INTRODUCTION

Narrow band imaging (NBI) endoscopy is a newly developed technique that uses 2 optical filters to pass only the short (blue/green) wavelengths enhancing the visualization of microvessels and their fine structures on the mucosal surface, based on the fact that the depth of light infiltration depends on its wavelength. The contrast on the vessel areas could be increased by artificially narrowing the wavelength area using filters because the sharpness may be improved by eliminating the wavelength areas with dispersed lights. NBI uses 415 nm and 540 nm of wavelength; the former enhances microvessels in the mucosal surface layer with brown image, whereas the latter enhances the submucosal layer or microvessels in the submucosal layer with green image, both enabling detailed observation of mucosal structure and capillary pattern.

Background/Aims: Narrow band imaging (NBI) is a new technique that uses optical filters for imaging of mucosal morphology. The aim of this study was to correlate findings of NBI with magnifying colonoscopy and histology for prediction of neoplastic colorectal lesion.

Methods: Between September 2005 and December 2007, 107 colon polyps from 68 patients were detected by conventional colonoscopy and subsequently evaluated by NBI with magnifying colonoscopy and analyzed for a pit pattern and a capillary pattern. More analysis was done regarding thickness and irregularity of capillary features.

Results: Pit pattern with NBI magnification to discriminate between neoplastic and non-neoplastic lesions had a sensitivity of 88.9% and a specificity of 87.5%; capillary pattern yielded test performance characteristics of 91.9% and 87.5%. In respect of capillary thickness, invisible capillaries were found significantly more often in hyperplastic lesions. All thick capillaries were found in neoplastic polyps, and found significantly more often in carcinomas with submucosal massive invasion (sm-m) (p<0.01). In respect of capillary irregularity, invisible capillaries were found significantly more often in hyperplastic lesions, and severely irregular capillaries were found significantly more often in sm-m lesions (p<0.01).

Conclusions: Observation of capillary thickness and irregularity by NBI magnification is useful for correlating histological grade with carcinoma, especially with depth of submucosal invasion.

Key Words: Narrow band imaging; Magnifying colonoscopy; Histology; Colorectal tumor
MATERIALS AND METHODS

Patients and colonoscopic observations

This study was performed in 107 colorectal lesions of 68 patients who received endoscopic resection of colorectal tumors at Soonchunhyang University Hospital in Bucheon, South Korea, between September 2005 and December 2007. These lesions were first detected by conventional view, and then observed by NBI system. Every lesion was detected using white-light colonoscopy (CF-Q240ZI, CF-H260AZI; Olympus, Tokyo, Japan), and EVIS LUCERA system (Olympus Optical, Tokyo, Japan) was used for videoendoscopy system. Endoscopic specialists with more than 5 years of experience in the field of colonoscopy performed the endoscopic observations in this study. After detailed observation by NBI magnification, all lesions were resected endoscopically. Specimens were pinned to a board and fixed in 10% buffered formalin for 24 hours. Then these specimens were cut into 2 to 3-mm blocks and performed on hematoxylin and eosin-stained sections. Pathologic examination was performed based on the World Health Organization criteria by a single pathologist unaware of the features of each case. Following histologic diagnosis, a total of 107 lesions were categorized into 8 groups based on their histologic grade and depth of submucosal invasion: hyperplastic polyp, inflammatory polyp, low grade tubular adenoma, high grade tubular adenoma, tubulovillous adenoma, villous adenoma, carcinoma with intramucosalc-scant submucosal invasion (m-sm1), and carcinoma with submucosal massive invasion (sm-m). Submucosal massive invasion was defined as the invasion of more than 1,000 µm for this study.

