The role of narrow band imaging in colorectal polyp detection

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ABSTRACT

Colonoscopic detection and removal of polyps represent the most important prevention method for colorectal cancer. We aimed to investigate the diagnostic yield of narrow band imaging (NBI) colonoscopy for polyp detection compared with standard colonoscopy. In this prospective study, 505 patients that underwent total colonoscopy were randomized into two groups: 226 patients in NBI group and 279 in non-NBI group (standard colonoscopy). The primary endpoints were polyp detection rate (PDR) and adenoma detection rate (ADR) in both groups. Polyps detected with NBI technique were characterized according to the NBI International Colorectal Endoscopic (NICE) classification. The total number of polyps detected in NBI group was significantly higher compared with non-NBI group (325 polyps in 226 patients versus 189 polyps in 279 patients, respectively). PDR in NBI group was 55.3%, versus 43.3% in non-NBI group. ADR in NBI group was significantly higher compared with non-NBI group (35.3% versus 20%, respectively). The proportion of detected adenomas in the left-sided colon was significantly higher in NBI group (72.8% versus 61.06% in non-NBI group), which was related to an increased number of small adenomas detected in NBI group. Also, in NBI group, a significant number of flat adenomas were detected (28 versus 9 in non-NBI group). A total of 147 (45.2%) polyps were classified according to the NICE classification, and showed a good correlation with histological analysis. In conclusion, this study demonstrated increased PDR and ADR for NBI colonoscopy. A good correlation between the NICE classification and histological analysis was also observed.

KEY WORDS: Colonoscopy; narrow band imaging; polyp detection rate; adenoma detection rate; colorectal cancer
DOI: http://dx.doi.org/10.17305/bjbms.2017.1686 *Bosn J Basic Med Sci. 2017;17(2):152-158. © 2017 ABMSFBIH*

INTRODUCTION

Colonoscopic detection and removal of polyps represent the most important prevention method for colorectal cancer (CRC) [1], with a decrease of 76-90% in CRC incidence, in large cohorts of patients who had adenomas removed [2]. However, because 17-24% of polyps are missed during colonoscopy [3], new endoscopic techniques have been developed to increase the detection rate of adenomas. These techniques include: high-definition endoscopy, conventional or virtual chromoendoscopy (i.e., narrow band imaging [NBI], i-Scan digital contrast [i-SCAN], and flexible spectral imaging color enhancement [FICE] technologies), and autofluorescence imaging [4]. Due to the ability to differentiate between neoplastic and other types of polyps (i.e. non-neoplastic polyps), these methods allow a better characterization of polyps and thus affect decision-making about polyps removal during colonoscopy. Even in the case when only adenomas are removed, a decrease in the complication rates after polypectomies is observed, the procedure time is reduced, and the cost of histological analysis is lowered [5-7].

Chromoendoscopy has a sensitivity of 91% and a specificity of 89% in differentiating neoplastic lesions from non-neoplastic polyps according to the Kudo's classification [8]. NBI, also called "electronic" or digital chromoendoscopy, uses optical filters to enhance the visualization of vascular details and mucosal surface morphology [9,10]. The sensitivity and specificity of NBI are similar to those of chromoendoscopy [11].

The working principle of NBI relies on the properties of the hemoglobin as the major tissue chromophore. The peak absorption of oxyhemoglobin is at 415 nm (blue light). A secondary peak of absorption is at 540 nm (green light). NBI technique uses a special filter placed in the light source that allows only narrow band of blue and green light to pass through. The vasculature of the mucosa appears bluish green; as a result the

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Submitted: 25 September 2016/Accepted: 17 November 2016

surface vascular pattern as well as the morphology of the tissue are enhanced [12]. Adenomas are easily recognized using NBI technique due to the presence of enhanced microvascular density [13]. Although several studies investigated the utility of NBI in detection, characterization, and differentiation of colon lesions [8-11], only few of these studies focused on the usefulness of NBI in daily practice.

The aim of this paper was to determine the diagnostic yield of NBI colonoscopy for polyp detection and characterization in comparison with standard colonoscopy. The primary endpoints were polyp detection rate (PDR) and adenoma detection rate (ADR) in patients who underwent NBI or standard colonoscopy.

