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Analysis of Texture and Color Enhancement Imaging for Improving the Visibility of Non-polypoid Colorectal Lesions

Naohisa Yoshida[1] · Ken Inoue[1] · Osamu Dohi[1] · Reo Kobayashi[1] · Yuri Tomita[1] · Hikaru Hashimoto[1] ·
Satoshi Sugino[1] · Ryohei Hirose[1] · Takaaki Murakami[2] · Yutaka Inada[3] · Yukiko Morinaga[4] · Yoshito Itoh[1]

Abstract

Introduction An endoscopic system using 5-color light-emitting diodes (LEDs) (EVIS X1; Olympus Co., Tokyo, Japan), which includes texture and color enhancement imaging (TXI), has been released. In this study, we analyzed the effects of TXI on the visibility of non-polypoid colorectal lesions and its diagnostic accuracy.

Methods We reviewed 101 non-polypoid lesions from 26 patients observed with white light imaging (WLI), narrow band imaging (NBI), and TXI. One representative image of each mode was evaluated by 6 endoscopists using a polyp visibility score of 4 (excellent) to 1 (poor). We calculated the color difference (CD) values for each lesion in the three modes. For tumor characteristics, one representative image of TXI and NBI magnification was evaluated by 3 experts according to a NBI classification.

Results The least squares means [95% confidence interval] of polyp visibility score of TXI (3.42 [3.06–3.77]) was significantly higher than that of WLI (2.85 [2.49–3.20], $p < 0.001$) but not that of NBI (3.33 [2.98–3.69], $p = 0.258$). The CD value of TXI (13.3 ± 6.3) was higher than that of WLI (9.7 ± 6.0, $p < 0.001$) but not that of NBI (13.1 ± 6.8, $p = 0.81$). For sessile serrated lesions, the CD value of TXI (11.1 ± 4.4) tended to be lower than that of NBI (12.6 ± 6.0, $p = 0.07$). The diagnostic accuracy and confidence level of magnification for NBI were significantly better than those for TXI (87.1 vs. 80.5%, $p = 0.027$, 87.5 vs. 62.7%, $p < 0.001$, respectively).

Conclusion TXI showed better visibility than WLI in terms of the endoscopist's score and CD value and may improve polyp detection.

Keywords Colonoscopy · Colonic polyps · Narrow band imaging · SSL · Adenoma

✉ Naohisa Yoshida
naohisa@koto.kpu-m.ac.jp

1 Department of Molecular Gastroenterology and Hepatology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajii-cho, Kawaramachi-Hirokoji, Kamigyo-ku, Kyoto 602-8566, Japan

2 Department of Gastroenterology, Aiseikai Yamashina Hospital, Kyoto, Japan

3 Department of Gastroenterology, Japanese Red Cross Kyoto Daiichi Hospital, Kyoto, Japan

4 Department of Surgical Pathology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan

Introduction

Resection of colorectal adenomatous polyps reduces colorectal cancer morbidity and mortality [1]. However, the polyp miss rate on white light imaging (WLI) is 22–28%, with non-polypoid lesions being one of the most important risk factors [2–4]. Narrow band imaging (NBI; Olympus Medical Co., Tokyo, Japan) was developed in 2006 to address this issue, but its ability to improve the rate of polyp detection was controversial [5–7]. A second-generation NBI developed in 2012 improved its brightness and resolution, and a recent meta-analysis showed that NBI had a higher adenoma detection rate than WLI, and the effect was greater when bowel preparation was good [8–10].

The EVIS X1 (CV-1500; Olympus Co.), an endoscopic system that uses light-emitting diodes (LEDs) of five colors as a light source, was released worldwide in July 2020. The

NBI images improved and had a new observational mode termed texture and color enhancement imaging (TXI) [11, 12]. TXI is designed to improve lesion visibility by enhancing three image factors (texture, brightness, and color), and there are two types of TXI (TXI1 and TXI2). Regarding the basis of the TXI algorithm, the image obtained from WLI is divided into a base image and a texture image. Then, texture and brightness are adjusted to these two images and they are combined to create TXI2. Then, color enhancement is performed to create the image of TXI1.

In the present study, we assessed the visibility of non-polypoid lesions using WLI, NBI, and TXI still images in the novel endoscopic system. We used two indicators for evaluation, namely, subjectively determined polyp visibility score by endoscopists and objectively determined color difference (CD) values. Additionally, we examined the diagnostic accuracy of magnified TXI, as compared to NBI.

