) during phase 2, with a 1.54-fold increase (95% CI: 1.17–2.02, $P = 0.002$) in polyp detection (Table 3). Regarding the miss rate (Figure 3), a significant lower polyp miss rate was detected in the 3D group (28.8%) compared with that of the 2D group (39.1%).
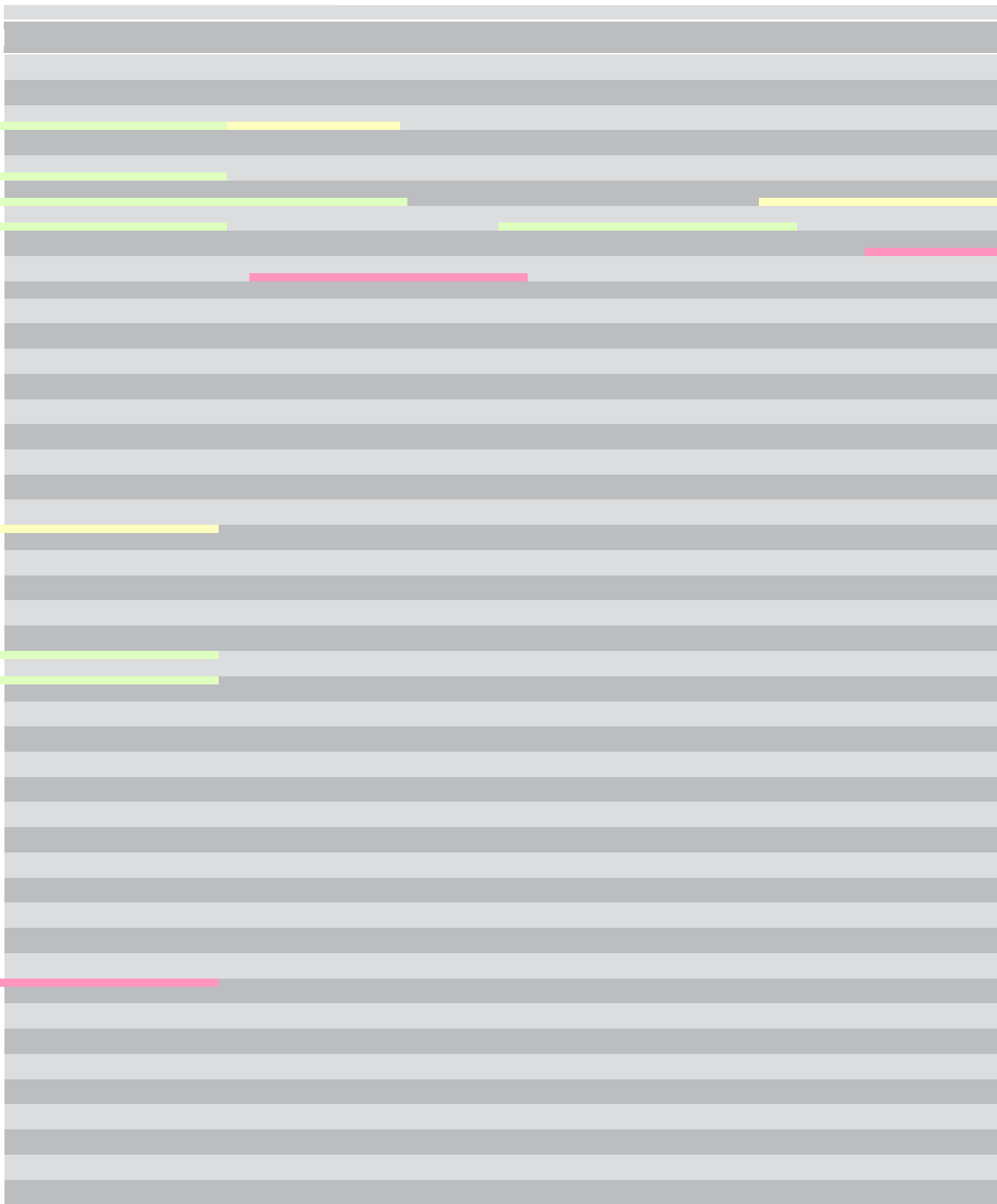
Table 2. Characteristics of polyps and adenomas