MATERIALS AND METHODS

Patient selection

A prospective, randomized study was carried out during October 2013 and July 2014, at an ambulatory center of digestive endoscopy in Cluj-Napoca, Romania. Patients who underwent total colonoscopy were included in the study. The working protocol was approved by the Ethical Committee of University of Medicine and Pharmacy Cluj-Napoca (374/2014) and informed consent was obtained from patients before every procedure.

The methodology in our study was similar to those described in a previous study [14]. Patients were randomized prior to sedation. Patients were asked to pick an envelope after the informed consent was obtained. The envelopes were numbered inside from 1 to 600. Patients who selected odd numbers were included in the group examined by standard colonoscopy (non-NBI group), and those with even numbers were included in the group examined by NBI colonoscopy (NBI group).

Inclusion and exclusion criteria

The inclusion criteria were: patients scheduled for colonoscopy due to lower gastrointestinal symptoms, screening for CRC in patients with a first-degree relative with CRC, and surveillance of patients with previous polyps or CRC.

The exclusion criteria included: incomplete colonoscopies, inadequate bowel preparation, familial adenomatous polyposis, CRC, inflammatory bowel disease, detection of CRC during examination, and coagulopathy.

After the exclusion criteria were applied, out of 580 patients, 505 were included in the study. Among the 505 patients, 226 were examined by NBI technique and 279 by standard colonoscopy.

Bowel preparation

For bowel preparation, a split-dose of polyethylene glycol solution was used in most patients. Endoscopists assessed the quality of bowel preparation as good (almost 100% of colonic mucosa visualized), satisfactory (more than 90% of colonic mucosa visualized), and precarious (less than 90% of colonic mucosa examined). Patients with inadequate bowel preparation were excluded from the study.

Colonoscopy

Three gastroenterologists performed the colonoscopies (mean cecal intubation rate: 99.2%) using video colonoscopes Olympus CL 160 (8 examinations) and Olympus CL 180, and Olympus Exera II and III endoscopy systems for NBI. The documentation of complete colonoscopies included photographs of the ileocecal valve, appendix, and terminal ileum.

Most colonoscopies (90.5%) were performed under superficial analgosedation using midazolam; in 8.4% of patients a deep analgosedation was used, and 1.1% of patients did not require sedation.

The withdrawal time was minimum 8 minutes in all patients. A detailed examination of every polyp was performed, and photographic documentation was obtained. In NBI group, the withdrawal examination was performed using only NBI filters. Polyps were considered to be on the right side of the colon if they were detected from the cecum to the splenic flexure, and to be on the left side of the colon if they were localized from the left colic flexure to the anus.

For each patient the following data were recorded: age, sex, referral reasons, number, size and location of polyps and histological analysis.

Polyp characterization

Polyps detected with NBI technique were characterized according to the NICE classification, which was recently validated by a panel of international experts [15]. Based on the NICE guidelines, polyps are classified according to the lesion color, microvascular architecture, and pit pattern classification of mucosa (the opening of crypts of Lieberkühn on the mucosal surface). Using this classification, three types of polyps were recorded: Type 1 - hyperplastic (Figure 1); Type 2 - adenomatous (Figure 2); and Type 3 - malignant (Figure 3).

All detected polyps were removed during colonoscopy. The dimension of a polyp was determined with biopsy forceps. Ninety-three percent of removed polyps were recovered and a histological analysis was performed to determine the type of a polyp, presence and degree of dysplasia, and whether the polyp was completely removed. Dysplasia was classified according to the Vienna classification into low-grade dysplasia (LGD) and high-grade dysplasia (HGD) [16]. Intramucosal carcinoma and *in-situ* carcinoma were included into HGD. Invasive carcinoma was considered if the malignant cells spread to the submucosa.