Methods

This study was a retrospective single-center study. We examined 101 colorectal non-polypoid lesions observed with WLI, NBI, and TXI with a dedicated endoscope (CF-XZ1200: Olympus Co.) using the new endoscopic system (EVIS X1) from February 2021 to July 2021 (Fig. 1). Lesions detected by WLI, NBI, or TXI were analyzed. In this study, TXI1 was used because previous papers showed a better visibility in TXI1 than in TXI2 [11, 12]. A representative image showing a whole polyp in a distant view (approximately 3–5 cm from the lesion depending on lesion size, morphology, and location) for evaluating polyp visibility was recorded using the three modes of WLI, NBI, and TXI. These images were arranged randomly and were examined retrospectively by six endoscopists using a 21.5-inch-monitor desktop computer. Regarding lesion

Fig. 1 Study flow

101 colorectal non-polypoid lesions of ≤20mm observed with WLI, TXI, and NBI in 26 patients using a new endoscopic system, EVIS X1 February 2021-July 2021

↓

Evaluation of polyp visibility (N=101) using recorded images of WLI, TXI, and NBI
1. Polyp visibility score by 6 endoscopists
2. Color difference score by a software

↓

Evaluation of polyp characterization (N=101) using recorded magnified images with TXI an NBI by 3 experts

characteristics, one representative image of all polyps with both TXI and NBI magnification was recorded and was evaluated by three expert endoscopists. We analyzed consecutive patients over 3 months. However, examinations were held only on Thursday (once a week) due to the expert's (N.Y.) shift. All colonoscopies were performed by a representative expert (N.Y.) or two other experts (K.I., Y.T.) under the supervision of the expert (N.Y.). Two to three patients were enrolled weekly. All polyps were histopathologically examined using either endoscopic resection or biopsy. The image enhancement settings for WLI and NBI were A5 and A8, respectively.

The inclusion criteria were as follows: patients with cancer screening, positive fecal immunohistochemical examination, or surveillance after surgical/endoscopic resection of polyps and cancers who underwent colonoscopy by one of the three experts (N.Y., K.I., and Y.T.) to maintain the quality of the images. All lesions, including recurrent cases and T1 cancers detected in the enrolled patients, were analyzed. In hyperplastic polyps (HPs) in the sigmoid colon and rectum, up to three lesions were analyzed. Patients with T2-T4 colorectal cancers were excluded. Additionally, we excluded patients who underwent urgent colonoscopy with severe bloody stools or without bowel cleansing agents.

On the day before the endoscopy, patients consumed a low-residue diet and 10 mL sodium picosulfate. All patients also received 1.0 L of a highly concentrated polyethylene glycol solution with ascorbic acid (MoviPrep; Ajinomoto Pharma Co., LTD, Tokyo, Japan) on the morning of the day of the examination [13].

The primary outcome of this study was to compare the polyp visibility of TXI, NBI, and WLI using subjective polyp visibility scores by endoscopists and objective CD values. The secondary outcomes were the feasibility of TXI magnification for tumor characteristics in NBI classification compared to NBI magnification.

The mean scores and ratios of polyps with low visibility (score 1) for each mode (WLI, NBI, and TXI) were examined. The scores of the endoscopist level (non-expert vs. expert), location (right-sided vs. left-sided), size (≥ 10 mm vs. < 10 mm), and histopathology (sessile serrated lesion [SSL] + HP vs. low-grade dysplasia [LGD] + high-grade dysplasia [HGD] + T1) were analyzed.

Polyp visibility was evaluated using the polyp visibility score, as previously described, with 6 endoscopists giving a score of 1–4: 4 indicating excellent visibility (easy to detect), 3 indicating good visibility (if an endoscopist looked in the direction of the polyp on the monitor, it would be easy to detect), 2 indicating fair visibility (where it would be difficult to detect the polyp without careful observation), and 1 indicating poor visibility (Fig. 2) [8].