Characteristic	Overall	2D-3D group	3D-2D group	*P* value
. y	1,0		10	
y				0.
	(0.)	1 (0.)	(0.)	
/ y ( )	(0.)	0 (0.0)	(0.)	
	(.)	(.1)	(.)	
	(.)	(.0)	0 (.1)	
(y y)	(.1)	(.1)	0 (.1)	
	(0.)	(0.)	(0.)	
y				0.
	1 (.)	(.)	(.)	
	1 (1 .)	(1 .)	(1 .)	
	(.)	1 (.)	1 1 (.)	
	1 (1 .)	0 (1 .0)	(1 .)	
	(1.)	1 (.)	10 (1.0)	
	0 (1 .)	10 (1 .0)	10 (0.)	
y				0. 00
	(.)	1 (.)	1 (.1)	
	(.)	1 (.)	1 (.)	
⁓	(.0)	(1.)	(.1)	
	(0.)	(0.)	(0.)	
y ( )	.0 ± .	.0 ± .	. ± .	0.
y y				0.10
0–	(.)	(1.)	(.1)	
–10	1 (1 .1)	(1 .)	(1 .)	
>10	(.)	(.)	(.)	
				0. 1
	(.)	1 (.)	1 (.)	
	(1 .1)	(1 .)	(1 .)	
	1 (1.1)	0 (.1)	(.)	
	(1 .)	0 (1 .)	(1 .)	
	11 (1.)	(0.)	(.)	
	0 (.)	(.)	(.1)	
				0.1 1
	(.)	1 (.)	1 (.1)	
	0 (.)	(.)	11 (.)	
⁓	0 (.)	1 (0.0)	1 (1.1)	
	(0.)	(1.1)	1 (0.)	
( )	. ± .	. ± .	. ± .	0.
y				0.
0–	(.)	0 (.)	1 (0.1)	
–10	1 (.)	(1.1)	(.)	
>10	(.)	1 (.)	11 (.)	
(%) .				
y ± .				

Table 3. Polyp and adenoma detection

Detection rate Total (N = 1,154)	2D-3D group N = 571	3D-2D group N = 583	OR (95% CI)	P value
1	(.)	(0.)	0. (0. –1.)	0. 01
	1 (.)	11 (1 .)	1. (1.1 – .0)	0.00
1	1 1(.)	1 (.)	1.0 (0. 0–1.)	0.
	(1 .)	(.)	1. (1.01– .0)	0.0 1
Subgroup analysis by endoscopist experience				
Senior (N = 291)	N = 141	N = 150		
1	(.0)	0 (0.0)	1.1 (0. –1.)	0.
	(.)	(.)	1. 0 (0. – . 1)	0.
1	(1.)	(.0)	1. 1 (0. – . 1)	0.0
	1 (11.)	1 (11.)	1.00 (0. – .0)	0.
Midlevel (N = 216)	N = 108	N = 108		
1	(.)	(1.)	1.0 (0. 1–1.)	0. 0
	(0.)	0 (1 .)	1. (1.0 – .)	0.0 0
1	(.1)	(.1)	1.00 (0. –1.)	1.000
	1 (1 .0)	10 (.)	1. (0. – .1)	0. 0
Junior (N = 647)	N = 322	N = 325		
1	11 (.)	1 1(0.)	0. (0. –1.1)	0.
	(.)	(1 .1)	1. (1.0 – .)	0.0 1
1	(1.)	1 (.)	0. (0. 0–1.)	0.
	0 (1 .0)	1 (.)	1. (1.0 – . 0)	0.0 1

compared with conventional 2D colonoscopy, suggesting that 3D imaging may have better depth recognition capability than 2D imaging. However, whether these increase in small and diminutive lesions' detection could translate into a decrease risk of interval CRC, thereby achieving a better CRC prevention in the long term, is still unclear to date. Further long-term studies are warranted to address this issue, which is the main goal of screening colonoscopy.

Owing to the lack of experience, it can be challenging for junior endoscopists to screen and diagnose the small and flat lesions in colonoscopy, leading to missed polyp and adenoma detection. Previous studies indicated that senior endoscopists had a much higher detection rate than junior endoscopists (18). Our findings demonstrated a significant improvement of PDR and ADR in midlevel and junior endoscopists, rather than in senior endoscopists. Hence, the application of the 3D imaging device might be more helpful for the beginner endoscopists in clinical practice, which could increase the detection rate and quality of colonoscopy.