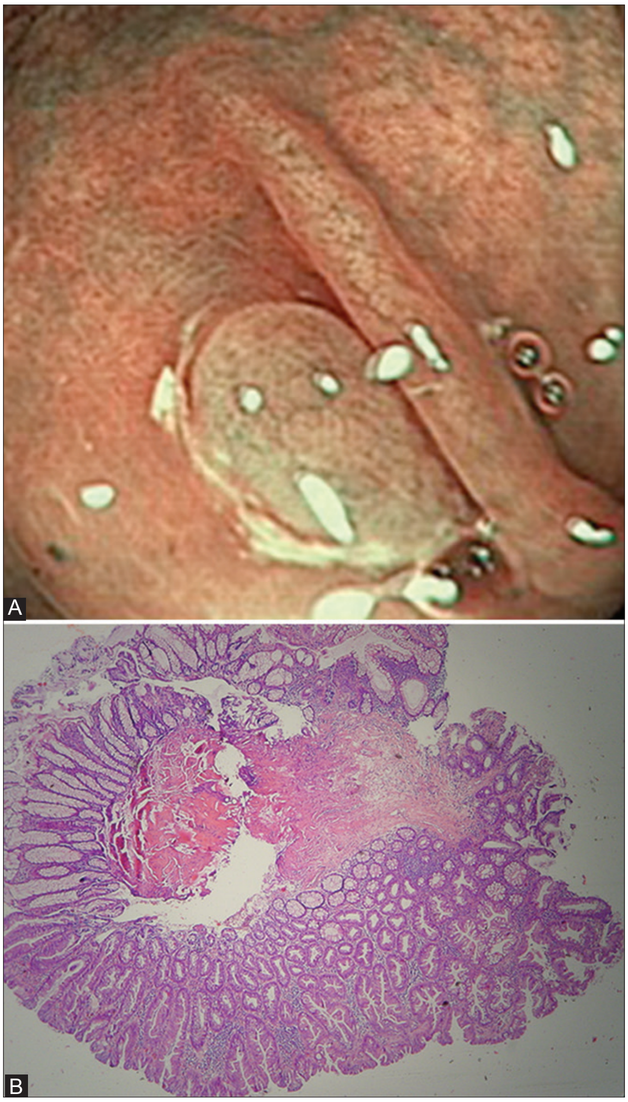

FIGURE 1. NBI colonoscopy. (A) Polyp type 1 according to the NICE classification; a hyperplastic lesion with circular pattern with small dots on the surface. (B) Histopathological appearance of the hyperplastic polyp. NBI: Narrow band imaging; NICE: NBI International Colorectal Endoscopic.

FIGURE 2. NBI colonoscopy. (A) Polyp type 2 according to the NICE classification; adenoma, presence of tubular structures on the surface, a lighter area in the center surrounded by brown vessels. (B) Histopathological appearance of the adenomatous polyp. NBI: Narrow band imaging; NICE: NBI International Colorectal Endoscopic.

Statistical analysis

IBM SPSS Statistics for Windows, Version 20.0. (IBM Corp., Armonk, NY) was used for statistical analysis. Parametric data were expressed as means ± standard deviations. The comparison between groups was done using the Mann–Whitney U test. Non-parametric data were expressed as frequencies and compared using the Fisher's exact or Chi-squared tests. Characteristics of groups such as polyp location and morphology were analyzed using the Student's t, Mann–Whitney U, and Fisher's exact test. The results were considered statistically significant if p value was less than 0.05. The correlation between NBI results and histological analysis was determined using the Pearson correlation coefficient (r = 0.8-1 was considered as a very high correlation, r = 0.6-0.8 as a high correlation, r = 0.4-0.6 as a reasonable correlation, and r > 0.4 as a low correlation). The diagnostic precision was calculated using the final histological report.

RESULTS

A total of 505 patients, who underwent complete colonoscopy, were included in the study. The patients were randomized into two groups: NBI group included 226 patients, and non-NBI group (patients who underwent standard colonoscopy) included 279 patients. The median age was 53.3 years in NBI group and 52.7 years in non-NBI group. No significant differences were observed between the groups with regard to the age, sex, quality of bowel preparation (Table 1), and referral reasons, except rectal bleeding (Table 2).

In 125 patients from NBI group and in 121 patients from non-NBI group at least one polyp was observed. In 80 patients

TABLE 1. General characteristics of patients in NBI and non-NBI groups

Characteristics	NBI group	Non-NBI group	*p* value
Number of patients	226	279	
Age (median)	53.3	52.7	0.55
Sex (%)			
Female	51	52	0.87
Male	49	48	
Bowel preparation (%)			
Good	68.5	66.8	0.59
Satisfactory	38.5	33.2	

NBI: narrow band imaging

TABLE 2. Referral reasons in NBI (n=226) and non-NBI (n=279) groups

Symptoms	n (%)		Total number	*p*
	NBI group	Non-NBI group		
Intestinal transit disorders	51 (22.56)	59 (21.14)	110	0.19
Rectal bleeding	45 (19.91)	72 (25.81)	117	0.006
Abdominal pain	107 (47.34)	122 (43.73)	229	0.13
Bloating	4 (1.76)	11 (3.94)	15	0.2
CRC screening	11 (4.86)	6 (2.15)	17	0.27
CRC surveillance	8 (3.53)	8 (2.87)	16	0.25
Anemia	0 (0)	1 (0.36)	1	0.24