Six endoscopists who had not previously viewed any of the pictures in this study evaluated the WLI, NBI, and TXI
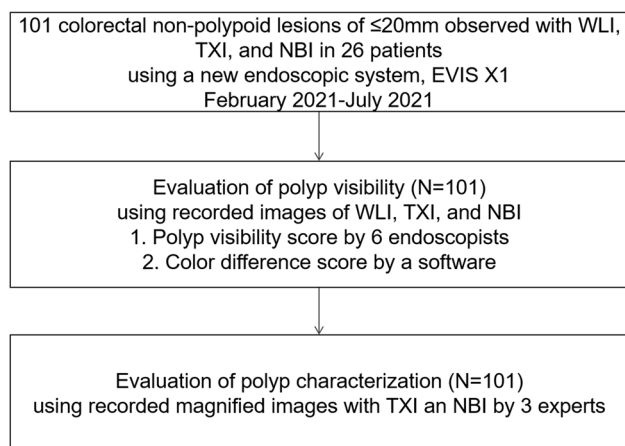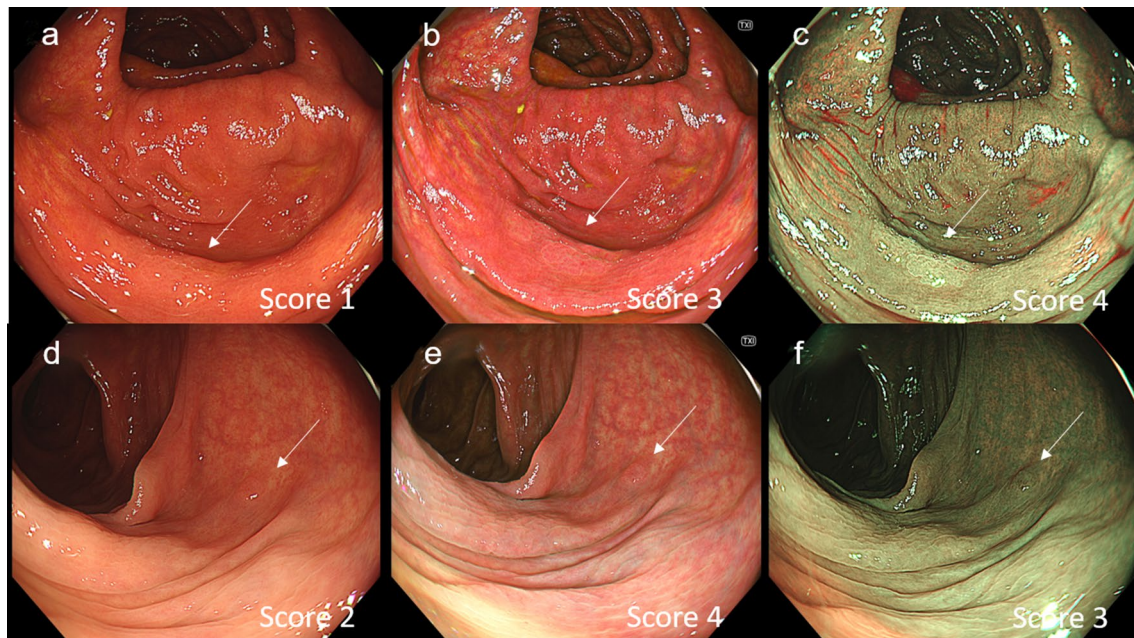
Fig. 2 Polyp visibility scores of SSL and low-grade dysplasia observed with WLI, TXI, and NBI. **a** WLI. Non-polypoid lesion, 10 mm, ascending colon (white arrow). SSL. Polyp visibility score 1. **b** TXI. Polyp visibility score 3 (white arrow). **c** NBI. Polyp visibility score 4 (white arrow). **d** WLI. Non-polypoid lesion, 3 mm, sigmoid colon (white arrow). Low-grade dysplasia. Polyp visibility score 2. **e** TXI. Polyp visibility score 4 (white arrow). **f** NBI. Polyp visibility score 3 (white arrow). TXI: texture and color enhancement imaging, NBI: narrow band imaging, WLI: white light imaging

images of each lesion and assigned a polyp visibility score to each polyp. Of the six endoscopists, three were classified as trainees (had performed < 500 colonoscopies), and they received a 1-h lecture about NBI and TXI images. The other three were classified as experts (had performed ≥ 5000 colonoscopies, ≥ 50 withdrawing colonoscopies using NBI, and ≥ 50 withdrawing colonoscopies using TXI).

The right-sided colon was defined as the region from the cecum to the transverse colon. The left-sided colon was defined as the region from the descending colon to the rectum. The size of a polyp was defined by its maximum diameter and was calculated in accordance with the size of the snares. Regarding morphology, all non-polypoid lesions were diagnosed according to the Paris classification [14]. For histopathological diagnosis, tumor specimens were obtained by either biopsy or endoscopic resection. Thereafter, they were fixed with 10% formalin and histopathologically evaluated. The histopathological diagnosis was performed by several clinical pathologists according to the World Health Organization classification [15]. Adenoma and intramucosal cancer in the Japanese criteria were defined as LGD and HGD, respectively.

