carcinoma, ESD $\geq$ 50 for gastric cancer and perforation rate $\leq$2% in total.

Treatment Methods

Endoscopic Mucosal Resection

EMR is performed against esophageal tumors within 30 days from registration. The technical methods of EMR approved in this trial are a two-channel method, a cap method or an esophageal endoscopic mucosal resection-tube method (8). Only the registered physicians are allowed to perform ESD in this trial. After EMR, it should be confirmed endoscopically that no iodine-unstained area is left. Physicians need to take pictures before and after EMR and submit them to the primary investigator for quality control of EMR technique and endoscopic diagnosis.

Chemoradiotherapy

In cases of pT1a tumor with negative resection margin and no vascular invasion, no additional treatment after EMR is given. In other cases, chemoradiotherapy was started at 29–70 days after EMR. The chemotherapy regimen is continuous 5-FU (700 mg/m^2/day, days 1–4 and 29–32) and CDDP (70 mg/m^2/day, days 1 and 29). The dose of radiotherapy is 41.4 Gy/23 Fr/5 weeks (5 days/week) for cases with negative resection margin and 50.4 Gy/28 Fr/5 weeks (5 days/week) with boost on the primary site for the case with positive resection margin, respectively.

Follow-up

Patients are followed with blood tests, upper gastrointestinal endoscopy and computed tomography at least every 4 months for 3 years.

Study Design and Statistical Methods

This trial determines the efficacy and the safety of combined treatment of EMR and chemoradiotherapy for cT1b esophageal cancer in terms of 3-year OS. Additionally, 3-year OS in all eligible patients are evaluated as the most important secondary endpoint. The sample size is 82 for pT1b cases with negative resection margin with the power of 90%. In case this hypothesis rejected, the secondary hypothesis for all eligible patients can be tested using hierarchical method keeping trial-wise α error nominal level, one-sided 5%, with the power of 80%. To test the hypothesis, 3-year OS estimated by Kaplan–Meier method and its confidence interval by Greenwood's formula is used. The total number of registered patients is estimated as 137, because the proportion of pT1b cases with margin-negative among all eligible patients is predicted as ~60%.

This study was registered with UMIN-CTR [www.umin.ac.jp/ctr/], identification number UMIN000000553.

Interim Analysis and Monitoring

Interim analysis is not planned. If the number of cases with treatment-related death, severe (Grade 4) bleeding or severe (Grade 4) perforation reaches seven, the registration will be suspended unless the JCOG Data and Safety Monitoring Committee approves to continue this trial. The JCOG Data Center is responsible for data management, central monitoring and statistical analysis. This center also provides semi-annual monitoring reports, each of which is submitted to and reviewed by the JCOG Data and Safety Monitoring Committee on demand of the JCOG Data Center. None of physicians administering the interventions are involved in the data analysis. For quality assurance, site-visit audits, not for a specific study basis but for the study group basis, are done by the JCOG Audit Committee.

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Conflict of interest statement

None declared.

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Appendix

The initially participating hospitals are as follows: Iwate Prefectural Central Hospital, Ibaragi Prefectural Central Hospital, Tochigi Cancer Center Hospital, National Cancer Center Hospital East, National Cancer Center Hospital, Tokyo Metropolitan Cancer and Infectious diseases Center Komagome Hospital, Showa University Hospital, Cancer Institute Ariake Hospital, Kitasato University East Hospital, Kanagawa Cancer Center Hospital, Ishikawa Prefectural Central Hospital, Saku Central Hospital, Shizuoka Cancer Center Hospital, Aichi Cancer Center Central Hospital, Kyoto University Hospital, Osaka Medical Center for Cancer and Cardiovascular Disease, Osaka City Medical Center, and Osaka Medical College Hospital.

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ENDOSCOPY MINISERIES

Improving visualization techniques by narrow band imaging and magnification endoscopy

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Key words
endoscopy, early detection, magnification, narrow band imaging, pre-malignant lesions.

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Abstract

Endoscopy plays an important role in the early detection of gastrointestinal tract neoplasms. Using conventional white light or dye-based image enhanced endoscopy, it has been difficult to assess pre-malignant and early neoplastic lesions precisely. However, narrow band imaging (NBI) dramatically improves the detection of these lesions, particularly in combination with magnifying endoscopy. This allows the endoscopist to accomplish accurate diagnosis. Such enhanced detection of pre-malignant and early neoplastic lesions in the gastrointestinal tract should allow better targeting of biopsy, improved and more appropriate treatment, and thereby contribute to optimal quality of life and patient survival.

Introduction

The ability to visualize mucosal surface abnormality of the gastrointestinal tract is essential to enhance early detection and make accurate diagnosis of the underlying disease. Recent advances in endoscopic imaging technologies have enabled endoscopists to observe microscopic structures, such as microvessels, tissue structure, cellular nuclei, and even macromolecules. These improvements of visualization are expected to provide much information, to not only physicians but also surgeons and radiologists.

Among these newer technologies, narrow band imaging (NBI) is one of the most promising. NBI is an innovative optical technology that can increase contrast of the precise morphological changes in the mucosal surface. When combined with magnifying endoscopy, use of NBI clearly visualizes microvascular structures.[1,2] These strengths have opened a brand new door for endoscopic diagnosis of gastrointestinal tract diseases. In this review, we focus on the role of NBI combined with magnifying endoscopy and discuss the clinical significance of this technique in gastroenterology.

Background of advances in optical endoscopic technologies

Videoendoscope system

The videoendoscope mounts the charge coupled device (CCD) on the tip of the endoscope as the imaging sensing device. Two different types of videoendoscope systems are currently in use. The difference is based on how a color image is created. One is based on a black and white CCD, in which color separation is achieved through use of a red-green-blue (RGB) rotary filter wheeled equipped within the light source unit. The RGB filter consists of three broadband optical filters and covers all wavelengths of the visible spectrum, ranging from approximately 400 to 800 nm (Fig. 1a). The other system is based on a color CCD chip that has several tiny color filters in each pixel (Fig. 2a). Both systems use a xenon lamp as a light source. Usually, the RGB sequential system is considered to provide more clear images compared with the color chip system.

Narrow band imaging

The NBI system has been in use since 1999 and was developed as a part of the joint research between the Japanese National Cancer Center Hospital East and Olympus Medical Systems Corporation (Tokyo, Japan). Gono *et al.* revealed that the use of 415 nm narrowband light could improve the capillary images, which are difficult to observe under conventional white light.[1,2] Subsequently, Sano *et al.* reported the capabilities of NBI in the gastrointestinal tract in 2001.[3] The NBI system is now expected as a new promising endoscopic diagnostic tool in the gastrointestinal tract all around the world.

The NBI system uses two narrow band illuminations of 415 nm and 540 nm by NBI filter (Figs 1b,2b). Under NBI observation, the broadband white light derived from the xenon lamp splits into two bands (wavelength of 415 nm and 540 nm) and illuminates the surface of the mucosa.

When the NBI is incorporated into an RGB sequential system, the NBI filter is placed on the light path in front of the RGB rotary filters. When observing with the NBI filter, the light illumination passes only B and G filters to obtain 415 nm and 540 nm images.