Capillary patterns and features according to NBI magnification (Table 1)

Pit patterns and capillary patterns were categorized using NBI magnification system (Fig. 1), the former following the Kudo’s classification and the latter Sano’s classification. Pit pattern types III, IV, and V based on Kudo’s classification and capillary pattern types II and III based on Sano’s classification were determined as neoplastic lesions. NBI magnification enables the observation of capillary patterns on the surface layer of tumors. Each lesion was further categorized according to thickness and irregularity of their capillary by close observation with NBI magnification. Capillaries were divided into invisible, thin, or thick capillary based on their thickness. Based on NBI findings, lesions without microvessel or of extreme opacity were determined as invisible capillary; lesions with thin pits and even blood vessel diameters throughout the lesion were determined as thin capillary; and mixture of blood vessels small but larger than 'thin' capillaries are determined as thick capillary. Capillaries were also divided into invisible, regular, or irregular type based on their irregularity. Invisible capillary type was determined by absence of or extremely opaque capillary; regular capillary type by smooth capillary running with apparent regular meshwork of capillaries across the pits and lesion; and irregular capillary type by irregular running of capillaries with apparent irregular meshwork of capillaries across the pits and lesion (Fig. 2). Lesions with thin and thick, or regular and irregular capillaries were determined as neoplastic. These capillary types by NBI and histologic findings were correlated afterwards.

SPSS for windows version 13.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis with χ² test for data analysis. p-values of less than 0.05 were determined statistically significant.

RESULTS

Patients characteristics

A total of 68 patients (49 male, 19 female) were enrolled in the study, and their mean age was 59 years old (range, 42 to 84) (Table 2). White-light colonoscopy and NBI with magnifying colonoscopy were performed in every patient, with successful intubation of cecum. Bowel preparation was well conducted in every test, and lesions in every patient were

| Capillary pattern | I | II | III |
|---|---|---|---|
|Absent meshed brown capillary vessel|Present meshed brown capillary vessel, slightly thicker and loose capillary density|Present meshed brown capillary vessel, thicker, branching, irregularity capillary and dense capillary density|

| Capillary thickness | Thin | Thick |
|---|---|---|
|Thin and even thickness|Uneven thickness|

| Capillary irregularity | Regular | Irregular |
|---|---|---|
|Capillaries running smoothly between pits and an apparent regular meshwork of capillaries throughout|Capillaries running irregularly between pits and an apparent irregular meshwork of capillaries throughout|

Table 1. Capillary Patterns and Capillary Features Identified by NBI Magnification

NBI, narrow band imaging.
Lesions and colonoscopic observations

A total of 107 colon tumors detected by white-light colonoscopy were distributed as follows: ascending colon 18 cases, transverse colon 26 cases, descending colon 14 cases, sigmoid colon 26 cases, and rectum 23 cases. The types of resected tumors were sessile polyp 32 cases (29.9%), subpedunculated polyp 35 cases (32.7%), flat-elevated polyp 18 cases (16.8%), laterally spreading tumor 13 cases (12.1%), and pedunculated polyp 9 cases (8.4%). The mean tumor size was 11.25 mm ranging from 2 mm to 40 mm (Table 2).

Histologic findings of lesions

Histologic findings of total 107 lesions were non-neoplastic in 8 cases, which were further divided again as 7 cases of hyperplastic polyp and 1 case of inflammatory polyp; the remaining 99 cases were neoplastic, which were divided again as low grade tubular adenoma in 55 cases, high grade tubular adenoma in 16 cases, tubulovillous adenoma in 10 cases, villous adenoma in 2 cases, carcinoma with intramucosal to scant submucosal invasion in 10 cases, and carcinoma with submucosal massive invasion in 6 cases (Table 2).
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NBI magnification and histological finding

Differential diagnosis of neoplastic lesions by Kudo’s pit patterns classification on NBI with magnifying colonoscopy showed sensitivity and specificity of 88.9% and 87.5%, respectively; the positive predictive value and negative predictive value were 98.9% and 38.9%, respectively. The capillary patterns by Sano’s classification also showed high sensitivity and specificity of 91.9% and 87.5%, respectively; the positive predictive value and negative predictive value were estimated as 98.9% and 46.7%, respectively. The classification by capillary thickness showed sensitivity and specificity of 99.0% and 62.5%, respectively; the positive predictive value and negative predictive value were estimated as 97.0% and 83.3%. The classification by capillary irregularity revealed sensitivity and specificity of 100% and 62.5%, respectively; the positive predictive value and negative predictive value were estimated as 97.1% and 100% (Table 3).