We evaluated the CD of each polyp in WLI, NBI, and TXI images using the CIEL*a*b* color space and delta ELab formulas. The CD value (delta ELab) was used to evaluate whether the observer noted a difference in color, which could be detected clearly if the CD value exceeded 5 [16]. In this CD value analysis, an endoscopist first identified the margin of a polyp and its center. The CD value between each polyp and the surrounding mucosa in four directions (north, east, south, and west) was then calculated (Fig. 3). The maximum value was set as the corresponding value for the polyp according to our previous studies [12, 17]. We evaluated the difference between the CD values of all polyps in WLI, NBI, and TXI images. We also analyzed the relationship between the CD values and various polyp characteristics, including polyp location, size, and histopathology.

Polyps on NBI and TXI magnification images were also classified using the JNET classification by 3 experts (Fig. 4) [18]. There are 4 categories in the JNET classification, which are as follows: Type 1, Type 2A, Type 2B, and Type 3. We defined Type 2A as an indicator of LGD. Types 2B and 3 were defined as that of HGD + T1a and T1b, respectively. Type 1 was that of HP and SSL, and we differentiated SSLs from HP using the findings of dilated glands or dilated vessels, as previously described [19–21]. According to this definition, we calculated the diagnostic accuracy for NBI and TXI, and confidence levels were analyzed according to a previous study [22].

This study was conducted in accordance with the World Medical Association Declaration of Helsinki and was approved by the institutional review board and the ethics committees of Kyoto Prefectural University of Medicine (ERB-C-1600). This study was retrospective in nature, and

Fig. 3 The calculation of CD values of a non-polypoid lesion of WLI, TXI, and NBI. A polyp 10 mm in size, low-grade dysplasia. The CD value between each polyp and the surrounding mucosa in four directions (north, east, south, west) was then calculated. The maximum value (red values) for each mode was decided as the corresponding value for the polyp. TXI: texture and color enhancement imaging, NBI: narrow band imaging, WLI: white light imaging, CD: color difference
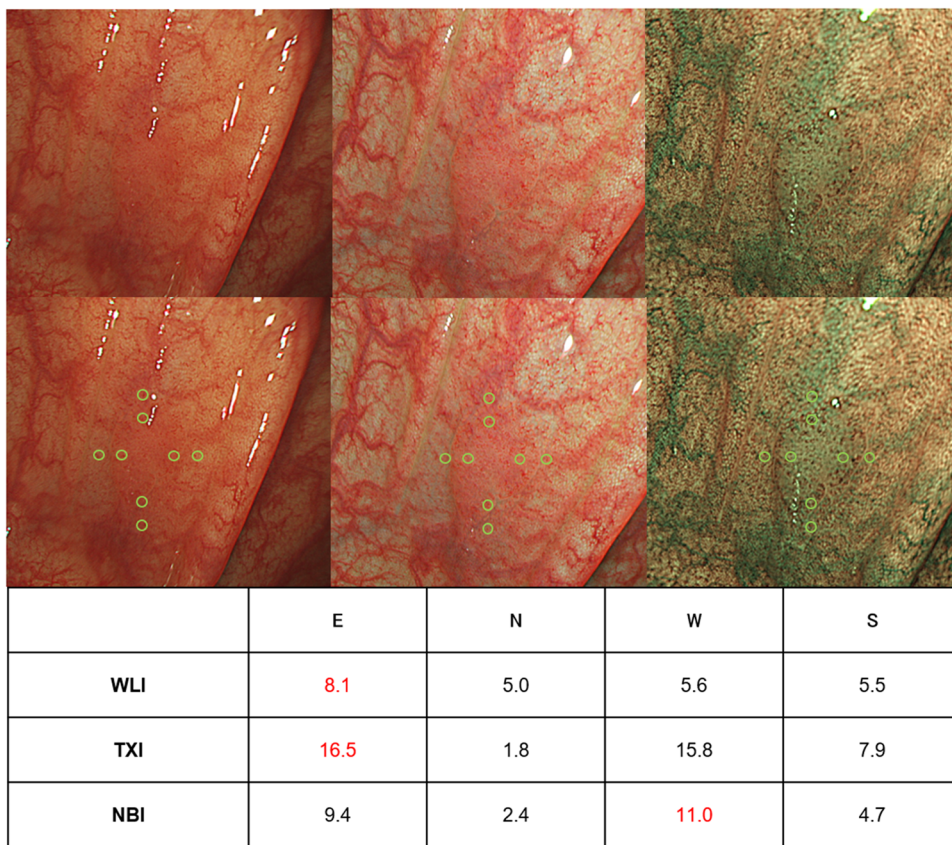