NBI: narrow band imaging; CRC: colorectal cancer

TABLE 3. Number and location of detected polyps in NBI (n=325) and non-NBI (n=189) groups

Polyp distribution	n (%)		Total	*p*
	NBI group	Non-NBI group		
Right colon (cecum and ascending colon)	91 (28)	31 (16.4)	122	0.03
Transverse colon	39 (12)	27 (14.3)	66	0.21
Left colon (descending and sigmoid colon)	139 (42.7)	86 (45.5)	225	0.06
Rectum	56 (17.23)	45 (23.4)	101	0.22

NBI: narrow band imaging

from NBI group and in 56 patients from non-NBI group at least one adenoma was detected. In NBI group, the PDR was 55.3% and ADR was 35.39 %. In non-NBI group, the PDR was 43.3% and ADR was 20.07%. The total number of polyps detected in the two groups and their locations are presented in Table 3.

Histological analysis of polyps in NBI group

In NBI group, a total of 325 polyps were detected: 215 adenomas (66.15%), 106 hyperplastic polyps (32.62%), and 4 carcinomas (1.23%). The majority of adenomas were tubular (n = 190; 88.37%). Serrated adenomas were detected in 19 patients (8.8%). Left-sided adenomas were more prevalent than right-sided (11% versus 8%, respectively). Right-sided adenomas represented one-third of all detected adenomas (n = 73; 33.95%). The largest polyps were detected in the sigmoid colon (9.69 ± 0.77 mm) and the smallest polyps were observed in the transverse colon (7 ± 0.59 mm).

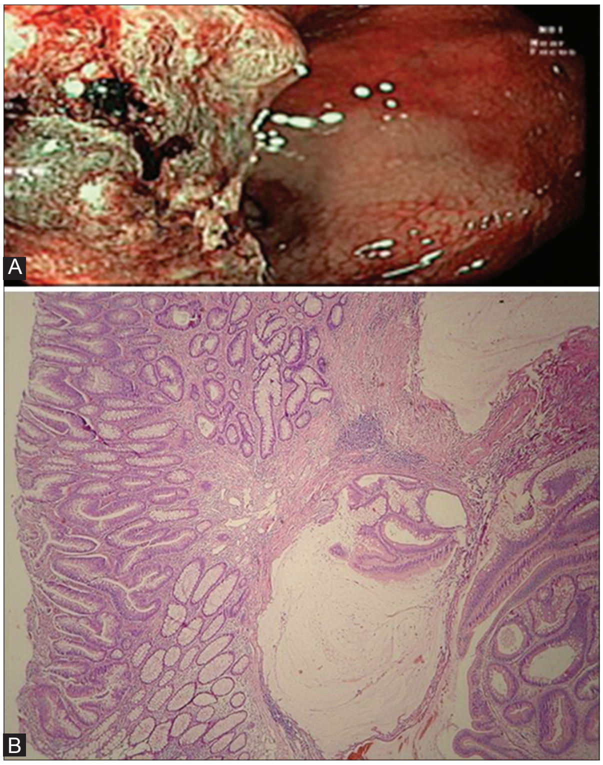

FIGURE 3. NBI colonoscopy. (A) Polyp type 3 according to the NICE; malignant tumor with no surface pattern, and with erosions. (B) Histological appearance of the malignant polyp (mucinous adenocarcinoma). NBI: Narrow band imaging; NICE: NBI International Colorectal Endoscopic.

Histological analysis of polyps in non-NBI group

In non-NBI group, a total of 189 polyps were detected: 118 adenomas (62.43%), 70 hyperplastic polyps (37.03%), and 1 carcinoma (0.5%). The majority of adenomas were tubular (n = 98; 83.05%). Serrated adenomas were detected in 11 patients (9.32%). Left-sided adenomas were more prevalent than right-sided (7% versus 4%, respectively). Right-sided adenomas represented one-third of all detected adenomas (n = 38; 32.2%). The majority of hyperplastic polyps were left-sided (71.42% [50/70]). The largest polyps were detected in the sigmoid colon (14.7 ± 2.48 mm) and the smallest polyps were observed in the rectum (5.84 ± 0.86 mm).