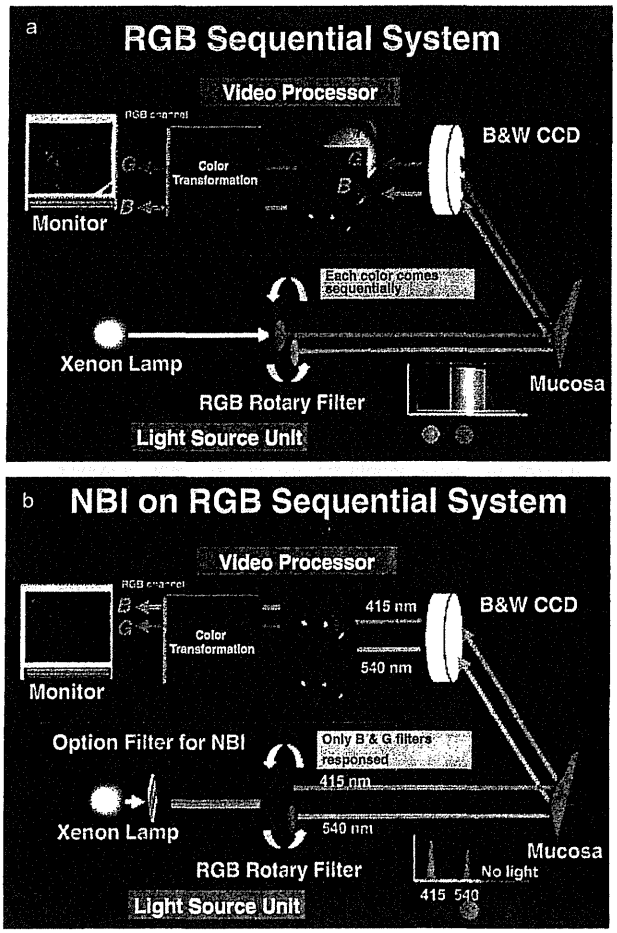

Figure 1 Schema of the red-green-blue (RGB) sequential illumination system. (a) In the RGB sequential illumination system, color separation is achieved through use of a red-green-blue rotary filter wheel equipped within the light source unit. The RGB filter consists of three broadband optical filters and covers all wavelengths of the visible spectrum, ranging from approximately 400 to 800 nm. (b) In the narrow band imaging (NBI) of RGB sequential system, the NBI filter is placed on the light path in front of the RGB rotary filters. When observing with the NBI filter, the light illumination passes only B and G filters to obtain 415 nm and 540 nm images. Subsequently, two narrow band images of 415 and 540 nm should be reproduced to visualize the images. However, to create a color image on the cathode ray tube (CRT) or liquid crystal monitor, three images are needed to be outputted to the R, B and G channels on the color monitor. For this purpose, 415 nm is allocated to the B and G channels so that the blood vessels on the mucosal surface are reproduced in a brownish color, and 540 nm is allocated to the R channel, so that the vessels in the deeper layer are indicated in a blue-color.

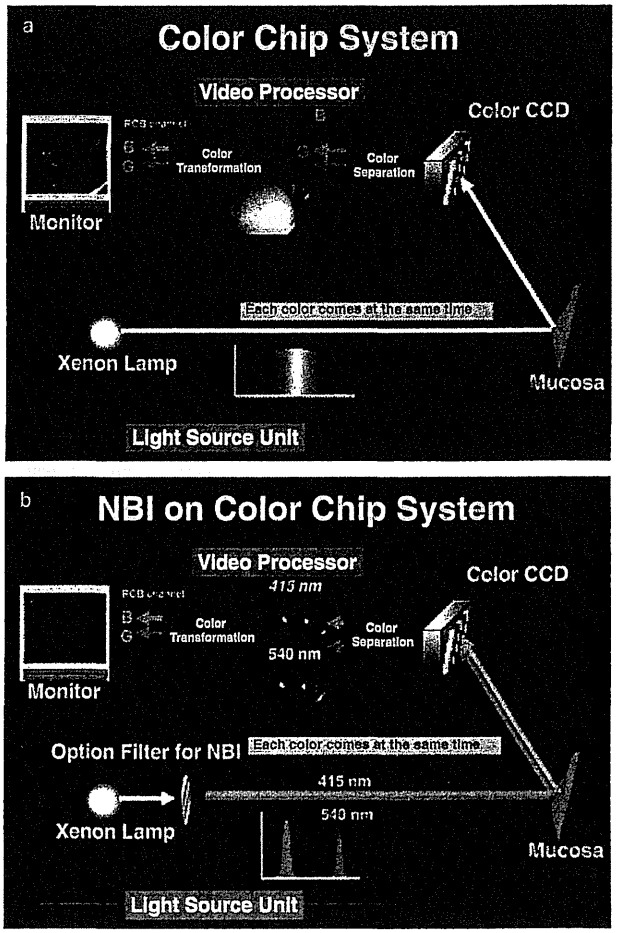

Figure 2 Schema of the color charge coupled device (CCD) chip system. (a) The color CCD chip system is based on a color CCD chip that has several tiny color filters in each pixel. (b) In the narrow band imaging (NBI) of color chip system, the NBI filter is also placed on the light.

Similarly, in the NBI color chip system (Fig. 2b), the NBI filter is placed on the light path, while this filter is removed under the conventional white light observation.

Subsequently, two narrow band images of 415 and 540 nm should be reproduced by placing the NBI filter. However, to create a color image on the cathode ray tube (CRT) or liquid crystal monitor, three images need to be outputted to R, B and G channels on the color monitor. Then, 415 nm is allocated to B and G channels so that blood vessels on the mucosal surface are reproduced in a brownish color, and 540 nm is allocated to the R channel so that the vessels in the deeper layer can be indicated in a greenish-blue color.

High definition endoscopy and monitor system

Image quality depends on its *resolution* and *contrast*. *Resolution* is the capacity to visualize minute patterns and is determined by the pixel number of each CCD. To enhance resolution, the number of pixels in the CCD has to be increased. However, a CCD with a higher number of pixels thus increases the size of the videoendoscope by expanding its outer diameter. On the other hand, if a thinner endoscope is made, the CCD must be smaller, thereby decreasing the number of pixels with a resulting reduction of image resolution. On the other hand, for insertion and operation of the endoscope, a thinner diameter tip is ideal and important. To

resolve this dilemma, a smaller sized CCD with a higher pixel count has been developed by solving several technical challenges.

Contrast is the ratio of density or brightness between a pattern and its background. Resolution is enhanced by high definition endoscopy and contrast is improved by NBI technology. High quality images are made by both high resolution and high contrast.

If the resolution of the monitor system is low, image quality will be poor even though we use a high definition endoscope. Then, we have to use both high definition endoscopy and high definition monitoring to obtain the highest quality of images. However, despite the importance of this aspect, none of the many published studies on high definition NBI appear to have described the specifications of the monitor used.

Magnifying endoscopy

Magnifying endoscopy has the capability of both standard video endoscopy and an adjustable image magnification. Using magnifying endoscopy, Kudo *et al.*,[4] Inoue *et al.*[5,6] and Yao *et al.*[7,8] have already reported the importance of the magnification in the colon, esophagus and stomach, respectively.

The RGB sequential system and the color CCD system differ in their magnification capabilities. Although the RGB sequential system allows optical magnification of the image up to 80 times, the color CCD system has digital zoom at 1.2 and 1.5 times magnification. However, high definition endoscope, even that using the color CCD system, possesses a physical zoom property that allows the tip of the endoscope to be advanced up to 2 mm away from the mucosal surface without decreasing resolution. This combination results in the capacity for at least a 50-times magnification.

Narrow band imaging combined with magnification is expected to give the maximum performance to make accurate diagnosis. Conversely, NBI observation without magnification has the potential disadvantage of producing conditions that are sometimes too dark to identify morphological and color changes. This reason for the dark image is simply because the NBI system uses only two narrow illumination lights, whereas conventional white light imaging uses a broadband visible light. For these reasons, it is important that users understand the technical backgrounds of these newer endoscopic procedures.

Improvement of visualization and clinical significance

Narrow band imaging combined with magnifying endoscopy enhances the contrast detailed morphological changes in the mucosal surface and clearly visualizes the microvascular structures. In particular, microvascular assessment is a novel target of epithelial neoplastic lesions in different organs, including oropharynx and hypopharynx,[9–11] esophagus,[5,6] stomach,[7,8] lung,[12] and colon.[13]

Inoue *et al.* first reported the importance of morphological changes of the intrapapillary capillary loop (IPCL) in making a diagnosis of esophageal squamous cell carcinoma.[5,6] Yao *et al.* also reported the importance of the irregular microvascular pattern within the gastric cancer.[7,8] However, assessment of the microvascular architecture has been difficult by conventional white light observation. In contrast, NBI made it possible to easily assess these structures. Demonstrable cases are shown in Figures 3–6.