	E	N	W	S
WLI	8.1	5.0	5.6	5.5
TXI	16.5	1.8	15.8	7.9
NBI	9.4	2.4	11.0	4.7

Fig. 4 TXI and NBI magnification of SSL and low-grade dysplasia. **a** SSL in Fig. 3. Dilated crypts and vessels were detected with high confidence using TXI, consistent with findings of SSL. **b** Dilated crypts and vessels were detected with high confidence using NBI. **c** Low-grade dysplasia in Fig. 3. Regular vessel pattern was detected with TXI, consistent with JNET Type 2A. Surface pattern was unclear. The confidence level was low. **d** Regular vessel and surface patterns were detected with NBI, consistent with JNET Type 2A. The confidence level was high. TXI: texture and color enhancement imaging, NBI: narrow band imaging, WLI: white light imaging, SSL: sessile serrated lesion

the opt-out approach was used and performed in the hospital, using their web site or a notice at the posting area.

Statistical Assessments

In the pilot study that used TXI and WLI to assess the visibility of 30 colorectal polyps by a single expert endoscopist (N.Y.), the rate of superior scores of the TXI setting, compared to that of the WLI setting, was 30% (9/30). Moreover, the rates of similar and inferior scores were 70% (21/30) and 0% (0/30), respectively. According to this pilot analysis, we hypothesized that the superiority, similarity, and inferiority of the TXI setting to the WLI setting were 30%, 60%, and 10%, respectively. We used a sign test to calculate the sample size, and the α and β errors were decided as 5% and 20%, respectively. Thus, the sample size was calculated to be 77. The pilot study was evaluated only by a single expert, and a subgroup analysis was performed based on the location and polyp size. We therefore decided to use a sample size of 101. Since this study had a repeated measures design, in which observations by six endoscopists were nested into individual endoscopic images (polyps), a mixed model analysis was used with endoscopists and endoscopic images as variables. A linear mixed model was employed to evaluate the polyp visibility score, and the independent variables were mode of endoscopic evaluation (WLI, NBI, and TXI), endoscopist level (non-expert or expert), location (right-sided or left-sided), size (≥ 10 mm or < 10 mm), and histopathology, and their interaction terms. The final comparison between the modes was made by estimating the least squares mean (95% confidence interval [CI]) and testing for contrast. Additionally, the Mann–Whitney U test, Wilcoxon's signed-rank test with Bonferroni correction, and the Chi-square test were used in this study (SPSS version 22.0, IBM Japan, Ltd., Tokyo, Japan). Statistical significance was set at p < 0.05.

Results

A total of 101 non-polypoid lesions (mean polyp size: 6.1 ± 5.4 mm) in 26 patients were investigated in this study (Table 1). Fifty-seven lesions (56.4%) were right-sided. Histopathologically, there were 30 HPs, 13 SSLs, 51 LGDs, 6 HGDs, and 1 T1 tumor. Among 13 SSLs, there were no SSLs with dysplasia.

Regarding the analysis of polyp visibility scores using linear mixed models, the least squares (LS) mean for TXI images (3.42, 95%CI: 3.06–3.77) among 6 endoscopists was significantly higher than that for WLI images (2.85, 95%CI: 2.49–3.20, $p < 0.001$), but not significantly different than that for NBI images (2.98, 95%CI: 2.98–3.69, $p = 0.258$) (Table 2). Additionally, the LS mean for NBI images was significantly higher than that of WLI images. For both

Table 1 Clinical characteristics of 101 non-polypoid colorectal lesions

Number of lesions	101
Patient number	26
Sex (male/female)	19:7
Median age, mean $\pm$ SD (range)	$66.5 \pm 10.3(41–81)$
Mean polyp size (mm) (range)	$6.1 \pm 5.4(2–20)$
≥ 10 mm: < 10 mm, %, n	16.8:83.2 (17:84)
Location, %, n (right-sided/left-sided)	56.4:43.6 (57:44)
Histopathological diagnosis, %, n (HP/SSL/LGD/HGD/T1)	29.7: 12.9: 50.5: 5.9: 1.0 (30:13:51:6:1)

SD Standard deviation, right-sided: from cecum to transverse colon, left-sided: from descending colon to rectum, *HP* Hyperplastic polyp, *SSL* Sessile serrated lesions, *LGD*: low-grade dysplasia, *HGD* High-grade dysplasia

trainees and experts, the scores for TXI images were significantly higher than those for WLI images. Regardless of the lesion location, size, and histopathology, the score of TXI images was significantly higher than those of the WLI images. There were no significant differences between TXI and NBI in the endoscopist's level, lesion location, size, and histopathology though the score of TXI was marginally higher than that of NBI in right-sided lesions.