Table 4 shows the relationship between capillary pattern as determined by NBI magnification and histologic findings. Hyperplastic polyp was most common among cases of capillary pattern type I (6/15), while carcinoma accounted 50% of capillary pattern type III cases (12/24) including submucosal massive invasion of 6 cases, suggesting the increasing trend of carcinoma and submucosal massive invasion toward the capillary pattern type III ($p<0.01$).

Table 5 shows relationship between capillary thickness as determined by NBI magnification and histologic findings. Invisible capillary was more common among hyperplastic polyp (5/6), while thin capillary was more common among low grade tubular adenoma (35/58). All cases with thick capillary were diagnosed as neoplastic lesions (43/43); 13 cases of them were carcinoma (13/43). Six cases with submucosal massive invasion were all determined as thick capillary ($p<0.01$).

![Fig. 3. Classification of microvascular features as determined by narrow band imaging. (A) Microvessels were classified regular when lesions had microvessels running smoothly between pits and an apparent regular meshwork of microvessels throughout. (B) Microvessels were classified irregular when lesions had microvessels running irregularly between pits and an apparent irregular meshwork of microvessels throughout.](image)

Table 2. Demographics of Study Participants and Clinicopathological Characteristics of Study Lesions

| Variable                        | Value |
|---------------------------------|-------|
| Patients                        | 68    |
| Sex, M:F                        | 49:19 |
| Mean age (minimum, maximum)     | 59 (42, 84) |
| Lesion                          | 107   |
| Location                        |       |
| Ascending colon                 | 18    |
| Transverse colon                | 26    |
| Descending colon                | 14    |
| Sigmoid colon                   | 26    |
| Rectum                          | 23    |
| Morphology                      |       |
| Sessile polyp (Is), No. (%)     | 32 (29.9) |
| Subpedunculated polyp (Isp), No. (%) | 35 (32.7) |
| Flat-elevated polyp (Iia), No. (%) | 18 (16.8) |
| Pedunculated polyp (Ip), No. (%) | 9 (8.4) |
| Laterally spreading tumor (LST) | 13 (12.1) |
| Mean size in mm (range)         | 11.25 (2-40) |
| Histolopathology                |       |
| Non-neoplastic                  | 8     |
| Hyperplastic polyp              | 7     |
| Inflammatory polyp              | 1     |
| Neoplastic                      | 99    |
| Tubular adenoma-low grade       | 55    |
| Tubular adenoma-high grade      | 16    |
| Tubulovillous adenoma           | 10    |
| Villous adenoma                 | 2     |
| Adenocarcinoma-m-sm1            | 10    |
| Adenocarcinoma-sm-m             | 6     |

m-sm1, intramucosal-scant submucosal invasion; sm-m, submucosal massive invasion.
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Table 3. Diagnostic Accuracy of NBI Colonoscopy

| Histologic diagnosis | Neoplastic | Non-neoplastic | Neoplastic | Non-neoplastic | Neoplastic | Non-neoplastic | Neoplastic | Non-neoplastic |
|----------------------|------------|----------------|------------|----------------|------------|----------------|------------|----------------|
| Neoplastic           | 88         | 11             | 91         | 8              | 98         | 1              | 99         | 0              |
| Non-neoplastic       | 1          | 7              | 1          | 7              | 3          | 5              | 3          | 5              |

Sensitivity, %
- Neoplastic: 88.9
- Non-neoplastic: 91.9

Specificity, %
- Neoplastic: 87.5
- Non-neoplastic: 87.5

PPV, %
- Neoplastic: 98.9
- Non-neoplastic: 98.9

NPV, %
- Neoplastic: 38.9
- Non-neoplastic: 46.7

NBI, narrow band imaging; PPV, positive predictive value; NPV, negative predictive value.