The major strength of this study is to highlight the efficacy of the 3D imaging device on detecting colorectal polyps/adenomas during colonoscopy for the first time, based on the well-designed randomized controlled trial. The cross-over and tandem design including 2 phases allowed the calculation of miss rate for polyps and adenomas in addition to the detection rate. The large sample size from multiple research centers allowed substantial subgroup analysis by endoscopist experience, polyp/adenoma size, and morphological classifications available with sufficient statistical power, further confirming the excellent performance of 3D imaging device on identifying small flat lesions. In addition, rigorous sensitivity analysis by accounting for bowel preparation status was conducted, verifying robustness of principal results.

Several limitations also need to be considered. First, it is impossible to conduct the double-blind randomized trial because of the 3D/2D colonoscopy procedure. Hence, the endoscopists could not be blinded during the colonoscopy procedure, which
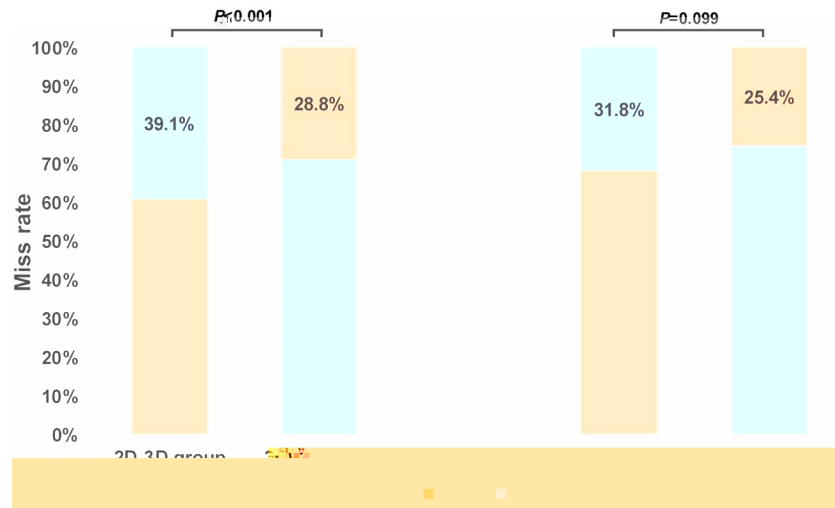
Figure 3.

may lead to the potential measurement error (i.e., favoring 3D view) in the detection of polyps or adenomas. However, the withdrawal time during the 2 phases, either including biopsy time or excluding biopsy time, was similar between the 2 groups (all *P* values > 0.05), suggesting the similar observation attentiveness of endoscopists from the 2 groups. Second, participants who underwent either diagnostic or screening colonoscopy were all included in our study with a relatively lower detection rate of polyps and adenomas compared with those in western countries (2,19,20). Moreover, our study was only conducted in tertiary hospitals instead of general endoscopy unit. Thus, it is unclear whether our results can be generalized to other western populations or other general endoscopy units. However, individuals aged 45 years or older in our trial achieved a higher detection rate of polyps and adenomas, suggesting the relative low detection rate may be due to the fact of enrolling some participants younger than 45 years (see Supplementary Table S2, http://links.lww.com/AJG/C990). Future randomized trials in different populations

within diverse levels of health care institutions are warranted to confirm our findings. Third, the average of no polyp withdrawal time in the first phase was relatively shorter than the time recommended by the guidelines. Thus, it may lead to missed polyps or adenomas and further lower detection rate because of inadequate time of inspection. Fourth, because this trial was conducted only using the Olympus colonoscopy equipment, it is yet unclear whether the 3D imaging device can achieve similar excellent performance on colonoscopy equipment manufactured by other companies. Fifth, a 4-arm design (i.e., 2D-2D, 2D-3D, 3D-3D, 3D-2D) would be better compared with our current 2-arm design (i.e., 2D-3D, 3D-2D), allowing to examine the impact of the tandem approach. Finally, as a cross-over design, all participants experienced twice withdrawal phase with one 3D imaging device and another conventional 2D device. Thus, our study could not mimic the colonoscopy procedure in real clinical setting. Further parallel, pragmatic controlled trials are needed to validate the efficacy of 3D imaging device in routine clinical practice.

Figure 4.

In summary, this randomized controlled trial showed that the 3D imaging device could improve overall PDR and ADR during colonoscopy, particularly in midlevel and junior endoscopists. Meanwhile, the 3D imaging device seemed helpful in detecting small and flat lesions during colonoscopy with lower miss rate. Considering the feasibility and excellent performance for polyps/adenomas' detection, the current 3D imaging device may potentially applicable in routine clinical practice for better detection of colorectal polyps or adenomas.

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