Regarding the rate of score 1 (poor visibility) in WLI, TXI, and NBI, the rate for the overall TXI images was significantly lower than that for the overall WLI images (3.0% vs. 12.7%, $p < 0.001$), but not significantly different than that for the overall NBI images (3.8%, $p = 0.426$) (Table 3).

The mean CD value of the TXI images (13.3 ± 6.3) was higher than that of the WLI images (9.7 ± 6.0, $p < 0.001$), but it was not significantly different than that of the NBI images (13.1 ± 6.8, $p = 0.81$) (Table 4). For SSL + HP lesions, the CD value of the TXI images was significantly higher than that of the WLI images (11.1 ± 4.4 vs. 7.0 ± 2.8, $p < 0.001$), but it tended to be lower than that of the NBI images (12.6 ± 6.0, $p = 0.07$). Conversely, for LGD + HGD + T1 lesions, the mean CD value of the TXI images was significantly higher than that of the WLI images (14.9 ± 7.1 vs. 11.8 ± 7.0, $p < 0.001$) and tended to be higher than that of the NBI images (13.5 ± 7.4, $p = 0.09$). In a representative lesion of LGD, the CD values of WLI, TXI, and NBI images for it were 8.1, 16.5, and 11.0, respectively (Fig. 3).

Regarding lesion characteristics, the diagnostic accuracy of TXI magnification was significantly inferior to that of NBI magnification (80.5% vs. 87.1%, $p = 0.027$) (Table 5, Fig. 4). The rate of high confidence level of TXI was also inferior to that of NBI (62.7% vs. 87.5%, $p < 0.001$). However, the

Table 2 Polyp visibility scores of WLI, TXI, and NBI evaluated by 6 endoscopists including 3 experts and 3 trainees using the analysis of linear mixed models

	WLI		TXI		NBI		P value	
	LS mean	95% CI	LS mean	95% CI	LS mean	95% CI	WLI vs. TXI	TXI vs. NBI
Overall	2.85	2.49, 3.20	3.42	3.06, 3.77	3.33	2.98, 3.69	<0.001	0.258
Trainees	2.84	2.38,3.31	3.38	2.91, 3.85	3.29	2.82, 3.76	<0.001	0.445
Expert	2.85	2.45, 3.24	3.45	3.06, 3.85	3.37	2.98, 3.77	<0.001	0.388
Right-sided	2.73	2.30,3.16	3.33	2.89, 3.76	3.15	2.71, 3.58	<0.001	0.068
Left-sided	3.00	2.52, 3.48	3.54	3.06, 4.01	3.58	3.10, 4.06	<0.001	0.689
≧10 mm	3.11	2.53, 3.69	3.62	3.04, 4.20	3.49	2.91, 4.07	<0.001	0.336
<10 mm	2.65	2.29, 3.01	3.26	2.90,3.62	3.22	2.86, 3.57	<0.001	0.548
SSL+HP	2.78	2.32, 3.24	3.38	2.92, 3.85	3.29	2.83, 3.75	<0.001	0.398
LGD+HGD+T1	2.93	2.51, 3.36	3.46	3.03, 3.88	3.38	2.96, 3.81	<0.001	0.440

LS Mean: least squares means, 95%CI: 95% confidence interval,*WLI* White light imaging, *TXI*: Texture and color enhancement imaging, *NBI* Narrow band imaging, right-sided: from cecum to transverse colon, left-sided: from descending colon to rectum, *SSL*: sessile serrated lesions, *HP* Hyperplastic polyp, *LGD* Low-grade dysplasia, *HGD*: High-grade dysplasia

Table 3 The rate of score 1 (poor visibility) in polyp visibility scores of WLI, TXI, and NBI evaluated by 6 endoscopists