In the head and neck region (Fig. 3) and esophagus (Fig. 4), NBI clearly visualizes the well-demarcated brownish area, while the lesion is difficult to identify by conventional white light image. In the stomach (Fig. 5), magnified NBI clearly revealed a demarcation line between non-neoplastic mucosa and the neoplastic lesion with its irregular microvascular pattern; this pattern was difficult to identify by white light image. In the colon (Fig. 6), papillary pattern was invisible in a hyperplastic polyp, while it is clearly identified in an adenomatous polyp. For such reasons, NBI is now expected to be a useful tool for endoscopic screening and surveillance for early cancers in several organs.

A recent meta-analysis revealed that NBI evaluation of epithelial lesions in the gastrointestinal tract and lung has a high level of diagnostic precision for neoplasia.[14] High diagnostic accuracy has the potential to allow accurate target biopsy, and also reduces unnecessary biopsies. In addition, NBI diagnosis has comparable diagnostic accuracy to chromoendoscopy, which has been recognized as a useful method for discriminating neoplasia from non-neoplasia. This evidence provides great merit for both patients and endoscopists, because with NBI there is no longer a need for either staining solution or spraying catheters. Dispensing with these procedures can potentially reduce the duration of the endoscopic examination and procedural cost.

Narrow band imaging has a sharp learning curve to the inexperienced endoscopist.[14,15] This is very important because educating non-experienced endoscopists to recognize early cancers is difficult. Yoshida *et al.* compared the ability of novices versus experienced endoscopists to identify and evaluate IPCL by NBI and white light observation.[16] Both assessors found that image contrast, identification and evaluation of IPCL by NBI were superior to that from white light observation. Furthermore, NBI with magnification improved the diagnostic accuracy for depth of invasion based on IPCL findings, especially for inexperienced endoscopists.

Head and neck region

Head and neck cancer

Early detection of cancers in the oropharynx and hypopharynx has been difficult even for ear-nose-throat (ENT) doctors, because image resolution of rhinolaryngoscopy is not very good for identifying epithelial neoplastic lesions. This can be partly attributed to the technological limitation of size to mount the high quality CCD to the tip of a rhinolaryngoscope.

Muto *et al.* first reported the usefulness of NBI combined with magnifying endoscopy (Q240Z, Olympus Medical Systems, Tokyo, Japan) for identification of superficial squamous cell carcinoma (SCC) in the head and neck region.[9] The NBI was based on an RGB sequential light source (EVIS 240, Olympus Medical Systems). Compared with white light observation, NBI significantly improved the visualization of cancerous lesions by enhancement of the contrast between the lesion and background non-neoplastic epithelium, as well as by clear magnification of microvascular architecture.[11] Under NBI observation, cancerous lesions are recognized as well-demarcated brownish areas, and after magnification, the micovascular irregularities can easily be identified.[9,10] These two characteristics are typical changes of epithelial neoplasms, and are histologically confirmed as

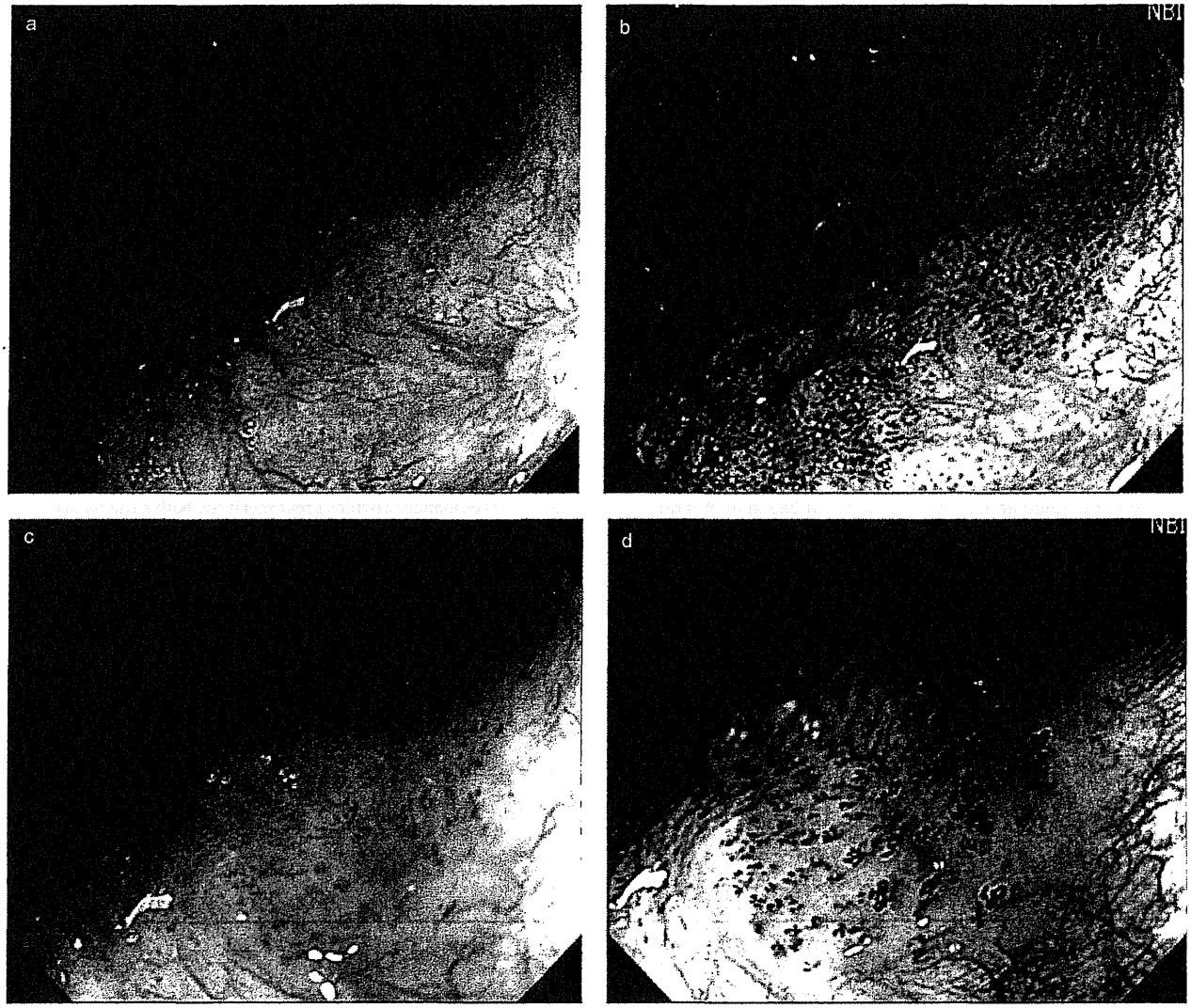

Figure 3 Superficial squamous cell carcinoma in the oropharynx. (a) Non-magnified white light image shows slightly reddish lesion with uneven surface in the posterior wall of the oropharynx. (b) Non-magnified narrow band imaging (NBI) shows a brownish area in which scattered tiny brown spots are easily seen. (c,d) Magnified NBI (d) clearly reveal irregular microvascular pattern, whereas this pattern was difficult to identify in the white light image (c).

angiogenetic changes. Based on these findings, we have proposed a new diagnostic approach to visualize angiogenesis in superficial neoplastic lesions.[10]

In the ENT field, Watanabe *et al.* reported that NBI rhinolaryngoscope (ENF-V2, Olympus Medical Systems) with the color chip light source (CLV-160B, Olympus Medical Systems) improved the diagnostic accuracy, and negative predictive value for superficial lesions in the oropharynx and hypopharynx.[17,18]

However, there is still a critical difference in image qualities between the RGB sequential system and color chip systems, and also between high-resolution and conventional endoscopy. Using a real time approach, Ugumori *et al.* compared the images taken by color chip based rhinolaryngoscope and those taken by RGB sequential system-based high-resolution endoscopy.[19] While conventional white light rhinolaryngoscope could identify a well demarcated line between neoplastic and non-neoplastic lesions in only 10% (5/51), and microvascular irregularities in 27% (14/51), NBI rhinolaryngoscope could identify these findings in 63% (32/51) and 94% (49/51), respectively. This result indicates that even through the conventional and color CCD endoscope, NBI can improve the visualization of epithelial neoplasms.