Comparative analysis between NBI and non-NBI groups

The total number of detected polyps in NBI group was significantly higher compared with non-NBI group (325 polyps in 226 patients versus 189 polyps in 279 patients, respectively; $p < 0.001$). The PDR in NBI group was 55.3%, versus 43.3% in non-NBI group. In addition, a statistically significant difference was observed in the ADR between NBI and non-NBI group (35.39 % versus 20.07%, respectively; $p = 0.01$).

The proportion of detected adenomas in the left-sided colon was significantly higher in NBI group compared with non-NBI group (72.8% versus 61.06%, respectively; $p < 0.01$). The increased number of left-sided adenomas in NBI group was related to the increased number of small adenomas (less than 5 mm) detected in this group.

The mean dimensions of detected polyps in the right-sided colon were significantly smaller in NBI group compared with non-NBI group (7.79 mm versus 10.06 mm, respectively; $p < 0.01$). This result was related to an increased number of hyperplastic polyps (less than 5 mm) detected in the right-sided colon in NBI group ($p = 0.01$). In the left-sided colon, the mean dimensions of detected polyps were similar between the two groups (8.57 mm in NBI group versus 8.61 mm in non-NBI group).

In NBI group, a significantly higher number of flat adenomas was detected (28 versus 9 in non-NBI group, $p = 0.02$).

HGD was detected in 19.53% of adenomas in NBI group and in 9.32% of adenomas in non-NBI group ($p < 0.001$). Among HGD, 19% were small polyps (less than 5 mm) in NBI group, and 9.09% in non-NBI group.

Out of 246 patients who underwent polypectomy, 2 (0.8%) presented bleeding, which was stopped after clip placement. All patients were evaluated three weeks after the procedure, by phone. No late side effects of colonoscopy or polypectomy were reported.

Diagnostic accuracy of NBI technique

Out of the total number of polyps detected using NBI technique, 147 (45.2%) were characterized according to the NICE classification. A strong correlation between the endoscopic appearance of polyps (according to the NICE classification) and histological analysis was observed (r = 0.8981). The majority of adenomas and all carcinomas were correctly characterized according to the NICE. However, one polyp was classified as type 2 according to the NICE, but described as carcinoma in the histological report. From 95 type 1 polyps (hyperplastic), 12 (12.62%) were serrated adenoma. The sensitivity and specificity of NBI technique combined with the NICE classification in predicting the results of histological analysis were 90.9% and 95.2%, respectively. The accuracy of NBI without magnification combined with the NICE classification in polyp characterization was 91.1%.

DISCUSSION

Because conflicting results have been reported regarding the role of NBI technique in polyp detection [12,14,17,18], this study focused on investigating the diagnostic yield of NBI technique for polyp detection and characterization in daily practice.

A number of studies evaluated the role of NBI colonoscopy in determining PDR and especially ADR, due to more detailed characterization of tissue and vascular pattern that is possible using NBI filters. ADR represents a direct measure of quality in colonoscopy, since the main goal in CRC screening and surveillance programs is more accurate detection of adenomas.

In pilot studies on the efficacy of NBI colonoscopy in polyp detection, a higher number of neoplastic polyps were detected with NBI compared with the standard procedure [12,14]. In the study conducted by Uraoka et al. [14], flat and right-sided adenomas were detected using NBI.

However, other studies showed contrasting results. In the study by Rex et al. [17], conducted in a medium-risk population for CRC in the USA, the same ADR was reported for NBI and standard colonoscopy procedure. In a study by Adler et al. [18], that involved 1256 patients split into two groups, an increased ADR was not observed in the group examined by high-definition NBI colonoscopy compared with the group examined by other high-definition colonoscopy procedures [18].

Two recent meta-analysis, one that included 2936 patients from 7 randomized studies [19], and the other that analyzed 3056 patients from 9 studies [20], did not find a significant difference between ADR, flat adenoma detection rate, or rate of missed adenomas between NBI and standard colonoscopy procedure in a medium-risk population for CRC.

In our study, both the PDR and ADR were significantly increased in NBI group. Interestingly, a higher number of adenomas were detected in the left-sided colon in our study, compared with previous studies that reported a higher ADR in the right-sided colon using NBI. Similar results as ours were obtained in a study by Inoue et al. [21]. The higher number of adenomas might be due to the presence of bile in the right colon, that is visualized in red color with NBI filters, and also due to a larger lumen that reduces the brightness of the NBI image.