Rate of score 1	WLI	TXI	NBI	P value	
				WLI versuss TXI	TXI versus NBI
Overall, n (%)	12.7 (77/606)	3.0 (18/606)	3.8 (23/606)	<0.001	0.426
Trainees, n (%)	14.9 (45/303)	4.6 (14/303)	6.3 (19/303)	<0.001	0.370
Expert, n (%)	10.6 (32/303)	1.3 (4/303)	1.3 (4/303)	<0.001	1.0
Right-sided, n (%)	14.0 (48/342)	2.0 (7/342)	4.1 (14/342)	<0.001	0.120
Left-sided, n (%)	11.0 (29/264)	4.2 (11/264)	3.4 (9/264)	0.003	0.648
≥10 mm, n (%)	5.9 (6/102)	2.9 (3/102)	2.9 (3/102)	0.306	1.0
<10 mm, n (%)	14.1 (71/504)	3.0 (15/504)	4.0 (20/504)	<0.001	0.389
SSL+HP, n (%)	10.5 (27/258)	2.7 (7/258)	2.7 (7/258)	<0.001	1.0
LGD+HGD+T1, n (%)	14.4 (50/348)	3.2 (11/348)	4.6 (16/348)	<0.001	0.326

WLI White light imaging, *TXI* Texture and color enhancement imaging, *NBI* Narrow band imaging, right-sided: from cecum to transverse colon, left-sided: from descending colon to rectum, *SSL* Sessile serrated lesions, *HP* Hyperplastic polyp, *LGD* Low-grade dysplasia, *HGD* High-grade dysplasia

Table 4 The CD value according to histopathological lesion characteristics

	WLI CD value	TXI CD value	NBI CD value	P value WLI versus TXI	P value TXI vs. NBI	P value WLI versus NBI
All (101)	9.7±6.0	13.3±6.3	13.1±6.8	<0.001	0.81	<0.001
SSL+HP (43)	7.0±2.8	11.1±4.4	12.6±6.0	<0.001	0.07	<0.001
LGD+HGD+T1 (58)	11.8±7.0	14.9±7.1	13.5±7.4	<0.001	0.09	<0.001

CD: Color difference, *WLI*: White light imaging, *TXI*: Texture and color enhancement imaging, *NBI*: Narrow band imaging, *SSL*: Sessile serrated lesions, *HP*: Hyperplastic polyp, *LGD*: Low-grade dysplasia, *HGD*: High-grade dysplasia

diagnostic accuracy of TXI for HP+SSL was 93.0%, which was not inferior to that of NBI (93.0%, $p=1.0$). The confidence level of TXI for HP+SSL was 78.3%, which was not inferior to that of NBI (84.5%, $p=0.200$).

Discussion

The main aim of this study was to assess the visibility of non-polypoid lesions using WLI, NBI, and TXI. On subjective evaluation, the mean polyp visibility score of TXI

Table 5 The diagnostic accuracy and confidence level with NBI and TXI magnification by 3 experts

Diagnostic accuracy confidence level	TXI	NBI	*P* value
Overall, % (n)	80.5 (244/303)	87.1 (264/303)	0.027
High confidence, % (n)	62.7 (190/303)	87.5 (265/303)	< 0.001
≥ 10 mm, % (n)	76.5 (39/51)	84.3 (41/51)	0.630
High confidence, % (n)	88.2 (45/51)	94.1 (48/51)	0.294
< 10 mm, % (n)	81.3 (205/252)	88.5 (223/252)	0.025
High confidence, % (n)	57.5 (145/252)	86.1 (217/252)	< 0.001
HP + SSL, % (n)	93.0 (120/129)	93.0 (120/129)	1.0
High confidence, % (n)	78.3 (101/129)	84.5 (109/129)	0.200
LGD + HGD + T1, % (n)	71.3 (124/174)	82.8 (144/174)	0.010
High confidence, % (n)	51.1 (89/174)	89.7 (156/174)	< 0.001

TXI: Texture and color enhancement imaging, *NBI*: Narrow band imaging, *HP*: Hyperplastic polyp, *SSL*: Sessile serrated lesions, *LGD*: Low-grade dysplasia, *HGD*: High-grade dysplasia

images was significantly higher than that of WLI images. Further, the objective CD value of TXI images was also higher than that of WLI images. However, there was no significant difference in either the polyp visibility score or the CD value between the TXI and NBI images. Additionally, we examined the diagnostic capability of lesion characteristics between TXI and NBI, and NBI showed a better diagnostic accuracy than TXI. To our knowledge, this is the first report comparing polyp visibility between TXI and NBI using the new five-color LED endoscopic system, EVIS X1.

