Precancers and early cancers are often subtle and can pose a challenge to gastroenterologists attempting to visualize them using standard white light endoscopy. The use of dye solutions aids the diagnosis of early gastrointestinal cancers; however, the constant use of dye solutions is cumbersome, and the solution often hinders observation by pooling in lesion depressions or ulcerations. To overcome this weakness, newer endoscopes have been developed that allow for “electronic chromoendoscopy.” The term electronic chromoendoscopy refers to endoscopic imaging technologies that provide detailed contrast enhancement of the mucosal surface and blood vessels. Electronic chromoendoscopy technologies include narrow-band imaging (NBI), i-scans, and flexible spectral imaging color enhancement (FICE).

1. Narrow-band imaging
   1) Principles

   NBI is a novel endoscopic technique that may enhance the accuracy of diagnosis using narrow-bandwidth filters in a red-green-blue (RGB) sequential illumination system. Because gastrointestinal cancers originate in the mucosa, the use of blue-colored, short-wavelength visible light, which can penetrate only into the mucosa, may be helpful in the observation of minute early expressions. Thus, scant differences in mucosal lesions can be expressed distinctly with color, and the capillary bed of the mucosal surface can be observed more clearly when illuminated with narrow-band blue (415 ± 15 nm) and green (540 ± 15 nm) wavelengths.

   The NBI system available in South Korea (Evis Lucera Spectrum System, CV-260SL; Olympus Medical Systems Co., Ltd., Tokyo, Japan) has a filter that transmits only 415 ± 15 nm and 540 ± 15 nm wavelengths; when the switch for NBI is activated while observing the upper gastrointestinal system under white light, this filter is inserted, and only a narrow-band around these two wavelengths is transmitted. After the lesions are illuminated, the monochromatic charge-coupled device (CCD) absorbs the reflected light and generates images. Because black and white images have a low resolution, the light absorbed by the monochromatic CCD is composited into RGB to generate color images. Consequently, the main image colors consist of brown and green, and the lesions can be observed in higher resolution than with black and white images.
2) Barrett’s esophagus

Although Barrett’s esophagus may be suspected by endoscopy, the yield of conventional biopsies for the detection of specialized intestinal metaplasia varies from 25% to 50% in short-segment Barrett’s esophagus and up to 80% in long-segment Barrett’s esophagus. Chromoendoscopy and magnifying endoscopy (ME) can help to overcome this problem, and surface analysis can be used to predict histological findings during endoscopy. Sharma et al. reported the use of ME with indigo carmine staining in 80 patients with endoscopic evidence of Barrett’s esophagus. ME-NBI was reported to be easier to perform than dye spraying, and it demonstrated a similar diagnostic value. Thus, NBI is widely used today and has replaced dyes such as methylene blue or acetic acid.

3) Esophageal cancer

Magnified observation of the esophageal mucosa may reveal tennis racket-shaped dark-brown capillaries in the mucosa that are derived from the side-branch blood vessels in the submucosal layer. These vessels are known as “intra-epithelial papillary capillary loops” (IPCLs). IPCLs demonstrate characteristic morphological changes according to the tissue atypism and cancer invasion depth. ME findings with regard to capillary pattern are classified into five types (I-V) according to the degree of change in the IPCL pattern, such as dilatation, tortuosity, or caliber change in one IPCL, or various shapes in multiple IPCLs. Classifications include type I (normal mucosa), type II (regenerating epithelium or inflammation), type III (low-grade dysplasia), type IV (high-grade dysplasia), and type V (cancer). Type V is further divided into types V-1 (m1), V-2 (m2), V-3 (m3, sm1), and VN (more invasion than sm2). However, it is difficult to assess the depth of invasion by ME with a regular system. Because of the NBI effect of capillary enhancement, the microscopic IPCL pattern is readily identified and evaluated by endoscopists with experience in ME. Yoshida et al. reported that ME-NBI improved the accuracy of the assessment of invasion depth in superficial esophageal cancer.

4) Chronic gastritis

The ME findings in the gastric body are categorized into four types: type 1, honeycomb-type subepithelial capillary network (SECN) with regular arrangement of collecting venules and regular, round pits; type 2, honeycomb-type SECN with regular, round pits, but loss of collecting venules; type 3, loss of normal SECN and collecting venules, with enlarged white pits surrounded by erythema; and type 4, loss of normal SECN and round pits, with irregular arrangement of collecting venules. Yao et al. reported that the sensitivity, specificity, and positive and negative predictive values of the type 2 and 3 patterns for predicting a Helicobacter pylori-infected stomach were 100%, 92.7%, 83.8%, and 100%, respectively. The sensitivity, specificity, and positive and negative predictive values of the type 4 pattern for predicting gastric atrophy were 90%, 96%, 85.7%, and 97.3%. A characteristic finding known as the light-blue crest was detected in intestinal metaplasia in the stomach through ME-NBI, and this finding was reported to have high specificity for representing histological intestinal metaplasia. The light-blue crest was defined as a fine, blue-white line on the crests of the epithelial surface or gyri, as visualized by ME-NBI. This appearance is speculated to be caused by reflection of the short- and narrow-wavelength light (400-430 nm) at the surface of the ciliated tissue structure; that is, the brush border in gastric intestinal metaplasia and in the duodenum.
5) Gastric adenoma