The high proportion of patients with colon polyps (55% in NBI group and 43% in non-NBI group) observed in our study might be due to several reasons, including: experience of endoscopist, exclusion of patients with poor bowel preparation, and withdrawal time of more than 8 minutes. The high PDR, observed in our study, was not biased by the inclusion of patients with a high risk of CRC, since the percentage of patients with first-degree relatives with CRC and patients with previous adenomas or CRC, was less than 10%. The higher PDR observed in our NBI group, compared with non-NBI group, is related to the higher number of small polyps (less than 5 mm), which has also been demonstrated in previous reports. In addition, a higher number of flat adenomas and HGD were detected in our NBI group, compared with non-NBI group, similarly as reported in other studies [14].

Although an increased detection rate of hyperplastic polyps was reported with NBI techniques [22], in our study this rate was only higher in the right-sided colon.

Many studies also focused on diagnostic accuracy of different techniques for colon polyp detection, such as standard colonoscopy, chromoendoscopy, and NBI. The accuracy to differentiate between neoplastic and non-neoplastic lesions is higher for standard or virtual chromoendoscopy [23], and there is no significant difference between these two techniques [8,24]. In the study conducted by Zhou at al. [25], a prediction rate for NBI in polyp detection was 93% in relation to histological analysis [25]. When NBI technique was used without magnification, the prediction rate was 80-86% [25]. In our study, the accuracy of NBI technique without magnification in polyp detection was 91.1% in relation to the results of histological analysis.

Although high accuracy rates in polyp detection were observed for NBI procedure, this technique depends on the experience of the endoscopist. Lower performance rates were reported for endoscopists who are not very familiar with NBI procedure; they showed 76-78% accuracy in the detection of polyps smaller than 1 cm [26,27]. In our study the endoscopists are experts in their field, which might explain the observed high accuracy rate for NBI. The majority of misdiagnosed hyperplastic polyps in our study, analyzed using NBI, were serrated adenomas.

In current clinical practice, all detected colon polyps are removed and histological analysis is performed. The majority of detected polyps are smaller than 5 mm without significant histological findings [28]. An adequate differentiation between neoplastic and non-neoplastic lesions is necessary during colonoscopy, for a proper management of small polyps (less than 5 mm). The American Society for Gastrointestinal Endoscopy proposed a system called Preservation and incorporation of valuable endoscopic innovations (PIVI) which includes two strategies: "resect and discard" and "do not resect". This system is based on photo documentation of detected polyps [29] and has an accuracy of 91% [30]. Nevertheless, this strategy for small polyps also depends on the experience of an endoscopist, where the accuracy of procedure in detecting small polyps is 83%, when performed by less experienced endoscopists [31].

CONCLUSION

We found increased PDR and ADR for NBI colonoscopy without magnification. A higher number of diminutive polyps were detected in the left-sided colon; also a higher number of flat adenomas and HGD were observed using NBI technique. In addition, we documented a high accuracy rate (91%) for NBI colonoscopy without magnification, with a sensitivity of 90.9% and specificity of 95.2%.

ACKNOWLEDGMENTS

This paper was published under the frame of Partnership in Priority Areas ProgrammePNII, developed with the support of MEN-UEFISCDI (Project No.154 [PN-II-PT-PCCA- 2013-4-0743]).

DECLARATION OF INTERESTS

The authors declare no conflict of interests.

REFERENCES

[1] Winawer SJ, Zauber AG. Colonoscopic polypectomy and the incidence of colorectal cancer. Gut 2001;48(6):753-4. https://doi.org/10.1136/gut.48.6.753.

[2] Winawer SJ, Zauber AG, Ho MN, O'Brien MJ, Gottlieb LS, Sternberg SS, et al. Prevention of colorectal cancer by colonoscopic polypectomy. The National Polyp Study Workgroup. N Engl J Med 1993;329(27):1977-81. https://doi.org/10.1056/NEJM199312303292701.

[3] Rex DK, Cutler CS, Lemmel GT, Rahmani EY, Clark DW, Helper DJ, et al. Colonoscopic miss rate of adenomas determined by back-to-back colonoscopies. Gastroenterology 1997;112(1):24-8. https://doi.org/10.1016/S0016-5085(97)70214-2.

[4] Rex DK. Maximizing detection of adenomas and cancers during colonoscopy. Am J Gastroenterol 2006;101(12):2866-77. https://doi.org/10.1111/j.1572-0241.2006.00905.x.