The clinical significance of these results is exemplified by the fact that no cases of superficial cancer in the oropharynx and hypopharynx had been reported before the emergence of NBI. Early detection of cancer in this region can introduce the possibility of minimally invasive treatments, such as endoscopic mucosal

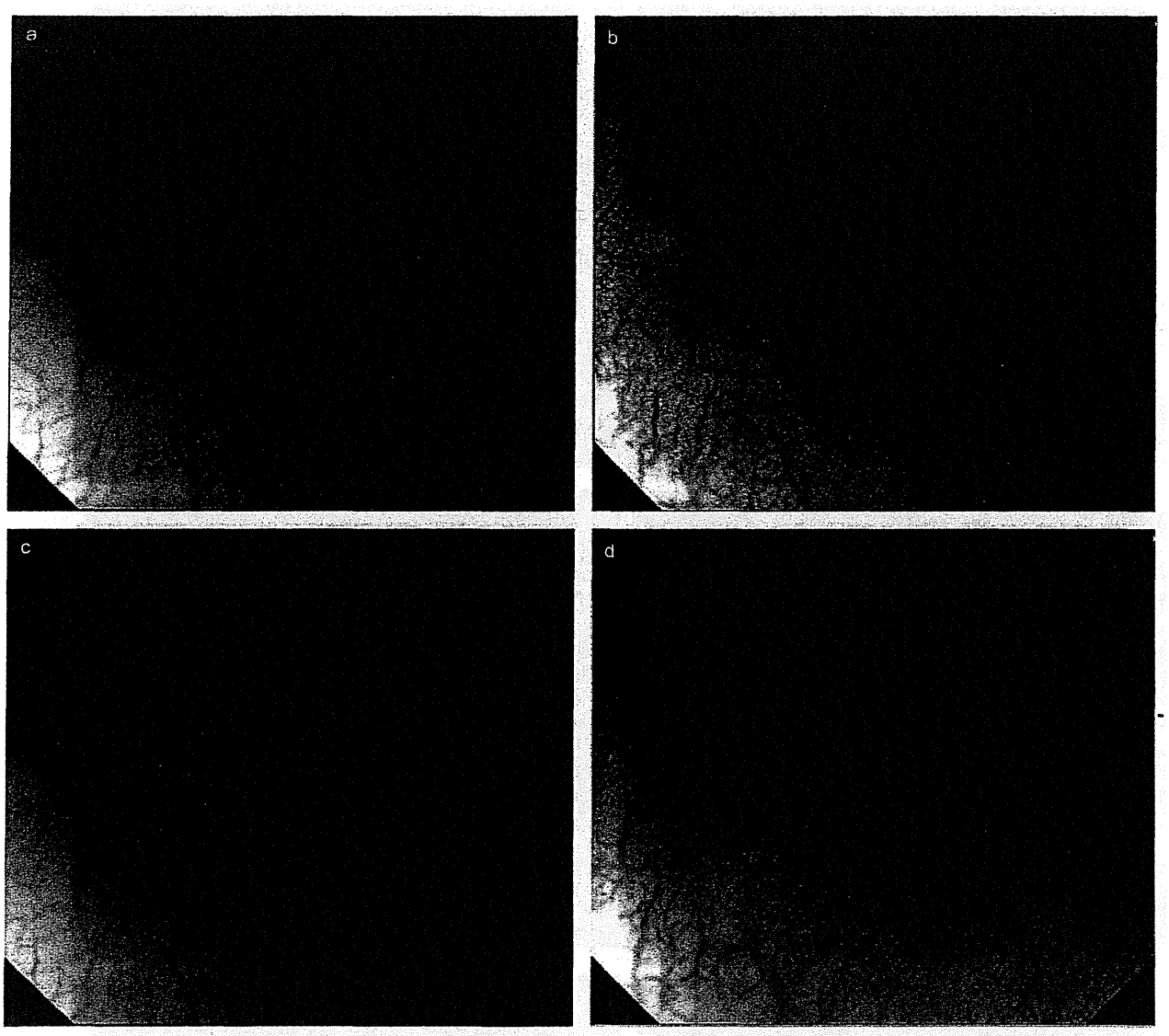

Figure 4 Superficial squamous cell carcinoma in the esophagus. Non-magnified narrow band imaging (NBI) (b) clearly demonstrates a well demarcated brownish area, while the lesion was difficult to recognize by white light imaging (a). Magnified NBI (d) clearly reveals irregular microvascular pattern, whereas this pattern was difficult to identify by white light image (c).

resection (EMR) and endoscopic submucosal dissection (ESD) methods, similar to the corresponding approaches in the gastrointestinal tract. The potential advantages to patients resulting from earlier diagnosis and preservation of organ and tissue functions are obvious.

Esophagus

Esophageal squamous cell carcinoma

Patients with esophageal SCC have a high risk of development of synchronous and/or metachronous SCC in the esophagus and head and neck region. This has long been explained by the 'cancer field' concept.[20] Thus, effective screening and surveillance are required to improve the survival and quality of life of patients with multiple SCC. Lugol chromoendoscopy is the standard method for detection of early cancer in the esophagus. However, lugol is an irritant and causes unpleasant reactions, such as pain and discomfort.[21,22] In contrast, NBI is less invasive, so it is expected to replace the role of lugol chromoendoscopy.

Preliminary results from a Japanese multicenter prospective randomized control study in a back-to-back fashion indicate that significantly high detection rates and high diagnostic accuracy of superficial SCC in the head and neck region and the esophagus are obtained using NBI compared with conventional white light observation.[23] This result may indicate that NBI should become the standard modality for examining squamous epithelium for cancer screening.