In cases of elevated gastric adenoma, it is sometimes impossible to visualize the microvascular pattern. According to a recent study, a characteristic white opaque substance (WOS) was found along the mucosal surface when an elevated gastric adenoma was observed with ME-NBI. An analysis of 46 cases of elevated-type adenoma and cancer found regularly shaped WOS in all adenoma cases and irregularly shaped WOS in 83% of carcinoma cases. The authors concluded that the morphological analysis of the WOS could provide an alternative new optical sign for the discrimination of adenoma from carcinoma when using ME-NBI.11

6) Early gastric cancer

ME-NBI is reportedly a sensitive and accurate diagnostic tool for the assessment of differentiation, margins, and depth of early gastric cancer.

Yao et al. reported that the ME findings for gastric differentiated carcinoma were the disappearance of the regular SECN pattern, presence of an irregular microvascular pattern, and presence of a demarcation line (a clear border between an irregular microvascular or microsurface pattern and surrounding, regular, normal mucosa). In undifferentiated gastric cancer, an ill-defined area with a reduced number of irregular minute vessels was observed. However, the authors did not report the incidence of the above finding.12 Nakayoshi et al. assessed the correlation between the ME-NBI and histological findings, especially with regard to the microvascular pattern, in 165 cases of superficial depressed-type early gastric cancer lesions (109 differentiated adenocarcinomas, 56 undifferentiated adenocarcinomas). A fine network microvascular pattern was observed in 72 of 109 (66.1%) cases of differentiated adenocarcinoma, and a corkscrew pattern was observed in 48 of 56 (85.7%) cases of undifferentiated adenocarcinoma ($P = 0.0011$). The authors concluded that ME-NBI was capable of predicting the histological characteristics of gastric cancer lesions.13

Yagi et al. assessed the relationship among microvessel, pit, and histological patterns using ME-NBI. They found that the magnified view of the cancerous area showed three types of patterns: a mesh pattern, a loop pattern, and an interrupted pattern. Most (94.9%) lesions showing a mesh or loop pattern were mucosal cancer, whereas 92.3% of lesions showing an interrupted pattern were submucosal differentiated adenocarcinoma. The authors clarified the characteristic features of the magnified view of mucosal differentiated gastric adenocarcinoma and the characteristics of invasive changes, including submucosal invasion.14

Kadowaki et al. reported the ease of recognition of the tumor margin. They investigated the effectiveness of four ME methods in enhancing the recognition of the tumor margin: conventional ME (CME), ME-NBI, enhanced ME with acetic acid (EME), and NBI-EME. They found that the average scores (expert and non-expert) of images acquired using NBI-EME were significantly higher than those acquired using other methods, and that images acquired by ME-NBI or EME also scored significantly higher than those acquired by CME.15 Kiyotoki et al. evaluated the usefulness of ME-NBI for determining the tumor margin. The rate of accurate marking of the ME-NBI group was significantly higher than that of the indigo carmine chromoendoscopy group (97.4% vs. 77.8%; $P = 0.009$).16

Ezoe et al. reported the accurate diagnosis of gastric small depressive lesions using ME-NBI. They found a significantly higher diagnostic accuracy (79% vs. 44%; $P = 0.0001$) and sensitivity (70% vs. 33%; $P = 0.0005$) for NBI than for white light imaging, and reported that the demarcation line and an irregular microvascular
pattern were valuable findings in the differential diagnosis of gastric small depressive lesions. They concluded that the addition of NBI to white light imaging examinations was essential to achieve an accurate diagnosis of such lesions. Kato et al. reported the superiority of ME-NBI in the differential diagnosis of superficial gastric lesions identified with conventional white light endoscopy. They set the minimal criteria for a diagnosis of gastric cancer by ME-NBI as the disappearance of fine mucosal structure, microvascular dilation, and heterogeneity. The sensitivity (92.9%) and specificity (94.7%) for an ME-NBI diagnosis with the use of these three criteria were significantly better than those for white light endoscopy (42.9% and 61.0%, respectively; \( P < 0.0001 \)). The authors concluded that ME-NBI might increase the diagnostic value of endoscopy in a population at high risk for gastric cancer.

2. i-scan

i-scan technology is the newly developed image-enhanced endoscopic technology from PENTAX (Japan). It consists of three types of algorithms: surface enhancement (SE), contrast enhancement (CE), and tone enhancement (TE). SE enhances light/dark contrast by obtaining luminance intensity data for each pixel and applying an algorithm that allows for the detailed observation of mucosal surface structure. SE allows for more extensive observation of minute glandular structures, which facilitates the evaluation of changes on the basis of structural differences. The SE component of the i-scan system is comparable with the SE function of Olympus and has a chromoendoscopic effect similar to that of acetic acid solution.