[5] Heresbach D, Barrioz T, Lapalus MG, Coumaros D, Bauret P, Potier P, et al. Miss rate for colorectal neoplastic polyps: A prospective multicenter study of back-to-back video colonoscopies. Endoscopy 2008;40(4):284-90. https://doi.org/10.1055/s-2007-995618.

[6] Consolo P, Luigiano C, Strangio G, Scaffidi MG, Giacobbe G, Di Giuseppe G, et al. Efficacy, risk factors and complications of endoscopic polypectomy: Ten year experience at a single center. World J Gastroenterol 2008;14(15):2364-9. https://doi.org/10.3748/wjg.14.2364.

[7] Sano Y, Saito Y, Fu KI, Matsuda T, Uraoka T, Kobayashi N, et al. Efficacy of magnifying chromoendoscopy for the differential diagnosis of colorectal lesions. Digestive Endoscopy 2005;17(2):105-16. https://doi.org/10.1111/j.1443-1661.2005.00483.x.

[8] Su MY, Hsu CM, Ho YP, Chen PC, Lin CJ, Chiu CT. Comparative study of conventional colonoscopy, chromoendoscopy, and narrow-band imaging systems in differential diagnosis of neoplastic and nonneoplastic colonic polyps. Am J Gastroenterol 2006;101(12):2711-6. https://doi.org/10.1111/j.1572-0241.2006.00932.x.

[9] Ng SC, Lau JY. Narrow-band imaging in the colon: Limitations and potentials. J Gastroenterol Hepatol 2011;26(11):1589-96. https://doi.org/10.1111/j.1440-1746.2011.06877.x.

[10] Gono K, Obi T, Yamaguchi M, Ohyama N, Machida H, Sano Y, et al. Appearance of enhanced tissue features in narrow-band endoscopic imaging. J Biomed Opt 2004;9(3):568-77. https://doi.org/10.1117/1.1695563.

[11] Tischendorf JJ, Wasmuth HE, Koch A, Hecker H, Trautwei C, Winograd R. Value of magnifying chromoendoscopy and narrow band imaging (NBI) in classifying colorectal polyps: A prospective controlled study. Endoscopy 2007;39(12):1092-6. https://doi.org/10.1055/s-2007-966781.

[12] Rastogi A, Bansal A, Wani S, Callahan P, McGregor DH, Cherian R, et al. Narrow-band imaging colonoscopy - a pilot feasibility study for the detection of polyps and correlation of surface patterns with

polyp histologic diagnosis. Gastrointest Endosc 2008;67(2):280-6. https://doi.org/10.1016/j.gie.2007.07.036.

[13] Konerding MA, Fait E, Gaumann A. 3D microvascular architecture of pre-cancerous lesions and invasive carcinomas of the colon. Br J Cancer 2001;84(10):1354-62. https://doi.org/10.1054/bjoc.2001.1809.

[14] Uraoka T, Saito Y, Matsuda T, Sano Y, Ikehara H, Mashimo Y, et al. Detectability of colorectal neoplastic lesions using a narrow-band imaging system: A pilot study. J Gastroenterol Hepatol 2008;23(12):1810-5. https://doi.org/10.1111/j.1440-1746.2008.05635.x.

[15] Hewett DG, Kaltenbach T, Sano Y, Tanaka S, Saunders BP, Ponchon T, et al. Validation of a simple classification system for endoscopic diagnosis of small colorectal polyps using narrow-band imaging. Gastroenterology 2012;143(3):599-607. https://doi.org/10.1053/j.gastro.2012.05.006.

[16] Schlemper RJ, Riddell RH, Kato Y, Borchard F, Cooper HS, Dawsey SM, et al. The Vienna classification of gastrointestinal epithelial neoplasia. Gut 2000;47(2):251-5. https://doi.org/10.1136/gut.47.2.251.

[17] Rex DC, Helbig CC. High yields of small and flat adenomas with high-definition colonoscopes using either white light or narrow band imaging. Gastroenterology 2007;133(1):42-7. https://doi.org/10.1053/j.gastro.2007.04.029.

[18] Adler A, Aschenbeck J, Yenerim T, Mayr M, Aminalai A, Drossel R, et al. Narrow-band versus white-light high definition television endoscopic imaging for screening colonoscopy: A prospective randomized trial. Gastroenterology 2009;136(2):410-6. https://doi.org/10.1053/j.gastro.2008.10.022.