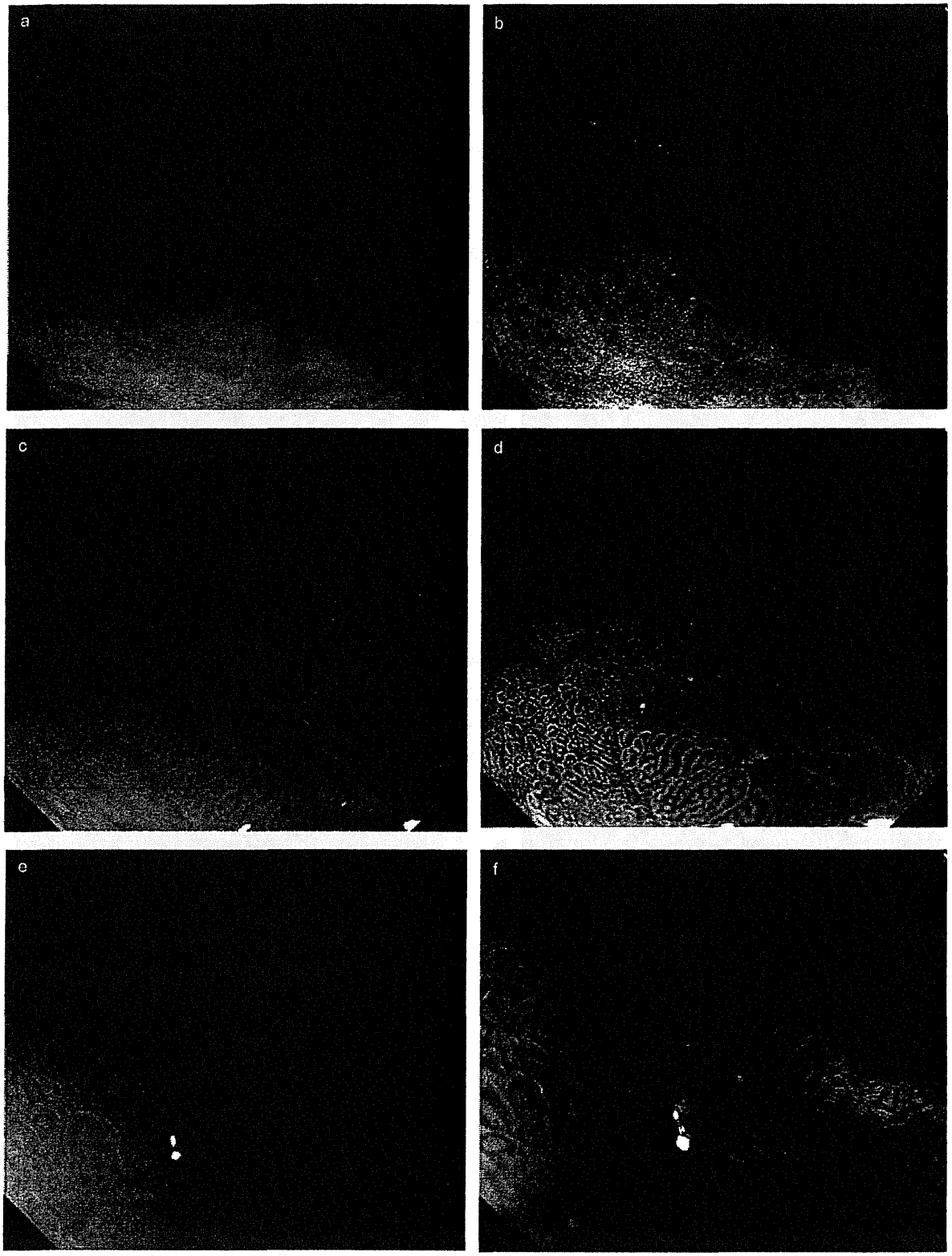

Figure 5 Mucosal cancer in the stomach. Both non-magnified conventional white light image (a) and narrow band imaging (NBI) (b) show a small depressed area in the greater curvature of the stomach. Magnified NBI (d,f) clearly reveals a demarcated line between non-neoplastic mucosa and the neoplastic lesion, and irregular microvascular pattern; this pattern was difficult to identify by white light image (c,e).

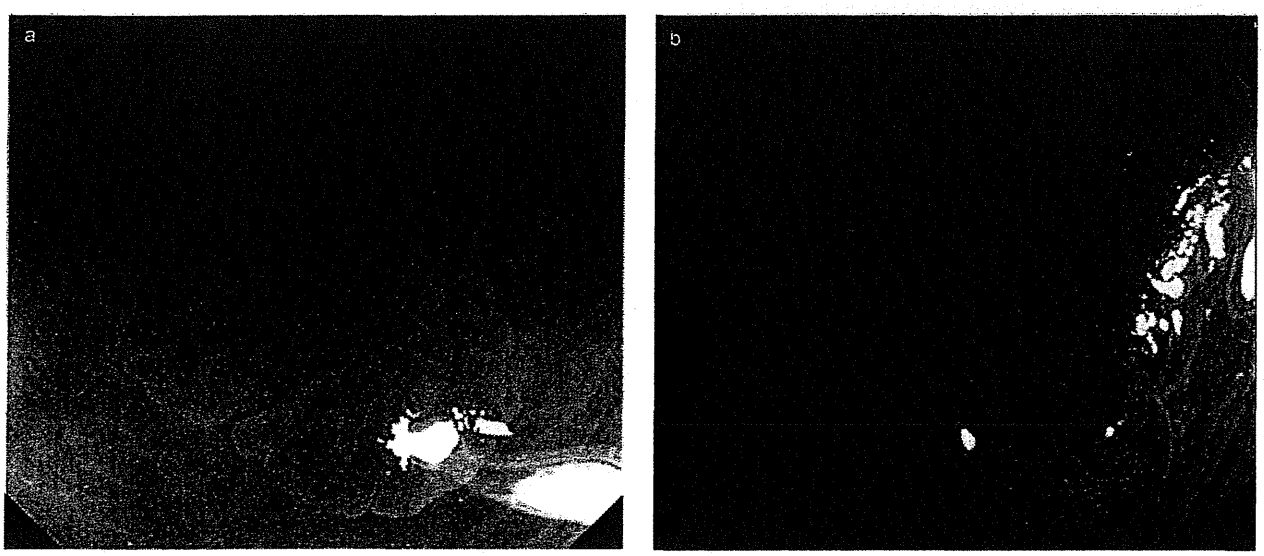

Figure 6 (a) In the hyperplastic polyp, a papillary pattern is not present. (b) In the adenomatous polyp, a papillary pattern is clearly evident.

Using an ultra-thin endoscope (5 mm in diameter at the distal end, XP260N, Olympus Medical Systems), Lee *et al.* reported the usefulness of NBI for detection and accurate diagnosis of esophageal SCC.[24] The sensitivity of NBI was significantly better than that of conventional white light observation. Specificity and positive predictive value of NBI were also better than lugol chromoendoscopy. Diagnostic accuracy and negative predictive value are comparable between NBI and lugol chromoendoscopy. These results may indicate that, even by adopting the ultra-thin endoscope, NBI is the best tool to screen superficial esophageal neoplasms.

Gastroesophageal reflux disease

Gastroesophageal reflux disease (GERD) causes heartburn and decreases quality of life. However, a significant number of patients with GERD symptoms show no signs of esophagitis endoscopically. This condition is described as endoscopy-negative reflux disease (NERD), and thus standard endoscopy has been an insensitive test for the diagnosis of GERD.

While NERD can also be considered as a 'functional' disease, there are no criteria on pH study or histology to accurately make the diagnosis of NERD. Using magnifying endoscopy based on the color chip system (EG3470ZK, Pentax, Hamburg, Germany, or 160Z, Olympus Medical Systems, Hamburg, Germany), Kiesslich *et al.* reported that patients with NERD showed endoscopic signs of minimal change esophagitis significantly more frequently than those in a non-reflux group.[25] Therefore, NBI is expected to overcome the limitation of invisible muscosal alterations, because it has the potential to visualize superficial and small esophageal lesions attributable to GERD that cannot be seen by conventional white light endoscopy.

Sharma *et al.* reported a feasibility study of NBI using a magnifying endoscope (Olympus GIF-Q240Z, Olympus Medical Systems, Tokyo, Japan) in patients with GERD.[26] Patients with GERD had increased number, dilation, and tortuosity of IPCL compared with controls. Patients with NERD also showed increased number and dilation of IPCL compared with controls. Multivariate analysis showed that increased number and dilation of IPCL were the best predictors of diagnosing both GERD and NERD. Then, they concluded that NBI endoscopy might improve the diagnosis of GERD, particularly in patients with NERD. The results of this pilot study indicate that NERD should be re-evaluated by novel technologies in prospective controlled trials.

Using a high-resolution endoscopy (Olympus GIF-H260, Olympus Medical Systems) with the RGB sequential illumination NBI system, Lee *et al.* reported that NBI improved the intra-observer and inter-observer reproducibility in grading esophagitis compared with conventional white light imaging.[27] As the observer variability in endoscopic diagnosis of GERD is an important issue for standardization, NBI is expected to improve judgment in the grading of esophagitis.

Barrett's esophagus

Barrett's esophagus (BE) is the most important risk factor for esophageal adenocarcinoma, and the incidence is rapidly increasing in developed countries.[28,29] The most important risk factors for development of BE is chronic acid reflux, which stimulates the replacement of distal esophageal squamous epithelium with specialized intestinal metaplasia (SIM). BE is defined as the presence of SIM histologically.

As esophageal adenocarcinoma has a poor prognosis when detected at an advanced stage, endoscopic surveillance has been recommended to detect high-grade dysplasia and mucosal neoplasia for patients with BE. However, it is difficult to identify the dysplastic and early neoplastic changes in SIM by conventional white light endoscopy. Four-quadrant random biopsies at 1–2 cm intervals within SIM[30,31] are widely accepted, but leads to sampling error because it is a 'blind approach'. Although Kara *et al.* reported that most high-grade dysplasias or early cancers in BE

could be identified by high resolution endoscopy alone if they showed macroscopically visible abnormalities, few cases were detected by random biopsy alone.[32] This indicates that random biopsies increase the number of negative biopsies.