CE digitally adds blue color in relatively dark areas by obtaining luminance intensity data for each pixel and applying an algorithm that allows for detailed observation of subtle irregularities around the surface. With TE, the RGB components of an ordinary endoscopic image are disintegrated into each component, and each component thus isolated is converted independently along the tone curve, followed by a re-synthesis of the three components to yield a reconstructed image. NBI is an optical-filter technology that uses two narrow-band filters to provide tissue illumination in the blue and green light spectra, whereas TE is a digital filter that modifies normal images through software functions.

At present, six types of TE are available: TE-p, TE-v, TE-b, TE-e, TE-g, and TE-c. TE-p, which enhances the dark R component, allows the ready identification of mucosal surface lesions and pit patterns. TE-v, which suppresses the R component in a manner similar to NBI filtration, allows the ready identification of vascular form. TE-b is similar to TE-p in the enhancement of dark-red color, but is designed for the observation of Barrett’s esophagus. With TE-e (for esophagus), the J-type tone curve, which suppresses the maximum output, is adopted for the R component to elevate G/B contrast and make structural changes clearer. With TE-g (for stomach), the J-type tone curve, which suppresses the maximum output, is adopted for the R component to elevate G/B contrast, and the S-type tone curve is adopted for the G and B components to elevate color contrast. In this way, TE-g yields images that allow the ready identification of a lesion because it can increase the contrast for even minor differences in color tone. TE-c, the J-type tone curve, is adopted for the R component, but the output is higher than that with TE-g, which results in a slightly reddish image. The EPK-i system is expected to play a role similar to that of other image-enhanced endoscopic techniques, although few detailed reports have assessed the application of this system to the evaluation of gastrointestinal cancers. In one study from Germany, the authors inspected the last 30 cm of the colon in a screening population with high-definition (HD) + resolution alone, in combination with i-scan, and subsequently with chromoendoscopy. In 69 patients, i-scan aug-
mented the identification of lesions from 176 to 335; chromoendoscopy brought this number to 646. Most (74%) lesions recognized only using i-scan or chromoendoscopy were flat (type IIb). The amount of neoplasia did not differ significantly, but all could be correctly predicted using i-scan or chromoendoscopy. Furthermore, the authors performed screening colonoscopies in 200 patients with HD+ colonoscopy in conjunction with i-scan surface enhancement or standard video colonoscopy. HD+ colonoscopy with i-scan functionality detected significantly more patients with colorectal neoplasia (38%) compared with standard-resolution endoscopy (13%). Significantly more neoplastic (adenomatous and cancerous) lesions and more flat adenomas could be detected using HD endoscopy with surface enhancement. Final histology could be predicted with high accuracy within the HD+ group.

3. Flexible spectral imaging color enhancement

Optimal band imaging (OBI), the generic term for FICE, enhances the visualization of mucosal structure and microcirculation by the selection of spectral transmittance with a dedicated wavelength. In contrast to NBI, in which the bandwidth of the spectral transmittance is narrowed by optical filters, the OBI system is based on a new computed spectral-estimation technique. In NBI, the observer must change optical filters to observe wavelengths other than the established wavelength; in OBI, however, the observer can select an optimal set of wavelengths by simply switching a key. Thus, an optimal wavelength can be used to evaluate the esophagus, stomach, and colon. In OBI, the endoscopist can select 60 spectral images per 5 nm at visible wavelengths between 400 and 695 nm, and set up five gradations of spectral image intensities. Because OBI was created by the selection of three of 300 series of spectral image intensities (60 × 5 steps), 27 millions of OBI images (300³) were obtained in one type of conventional endoscopic image. In the present study, the demarcation of depressed-type early gastric cancer was identified in 26 of 27 cases (96%), and elevated-type early gastric cancer was identified in all 81 cases without magnification, which allowed for planning of endoscopic submucosal dissection. In 61 patients undergoing upper endoscopy for a clinical history of malabsorption or serologic suspicion of celiac disease, which is rare in Korea, the sensitivity, specificity, and positive and negative predictive values of OBI-based duodenoscopy were 100% in the evaluation of villous patterns.22

Conclusions

The early detection and treatment of gastrointestinal cancer and premalignant lesions is very important for the efficacy of treatment and the maintenance of a high quality of life; therefore, the gastrointestinal endoscopist has tremendous responsibilities. Optical imaging technology is advancing due to the development of endoscopic technology; the diagnostic accuracy and image reconstruction capabilities of this technology are similar to those of pathological imaging. If we give attention to various endoscopic features and are well informed of advantages and disadvantages, optical imaging technology will become helpful for the diagnosis and treatment of gastrointestinal abnormalities.

References

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