Our previous study examining WLI and NBI using the second-generation NBI EVIS LUCERA Elite and a dedicated colonoscope (CF-HQ290I) showed that NBI improved polyp visibility compared to WLI (3.14 ± 0.87 vs. 2.75 ± 0.98, $p < 0.001$) in 80 lesions (mean lesion size: 5.9 mm), regardless of lesion characteristics such as location, size, histopathology, morphology, and endoscopist skill [8]. Among 25 non-polypoid lesions, there was a significant difference in polyp visibility score between NBI and WLI images (3.14 ± 0.87 vs. 2.75 ± 0.98, $p < 0.001$). However, only 11.2% of patients had HP + SSL, although we still observed a significant difference in the mean polyp visibility score between NBI and WLI images in this subgroup (2.79 ± 0.84 vs. 2.16 ± 1.04, $p < 0.001$). These NBI scores were inferior to the LS mean of NBI and TXI for non-polypoid lesions in the current study (overall: 3.33 and 3.42, HP + SSL: 3.29 and 3.38), although the method of the analysis was different from that of the previous study. This suggests that this new NBI may improve polyp visibility more than the second-generation NBI. This is possible due to the bright high-resolution images of NBI with EVIS X1. However, our sample size was small and further large-scale studies should be conducted.

The polyp visibility score is a subjective indicator. In our previous study, we identified a relationship between the polyp visibility score and the CD values as an objective indicator of WLI and linked color images [22]. We also used both indicators in the current study. The TXI images had a significantly better overall polyp visibility score than the WLI images, although they were not significantly better than those of NBI images. The analysis of the CD values also showed similar results. For LGD + HGD + T1 lesions, the TXI polyp visibility scores were significantly better than the WLI. Further, the CD values of the TXI images were also significantly better than those of the WLI images and tended to be better than the NBI images. For SSL + HP lesions, the TXI polyp visibility scores and CD values were significantly better than those of the WLI and tended to be worse the NBI in CD values. Regarding lesion location, TXI was marginally better for right-sided lesions than NBI in this study. We speculated that this might be due to two reasons. One was the brighter view of TXI compared to that of NBI. The other was that NBI made residual liquid reddish and endoscopic views dark, although TXI made it yellowish and kept them bright. Our data suggest that TXI or NBI should be used for polyp detection instead of WLI. However, a previous study on second-generation NBI showed that NBI might increase the detection of serrated lesions more in the proximal colon than WLI, but the result in this trial did not reach significance [23]. Thus, future studies should examine whether TXI or improved NBI have better polyp detection than WLI using the EVIS X1.

For detecting and diagnosing polyps efficiently, various technologies and equipment including image-enhanced endoscopy and artificial intelligence have been developed recently and analyzed well [24–27]. We analyzed a new endoscopic system (EVIS X1) for tumor detection and characterization. In this system, there are two types of dedicated colonoscopes. One is a colonoscope with a dual focus function (CF-EZ1500DI) using the simultaneous method. The endoscope is equipped with TXI, improved NBI, extended depth of field (EDOF), and red dichromatic imaging [28, 29]. The other is a manually magnified endoscope (CF-XZ1200I) that incorporates these technologies, except EDOF, and this endoscope can magnify the lesions 135 times and uses the frame sequential method. Both endoscopes have a viewing angle of 170°. In this study, we used only the CF-XZ1200 so that further studies are needed to confirm the efficacy of CF-EZ1500.

Regarding lesion characteristics, the diagnostic accuracy and confidence level of TXI magnification were inferior to those of NBI magnification. The inferiority was possibly due to the lower contrast of TXI than that of NBI for some lesions (Fig. 4). However, 80.5% of all polyps were accurately diagnosed with TXI. Thus, we suggest that lesion

characterization with TXI is acceptable for some lesions, compared to NBI, when a lesion is detected with TXI.

There were several limitations in the present study. This was a single-center study with a small sample size, and polyps detected by only three endoscopists using a dedicated endoscope for the EVIS X1 were analyzed. Further, the cases were collected only once per week because of the expert's work schedule. Therefore, there may have been a selection bias. Regarding lesion size, 83.2% of lesions were < 10 mm and all lesions were < 20 mm. Thus, the efficacy of TXI and NBI for large lesions of ≥ 20 mm should be examined, especially for diagnostic accuracy. The observation mode of still images was not blinded for evaluators. We used not movies but still images for examining polyp visibility. Moreover, our ultimate goal is to improve polyp detection, but improved polyp visibility of TXI may not necessarily lead to improved polyp detection in the clinical setting, as polyp detection is influenced by a number of factors in addition to polyp visibility.

In conclusion, our single-center pilot study showed that TXI improved the colorectal non-polypoid lesion polyp visibility score and CD value compared to WLI. Further prospective large-scale studies should be performed for the improvement of polyp detection with TXI.

Declarations

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