Table 4. Relationship between Capillary Pattern as Determined by NBI Findings and Histologic Findings

| HP       | IP       | Tubular adenoma | TVA | VA | Carcinoma | No. |
|----------|----------|-----------------|-----|----|-----------|-----|
|          |          | Low             | High|     |           |     |
|          |          | CP I            | (%) | (%)|           |     |
|          |          | 6(40)           | 1(6.7)| (53.3)|           |     |
| CP II    |          | 1               | 43  | 12 | 7         | 1   | 4   | 68 |
|          |          | (1.5)           |     | (63.2)| (17.6) | (10.3)| (1.5)| (5.9)|     |
| CP III   |          | 4               | 4   | 3  | 1         | 6   | 6   | 24 |
|          |          | (16.7)          | (16.7)| (12.5)| (4.2)  | (25) | (25)|     |
| Total    |          | 7               | 1   | 55 | 10        | 2   | 10  | 6  |

NBI, narrow band imaging; CP, capillary pattern; HP, hyperplastic polyp; IP, inflammatory polyp; TVA, tubulovillous adenoma; VA, villous adenoma; m-sm1, intramucosal-scant submucosal invasion; sm-m, submucosal massive invasion.

Table 5. Relationship between Capillary Thickness as Determined by NBI Findings and Histologic Findings

| HP       | IP       | Tubular adenoma | TVA | VA | Carcinoma | No. |
|----------|----------|-----------------|-----|----|-----------|-----|
|          |          | Low             | High|     |           |     |
| InVisible|          | 5(83.3)         | 1(16.7)|     |           |     |
| Thin     |          | 2(3.4)          | 1(1.7)|     |           |     |
| Thick    |          | 19(60.3)        | 11(19)|     |           |     |
|          |          | (44.2)          | (11.6)|     |           |     |
| Total    |          | 7               | 1   | 55 | 16        | 10  | 2   | 10 |

NBI, narrow band imaging; HP, hyperplastic polyp; IP, inflammatory polyp; TVA, tubulovillous adenoma; VA, villous adenoma; m-sm1, intramucosal-scant submucosal invasion; sm-m, submucosal massive invasion.

DISCUSSION

Magnifying endoscopy provides details of the surface of the gastrointestinal tract, and enables pit pattern examination of colorectal tumors by using indigo carmine or cresyl violet. The pit pattern of colorectal tumors (type I-V pit pattern) was suggested by Kudo et al. using stereomicroscopy, and is useful for histologic evaluation of tumors. The pit pattern was developed for differential diagnosis between...
neoplasia and non-neoplasia, and is used for determining the
degree of histologic atypia and depth of early carcinoma,
presence of minute residual tumor after endoscopic resec-
tion,11-15 the degree of histologic inflammation when ulcer-
ative colitis is present, and diagnosis of dysplasia and colitis-
associated carcinoma.16-18

NBI with magnifying endoscopy is capable of observing
both the mucosal pit pattern and surface layer capillary pat-
tern without dye spray but only with mode conversion.3 This
is why the NBI endoscopy is also called as an ‘electronic
chromoendoscopy’. NBI with magnifying endoscopy can in-
directly measure capillary pit patterns similar to the regular
pit pattern type II, III, and IV, although the capillary pit pat-
tern type V, a marker of carcinoma, is not measured suffi-
ciently yet.19-22 Capillary evaluation is a useful alternative to
the pit patterns for the diagnosis of a colorectal tumor ap-
ppearing as a type V pit pattern. Recently, a number of studies
are attempting to evaluate capillary features (vessel diameter,
irregularity and capillary structure) for the diagnosis of
colorectal tumors using NBI magnification.5,19,21-25

This study classified lesions firstly by the capillary patterns
by Sano’s classification, and additionally classified by capil-
ary features; that is, thin or thick according to the capillary
thickness and regular or irregular according to the capillary
irregularity. Thin and regular capillary could be included in
the capillary pattern type II, while thick and irregular capil-
ary could be included in the capillary pattern type III, with
similar features on tumor observation. Capillary pattern type
I was quite common including invisible or faintly visible mu-
cosal capillary meshwork. The capillary meshwork in this
type was invisible in general or regional in some cases, and
previous biopsy site performed in some cases at other hospi-
tals revealed regional capillary meshwork (Fig. 1B).