To carry out the accuracy of biopsies, improved visualization of Barrett's columnar epithelium, and capability to distinguish metaplasia from dysplasia or neoplasia are needed. Chromoendoscopy using indigocarmine or acetic acid allows biopsies to be more specifically targeted. However, this requires additional equipment, solution, time and training. In contrast, NBI with magnifying endoscopy enables us to visualize the details of mucosal surface and capillary networks without additional equipment or dye solutions. Hamamoto *et al.* first reported that NBI could provide better visualization of the esophagogastric junction, net-like capillary vessels and columnar-lined esophagus (BE) than conventional white light endoscopy.[33] Kara *et al.* reported that indigocarmine chromoendoscopy and NBI were comparable to make diagnosis of high-grade dysplasia or early cancer in BE.[34]

Several studies[32,35–38] on the characteristics of SIM and high-grade dysplasia observed by high-resolution NBI endoscopy have been reported (Table 1). Most of these studies have assessed both pit pattern (mucosal pattern) and superficial microvascular pattern. SIM is generally characterized by villous mucosal pattern with regular microvasculature, whereas high-grade dysplasia shows irregular/distorted mucosal pattern with irregular microvasculature. Combination of the typical features of pit pattern (mucosal pattern) and superficial microvascular pattern confers diagnostic accuracy and reproducibility.[36,38]

Detection of mucosal dysplasia is most important in patients with BE to prevent the progression to invasive carcinoma. Using a high resolution endoscopy (H180, Olympus Medical Systems) with color chip NBI system (Evis Exera II, Olympus Medical Systems), Wolfsen *et al.*[39] reported that high resolution NBI can detect dysplastic lesions more efficiently with fewer biopsy samples compared with standard resolution white light endoscopy (Q160, Olympus Medical Systems). This means that NBI is no longer a standard examination to detect high grade dysplasia and superficial cancer in patients with BE. In addition, differences in video endoscopy systems seem to be not so important when we discuss diagnostic capabilities in BE.

Table 1 Characteristics of SIM and high-grade dysplasia in Barrett's esophagus according to NBI endoscopy

Author	Year	NBI system	Endoscope	Magnification	SIM		High-grade dysplasia	
					Mucosal pattern	Vascular pattern	Mucosal pattern	Vascular pattern
MA Kara	2005	RGB sequential illuination	240Z	+	Villous/gyrus-forming pattern	Regular vascular pattern	Irregular/disrupted pattern	Irregular vascular pattern/Abnormal blood vessel
P Sharma	2006	RGB sequential illuination	240Z	+	Ridge/villous pattern	–	Irregular/distorted pattern	–
GA Anagnostopoulos	2006	RGB sequential illuination	240Z	+	Regular microstructual pattern (tubular/linear/villous)	Absent microvascular pattern	Irregular microstructual pattern	Irregular microvascular pattern
K Goda	2007	RGB sequential illuination	240Z	+	Cerebriform fine mucosal pattern	Ivy- or DNA-like capillary pattern	–	–
R Singh	2008	RGB sequential illuination	240Z	+	Ridge/villous pattern Absent pit	Regular microvasculature	Distorted pit	Irregular microvasculature

NBI, narrow band imaging; RGB, red-green-blue; SIM, specialized intestinal metaplasia.

Stomach

Gastric intestinal metaplasia

In patients with atrophic gastritis, intestinal metaplasia (IM) is a risk factor for intestinal type adenocarcinoma.[40] However, conventional endoscopy is insensitive for diagnosing IM because of the high rate of inter-observer variability and poor correlation with histological confirmation. At present, the diagnosis of IM has to be made by histological evaluation. However, if we could correctly identify IM endoscopically, we could evaluate the risk of gastric adenocarcinoma without biopsy.

Uedo *et al.*[41] reported that the appearance of a light blue crest in the gastric mucosa by magnifying NBI was highly accurate to predict the presence of histological IM. Bansal *et al.*[42] also reported that NBI helps predict the presence of *in vivo* histopathological conditions, such as non-*Helicobacter pylori* gastritis, *H. pylori* gastritis and IM. These results indicate that the entire

surface area of the stomach can be evaluated without the need for biopsy. This would also confer the advantages of decreasing cost and unnecessary biopsy, and reducing examination time.

Gastric cancer

In the stomach, NBI should be used during magnifying observation. This is because the light intensity under the NBI filter is scant, and thus the non-magnifying image appears dark compared with the white light image. In addition, the non-magnifying NBI image becomes noisy using the electrical enhancement required to keep the endoscopic image bright. As the result of these considerations, non-magnifying NBI observation is not suitable as a screening examination in the stomach. When conducted by those disregarding these limitations, endoscopic diagnosis could be misleading and lesions could be missed.

Accordingly, we should not discuss the detection rate of cancer by NBI in the stomach. As for detailed endoscopic examination in the stomach, it has been impossible to make a correct diagnosis of flat gastric cancer by endoscopy alone, because such lesions sometimes show similar pathology to gastritis. Using only high definition endoscopy (Q240Z, Olympus Medical Systems) without a NBI system, Yao *et al.*[43] reported that magnifying observation of microvascular architecture was useful to discriminate flat reddened carcinoma from gastritis. They proposed unique endoscopic findings for intestinal type gastric cancers as follows; (i) presence of a demarcation line between the reddish lesion and the surrounding mucosa; (ii) disappearance of the regular subepithelial capillary network (SECN); and (iii) the presence of an irregular microvascular pattern within the flat lesions.[7,8] These characteristics based on mucosal and microvascular architecture are also reliable makers for differentiating between depressed gastric cancer and benign lesions.

In cases of elevated gastric neoplasia, it is sometimes impossible to visualize the microvascular architecture, because a white opaque substance (WOS) obscures the subepithelial microvascular architecture. The WOS could not be visualized by non-magnifying observations, even by high resolution endoscopy.[44] While high resolution magnifying endoscopy with both white light imaging and NBI could detect the WOS, visualization is clearer in the latter. Elevated gastric cancer showed WOS in either a regular distribution or as regular microvascular architecture. This feature is useful for discriminating adenomas from cancer of the stomach.

Nakayoshi *et al.*[45] classified the microvascular pattern of superficial gastric cancers based on their magnifying NBI images into three groups: (i) fine network pattern; (ii) corkscrew pattern; and (iii) unclassified pattern. They also compared the endoscopic pattern with the histological findings. Fine network pattern and corkscrew pattern are useful to identify differentiated adenocarcinoma and undifferentiated adenocarcinoma, respectively. Magnifying NBI is also useful to identify the lateral extension of superficial gastric cancer.[46] This strength is very important in detailed assessment of the safety margin and to improve the targeting of endoscopic treatment for neoplastic lesions.

Gastric adenoma

Most gastric adenomas are of elevated type. While depressed type adenomas are rare, they are clinically important because of the higher malignant potential than elevated adenomas. However, detection of depressed type adenomas has been difficult because endoscopic findings have not been clearly defined. Tamai *et al.*[47] reported that, by magnifying NBI, depressed type adenomas display a regular ultra-fine pattern in which a network of microvessels is composed of small and regular circles. This differs from the irregular fine network pattern of well differentiated adenocarcinomas.

Duodenum

Duodenal neoplasm

Ampullary tumors are relatively rare neoplasms and data on their endoscopic appearances are correspondingly limited. However, the assessment of ampullary lesions has particular relevance for the surveillance of patients with familial adenomatous polyposis, because such individuals are at risk of duodenal cancer. As differential diagnosis between adenomas and adenocarcinoma in the ampullary region is difficult, biopsies are routinely taken for differential diagnosis. In addition, the evaluation of lateral margins of the neoplasm is also difficult. Accordingly, the method of case selection for treatment, and the type of management remain controversial.

Uchiyama *et al.*[48] reported that inflammatory changes showed oval-shaped villi, while all adenomas and adenocarcinomas displayed pinecone leaf-shaped villi, and/or an irregular/non-structured pattern. Itoi *et al.*[49] reported that NBI is more useful than indigocarmine chromoendoscopy and white light image to identify the tumor margin at this site.