[19] Dinesen L, Chua TJ, Kaffes AJ. Meta-analysis of narrow-band imaging versus conventional colonoscopy for adenoma detection. Gastrointest Endosc 2012;75(3):604-11. https://doi.org/10.1016/j.gie.2011.10.017.

[20] Pasha SF, Leighton JA, Das A, Harrison ME, Gurudu SR, Ramirez FC, et al. Comparison of the yield and miss rate of narrow band imaging and white light endoscopy in patients undergoing screening or surveillance colonoscopy: A meta-analysis. Am J Gastroenterol 2012;107(3):363-70. https://doi.org/10.1038/ajg.2011.436.

[21] Inoue T, Murano M, Murano N, Kuramoto T, Kawakami K, Abe Y, et al. Comparative study of conventional colonoscopy and pan-colonic narrow-band imaging system in the detection of neoplastic colonic polyps: A randomized, controlled trial. J Gastroenterol 2008;43(1):45-50. https://doi.org/10.1007/s00535-007-2125-x.

[22] East JE, Suzuki N, Saunders BP. Comparison of magnified pit pattern interpretation with narrow band imaging versus chromoendoscopy for diminutive colonic polyps: A pilot study. Gastrointest Endosc 2007;66(2):310-6. https://doi.org/10.1016/j.gie.2007.02.026.

[23] Rastogi A, Pondugula K, Bansal A, Wani S, Keighley J, Sugar J, et al. Recognition of surface mucosal and vascular patterns of colon polyps by using narrow-band imaging: Interobserver and intraobserver agreement and prediction of polyps histology. Gastrointest Endosc 2009;69(3 Pt 2):716-22. https://doi.org/10.1016/j.gie.2008.09.058.

[24] Chiu HM, Chang CY, Chen CC, Lee YC, Wu MS, Lin JT, et al. A prospective comparative study of narrow-band imaging, chromoendoscopy, and conventional colonoscopy in the diagnosis of colorectal neoplasia. Gut 2007;56(3):373-9. https://doi.org/10.1136/gut.2006.099614.

[25] Zhou QJ, Yang JM, Fei BY, Xu QS, Wu WQ, Ruan HJ. Narrow-band imaging endoscopy with and without magnification in diagnosis of colorectal neoplasia. World J Gastroenterol 2011;17(5):666-70. https://doi.org/10.3748/wjg.v17.i5.666.

[26] East JE, Suzuki N, Stavrinidis M, Guenther T, Thomas HJ, Saunders BP. Narrow band imaging for colonic surveillance in hereditary non-polyposis colorectal cancer. Gut 2008;57(1):65-70. https://doi.org/10.1136/gut.2007.128926.

[27] Kuiper T, Marsman WA, Jansen JM, van Soest EJ, Haan YC, Bakker GJ, et al. Accuracy for optical diagnosis of small colorectal polyps in nonacademic settings. Clin Gastroenterol Hepatol 2012;10(9):1016-20. https://doi.org/10.1016/j.cgh.2012.05.004.

[28] Rex DK, Overhiser AJ, Chen SC, Cummings OW, Ulbright TM. Estimation of impact of American College of Radiology recommendations on CT colonography reporting for resection of high-risk adenoma findings. Am J Gastroenterol 2009;104(1):149-53. https://doi.org/10.1038/ajg.2008.35.

[29] Rex DK, Kahi C, O'Brien M, Levin TR, Pohl H, Rastogi A, et al. The American Society for Gastrointestinal Endoscopy PIVI (Prevention an Incorporation of Valuable Endoscopic Innovations) on real-time endoscopic assessment of the histology of diminutive colorectal polyps. Gastrointest Endosc 2011;73(3):419-22. https://doi.org/10.1016/j.gie.2011.01.023.

[30] Hewett DG, Huffman ME, Rex DK. Leaving distal colorectal hyperplastic polyps in place can be achieved with high accuracy by using narrow-band imaging: An observational study. Gastrointest Endosc 2012;76(2):374-80. https://doi.org/10.1016/j.gie.2012.04.446.

[31] Paggi S, Rondonotti E, Amato A, Terruzzi V, Imperiali G, Mandelli G, et al. Resect and discard strategy in clinical practice: A prospective cohort study. Endoscopy 2012;44(10):899-904. https://doi.org/10.1055/s-0032-1309891.