The sensitivity and specificity of differential diagnosis be-
 tween neoplasia or non-neoplasia based on the capillary
meshwork of Sano’s classification were 96.4% and 92.3%, re-
spectively in a previous study,26 and were slightly lower in
this study with 91.9% and 87.5%, respectively. Classification
by capillary thickness or irregularity showed higher sensitivi-
ty but slightly lower specificity compared to the classification
by capillary pattern (Table 3).

Among capillary patterns based on the NBI with magnify-
ing endoscopy, neoplastic lesion was slightly more common
among capillary pattern type I, carcinoma was more appar-
ent in type III, and all 6 cases of submucosal massive inva-
sion were type III. Among capillary thickness based on the
NBI with magnifying endoscopy, invisible capillary was
more common among hyperplastic lesions but only 1 case of
neoplastic lesions belonged to it. Most carcinoma and all 6
cases of submucosal massive invasion showed thick pattern.
Among capillary irregularity, irregular capillary was histo-
logically worse than regular pattern and most common
among carcinoma lesions included all 6 cases of submucosal
massive invasion. Since capillary pattern by Sano’s classifica-
tion could be interpreted differently between observer, we
simplified to capillary thickness or irregularity for this study.
The results showed that capillary thickness or irregularity by
NBI endoscopy was useful enough to correlate between sub-
mucosal massive invasion and histologic finding of colorectal
tumor.

This study confirmed that NBI with magnifying endosco-
py enables the differential diagnosis between neoplastic and
non-neoplastic lesion.1 NBI with magnifying endoscopy was
also found useful when determining whether the depth of
submucosal invasion is more than 1,000 µm or not, a key
factor in deciding an endoscopic therapy of early colorectal
carcinoma. NBI endoscopy is simple to perform for both en-
doscopists and patients, and does not require special instru-
ment or dye. The capillary features such as capillary thickness
or irregularity by NBI magnification is simpler and easier for
clinical use than classifications by pit patterns or capillary
patterns.

| Table 6. Relationship between Capillary Irregularity as Determined by NBI Findings and Histologic Findings |
|-----------------------------------------------|
| HP | IP | Tubular adenoma | TVA | VA | Carcinoma | No. |
|-----------------------------------------------|
| | | Low | High | | | |
| Invisible | 5 | 1 | 51 | 11 | 8 | 1 | 4 | 5 |
| (%) | (100) | (100) | (14.1) | (10.3) | (1.3) | (5.1) | |
| | 2 | 1 | 35 | 11 | 8 | 1 | 4 | 78 |
| Regular | (2.6) | (1.3) | (65.4) | (14.1) | (10.3) | (1.3) | (5.1) | |
| | 4 | 5 | 2 | 1 | 6 | 6 | 24 |
| Total | 7 | 1 | 55 | 16 | 10 | 2 | 10 | 107 |

NBI, narrow band imaging; HP, hyperplastic polypl; IP, inflammatory polypl; TVA, tubulovillous adenoma; VA, villous adenoma; m-sm1, in-
tramucosal-scant submucosal invasion; sm-m, submucosal massive invasion.

*p<0.01; **p<0.001.
NBI with magnifying endoscopy is expected to be widely used clinically for capillary evaluation and proper diagnosis of colorectal tumor. This was a small retrospective study, and the classifications presented in the study require further investigation in multicenter, randomized, controlled trials, regarding the degree of conformity with endoscopic findings and the superiority of NBI colonoscopy compared to conventional colonoscopy in detection and prediction of histologic diagnosis of the tumor.

Conflicts of Interest

The authors have no financial conflicts of interest.

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