Colon

Colorectal neoplasms

Because the majority of colorectal cancers (CRC) arise from adenomas,[50] early detection and removal of colorectal adenoma is important to reduce both the incidence of colorectal cancer (CRC) and cancer-related death.[51,52] Colonoscopy is the standard method to detect adenomas.[53] However, previous studies have shown polyp miss rates of 10–30% during back-to-back colonoscopy.[54–56] The reasons for these high miss rates might include poor insertion and withdrawal techniques of the operator, poor bowel preparation, and/or limitation of imaging method, and so on.[57]

Indigocarmine chromoendoscopy significantly increases the detection rate of small flat and/or depressed lesions.[58–60] However, as was already mentioned in the 'Barrett's Esophagus' session, chromoendoscopy requires additional equipment and dye solutions, and is time consuming. Again, NBI can be done only by pushing the button on the endoscopy to change the filter. Thus, NBI is expected to be an instantaneous method to accurately detect adenoma.

As for detection capability of colorectal neoplasm, seven studies[61–67] have been published comparing NBI and white light observations (Table 2). Three studies[62,66,68] used the color CCD chip NBI system and three used the RGB sequential illumination NBI system,[62,64,66] and one did not describe the technical details. Three studies used high resolution magnifying endoscope and three did not (one did not describe any detail). Taken together,

Table 2 Comparison of colorectal adenoma detection ability between white light image and NBI

Author	Year	Evaluation methods	Institute	No. endoscopists	*n* (pts)	Endoscopy system	Magnification	Modality	Results	*P*-value	Reference no.
DK Rex	2007	Prospective RCT	Single	1	434	Color CCD chip	–		Percentage of patients with >1 adenoma (all size)	46	
								WLI	67%	NS	
								NBI	65%		
JE East	2007	Back to back fashion (WLI followed by NBI)	Single	3	62	RGB sequentia illuination	+		Percentage of patients with >1 adenoma		51
								WLI	27%	0.004	
								NBI	42%		
A Adler	2008	Prospective RCT	Single	7	401	not mentioned	not mentioned		Percentage of patients with adenoma		47
								WLI	16.7%	NS	
								NBI	22.7%		
T Inoue	2008	Prospective RCT	Single	6	243	RGB sequentia illuination	+/–		Percentage of patients with >1 adenoma		52
								WLI	34%	0.2	
								NBI	42%		
									Percentage of patients with >1 adenoma (<5mm)		
								WLI	17%	0.011	
								NBI	30%		
									Total no. adenoma		
								WLI	65	0.046	
								NBI	102		
A Rastogi	2008	Back to back fashion after polypectomy (WLI followed by NBI)	Single	1	40	Color CCD chip system	–		Number of detected adenoma	NE	48
								WLI	43		
								NBI	29 additional adenomas		
T Uraoka	2008	Back to back fashion (WLI followed by NBI)	Single	5	47	RGB sequentia illuination	+		Number of detected neoplams		
								WLI	116	0.02	
								NBI	134		
									Miss ratio of flat neoplastic lesions		
								WLI	32%	NE	
								NBI	15%		
									Miss ratio of polypoid neoplastic lesions		
								WLI	15%	NE	
								NBI	9%		
T Kaltenbach	2008	Prospective RCT	Single	6	276	Color CCD chip	–		Miss ratio of adenoma (95%CI)		
								WLI	12.1% (7.2–18.6)	NS	
								NBI	12.6% (7.5–19.4)		
									Percentage of patients with neoplasm		
								WLI	44%	0.29	
								NBI	50%		

CCD, charge coupled device; CI, confidence interval; NBI, narrow band imaging; NE, not evaluated; NS, not significant; RCT, randomized controlled trial; WLI, white light image.

Table 3 Comparison of diiagnositic performance for neoplastic and non-neoplastic lesions between white light colonoscopy, chromoendoscopy and NBI

Author	Year	Evaluation method	Institute	No. endoscopists	*n* (polyp/pts)	NBI system	Magnification	Comparison	Endopoints	Assessment	Results
H Machida	2004	Pilot study	Single	2	43/34	RGB sequential illuination	+	NBI vs CE vs WLI	Differential diagnosis	Pit pattern (Kudo's classification) and vascular network	NBI = CE > WLI
MY Su	2006	Feasibility test	2 hospitals	3	110/78	RGB sequential illuination	–	NBI vs CE	Differential diagnosis	Pit pattern (Kudo's classification)	NBI = CE
HM Chiu	2007	Retrospective image review	2 hospitals	4	180/133	RGB sequential illuination	+	NBI vs CE vs WLI	Differential diagnosis	Pit pattern (Kudo's classification)	NBI = CE > WLI
M Hirata	2007	Retrospective study	Single	2	189/163	RGB sequential illuination	+	NBI alone	Prediction of histology	Vascular thickness & vascular iregularity	NBI can predict histologic grade and depth of invasion
M Hirata	2007	Retrospective study	Single	Not described	148/99	RGB sequential illuination	+	NBI alone	Differential diagnosis	Pit pattern (Kudo's classification)	NBI = CE
JJW Tischendorf	2007	Prospective RCT	Single	2	200/99	color CCD chip	+	NBI vs CE	Differential diagnosis	Pit pattern (Kudo's classification) and vascular intensity and shape	Pit patten (NBI = CE) Vascular pattern (NBI > CE)
JN Rogart	2007	Prospective polyp series	Single	4	265/131	color CCD chip	–	NBI vs WLI	Differential diagnosis	Pit pattern (Kudo's classification) and vascular color intensity	NBI = WLI
JE East	2008	Prospective polyp series	Single	1	33/20	RGB sequential illuination	+	NBI vs CE	Differential diagnosis	Pit pattern (Kudo's classification) and vascular pattern intensity	NBI = CE
T Katagiri	2008	Prospective polyp series	Single	1	139/104	RGB sequential illuination	+	NBI alone	Prediction of histology	Micro vessel shape	NBI capillary pattern can assess the degree of atypia
Y Sano	2008	Prospective polyp series	Single	1	150/92	RGB sequential illuination	+	NBI alone	Differential diagnosis	Visibility of meshed capillary pattern	NBI meshed capillary pattern is useful for differential diagnosis
S Sikka	2008	Retrospective image review	Single	2	80/31	color CCD chip	–	NBI vs WLI	Prediction of histology	Modified Kudo's classification and vascular markig	NBI > WLI
A Rostagi	2008	Feasibility test	Single	1	123/40	color CCD chip	–	NBI vs WLI	Prediction of histology	Mucosal and vascular pattern	NBI can predict histologic diagnosis

CCD, charge coupled device; CE, chromoendoscopy; NBI, narrow band imaging; RGB, red-green-blue; WLI, white light image.

when a high resolution magnifying endoscope is combined with a RGB sequential illumination NBI system, the adenoma detection rate appears to be significantly increased. In contrast, if a non-magnifying endoscope is used, the adenoma detection rate will not improve, even by using high resolution. However, NBI is useful to detect additional adenomas in the back-to-back fashion after white light observation.[62,65] To date, there are no data on direct comparison of detection of neoplasms in the colon (and also other parts of the gastrointestinal tract) between the RGB sequential illumination NBI system and color CCD chip NBI system. Therefore, investigation is required to establish whether there are any differences of detection power between these technologies, using large-scale multicenter prospective randomized control studies.

Overlooking neoplastic colonic polyps has been one of the major problems to solve in CRC screening programs; such oversight can lead to the development of colon cancer within a few years after an apparently complete colonoscopy. While Kaltenbach *et al.*[67] reported that NBI did not reduce the miss rate of colorectal neoplasms compared with white light observation, Uraoka *et al.*[66] reported that the miss ratio of both flat and polypoid neoplasic lesions decreased by the use of NBI compared with white light observation. It is unclear whether this difference depends on the difference of NBI systems. A ratio of high detection rates and low missing rates is ideal for any cancer screening test. Therefore, the future challenge is to investigate which system (RGB sequential or color chip) is superior for decreasing the missing rate of colorectal neoplasms.

Machida *et al.*[13] first evaluated the diagnostic performance of the NBI system for colorectal lesions. In their pilot study, NBI with magnifying endoscope achieved better visualization of the mucosal vascular network pattern than conventional white light imaging. Further, the accuracy for diagnosing neoplastic polyps by NBI was equivalent to chromoendoscopy. To date, 12 studies[13,65,68–77] on diagnostic performance of NBI have been published (Table 3). Of them, eight studies were aimed at differential diagnosis, six showed comparable performance between NBI and chromoendoscopy, three showed superiority of NBI to white light imaging, and one study showed the superiority of NBI to chromoendoscopy when assessment had been based on microvascular pattern. One study showed that NBI 'meshed capillary pattern' was useful for differential diagnosis. The remaining four studies were aimed at prediction of polyp histology. All four reported that NBI assessment based on vascular pattern was useful in predicting histology of colorectal polyps.

A recent meta-analysis showed that, in the colon, there was no significant difference in diagnostic accuracy for neoplasm between NBI and chromoendoscopy, but NBI was significantly more accurate than white light observation alone.[78] In addition, this meta-analysis showed that simple assessment of the microvasculature is enough to make an accurate diagnosis of colonic neoplasm. This means that NBI could become the standard endoscopic procedure for detection and diagnosis of colonic neoplasms.

Conclusions

Narrow band imaging is now a promising endoscopic technology to improve the detection and diagnostic accuracy of neoplastic lesions in the head and neck region and the gastrointestinal tract. However, most studies have been conducted at a single institution and carried out by one or a few observers. Thus, we should confirm these data with a large scale prospective randomized trial to standardize both technological aspects and precise indications for NBI.

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Teleteaching endoscopy: the feasibility of real-time, uncompressed video transmission by using advanced-network technologies

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Background: Teleteaching of endoscopy has been limited by the exorbitant cost and time inherent in high-quality digital endoscopy video transmission. The Digital Video Transport System (DVTS) transmitted over advanced networks, such as Internet2 and the Asia-Pacific Advanced Network (APAN), provides a unique infrastructure for sharing uncompressed digital videos of endoscopy. This may allow high-quality, real-time, international training of diagnostic and therapeutic endoscopy techniques at a low cost.

Objective: To test the proof of concept of long-distance teaching through live, interactive, high-resolution video transmission by using advanced networks and the DVTS. We used teleteaching of image-enhanced endoscopy techniques as a model..

Design: Prospective multicenter pilot study.

Setting and Participants: Trainees, faculty, and staff at 3 international endoscopy units.

Intervention: An image-enhanced endoscopy video lecture with advanced-network technologies.

Main Outcome Measurements: We compared image-based prelecture and postlecture test scores and secondarily assessed technical feasibility and quality.

Results: The DVTS transmitted over advanced networks successfully transmitted uncompressed, high-resolution, digital lectures with endoscopic video (digital video format 720 × 480 pixels). Postsession scores improved. Participants highly rated the technical and informational quality. The majority reported a definite interest in participating in future sessions, with a mean rating (out of 5 [scale 1-5]) of 4.7 ± 0.5.

Limitations: Pilot study with a limited number of participants and sessions.

Conclusion: The DVTS transmitted over advanced networks such as Internet2 and APAN can provide the infrastructure for transmission of high-resolution, uncompressed video endoscopy for the purpose of teleteaching endoscopy.

Progress in endoscopy requires the efficient and effective transfer of knowledge. A promising method of transferring knowledge is through teleteaching.[1-4] Teleteaching of endoscopy has been limited by the exorbitant cost and amount of time inherent in high-quality, digital endoscopy video transmission.[5,6] The development of high-bandwidth networks—Internet2 and the Asia-Pacific Advanced Network (APAN)—coupled with a specialized program to transmit high-resolution, uncompressed video, such as the Digital Video Transport System (DVTS), may provide the ability to teleteach endoscopy to academic centers worldwide.

The advanced networks, such as Internet2 and APAN, are a nonprofit consortium, which develops and deploys applications and technologies for high-speed intensive data transfer within the research and education community. The physical network combines several robust,

Abbreviations: APAN, Asia-Pacific Advanced Network; DVTS, Digital Video Transport System; IEE, image-enhanced endoscopy.

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logistically distinct but related networks to create a superbroadband Internet line with a backbone of up to 10 gigabits per second—key to the effective and efficient transfer of large-bandwidth data (ie, real-time conferencing, high-definition video). Internet2 is available at more than 210 U.S. and 1000 Asian institutions and is connected globally to other similar networks. The client software for DVTS is freely available, simple, and inexpensive. It is designed for high-quality video and audio transmission over the Internet, with minimal image compression and low latency between sites during videoconferencing.[7] Video compression typically requires a powerful computer processor and time to render. Eliminating compression allows the utilization of commercially available personal computers and a minimal time lag between sending and receiving images, respectively. Thus, the use of the DVTS transmitted over an advanced network is a potential vehicle for teleteaching high-quality video endoscopy with live participant interaction.

We aimed to test the proof of concept of long-distance teleteaching through live, interactive, high-resolution video transmission by using advanced networks and the DVTS. We used teleteaching of image-enhanced endoscopy (IEE) techniques as a model, whereby dye, optical, and electronic methods are applied during endoscopic examination to augment the detection and diagnosis of subtle, precancerous lesions and early GI mucosal cancers.[8]

METHODS

Participants and study design

We conducted a prospective, multicenter, pilot study. Endoscopy units at 3 international sites—Veterans Affairs Palo Alto and Stanford University, USA; Kyoto University, Japan; and Kyushu University, Japan—participated. Hanyang University, South Korea, served as a technical site. We provided participants with written information about the approved study as requested by our institutional review board.

Teleteaching technology and content

We connected sites to high-speed networks with large bandwidths and used the DVTS for bidirectional video and audio. Two streams signaled from each site—the participants obtained by a digital video camera and the lecture and video images from the computer processor—without display or transfer of personally identifiable information.

Kyushu researchers led the system configuration. They connected stations with the DVTS by using the QualImage/Quatre server software (Information Services International-Dentsu, Ltd, Tokyo, Japan), and distributed uncompressed images. Upon request, they merged the 4 DVTS signals onto 1 screen and then returned the signal to the other centers for display (Fig. 1) or, alternatively, from the speaker or video images only (Fig. 2).

Capsule Summary

What is already known on this topic

- Information on advanced endoscopic techniques is often difficult to disseminate because of the limited number of experts, costs of travel, and deficiencies in learning in a text-based, didactic lecture.

What this study adds to our knowledge

- Image-based, prelecture and postlecture test scores from trainees, faculty, and staff at 3 international endoscopy units revealed that digital video transmitted over advanced networks resulted in effective endoscopy training.

Over a 6-week period, we organized four 1-hour sessions on the use of IEE in the detection and diagnosis of precancerous lesions and early GI cancers. Experts in IEE provided the lectures, in English, at 1600 Pacific standard time and 0800 Japan time.

Endpoints and statistics

We aimed to determine the teaching efficacy by using the DVTS transmission system of high-resolution images and video over advanced networks. Participants completed image-based, prelecture and postlecture tests in real-time (Appendix, available online at www.giejournal.org). We secondarily assessed the technical feasibility and quality (Appendix).

In this pilot study, we were careful to perform inferential statistical analyses. We focused on descriptive analyses and primarily used histograms for data illustration.

RESULTS

Participants (n = 42) showed overall improvement from 57% ± 25% prelecture test scores to 83% ± 17% postlecture test scores. Scores improved across sessions: 35% (53% ± 27% to 88% ± 15%; n = 15) in session 2, 31% (46% ± 23% to 77% ± 20%; n = 12) in session 3, and 13% (70% ± 18% to 83% ± 17%; n = 15) in session 4. Figure 3 illustrates the learning trend over each session and site. Participants highly rated the usefulness of the endoscopy images and videos (5.0 ± 0.4 [scale 1-5]), the commentary from remote and local faculty (4.8 ± 0.5), and the interactions with remote (4.9 ± 0.4) and local audiences (4.8 ± 0.5).

The large bandwidth (about 100 megabits per second) provided network stability during the televideo conference. The measured latency between sites is shown in Table 1. One interruption of the transmission occurred during the first (practice) session from Kyoto University because of a laptop malfunction and required network reconnection. The other 3 sites remained connected during the 8-minute period.

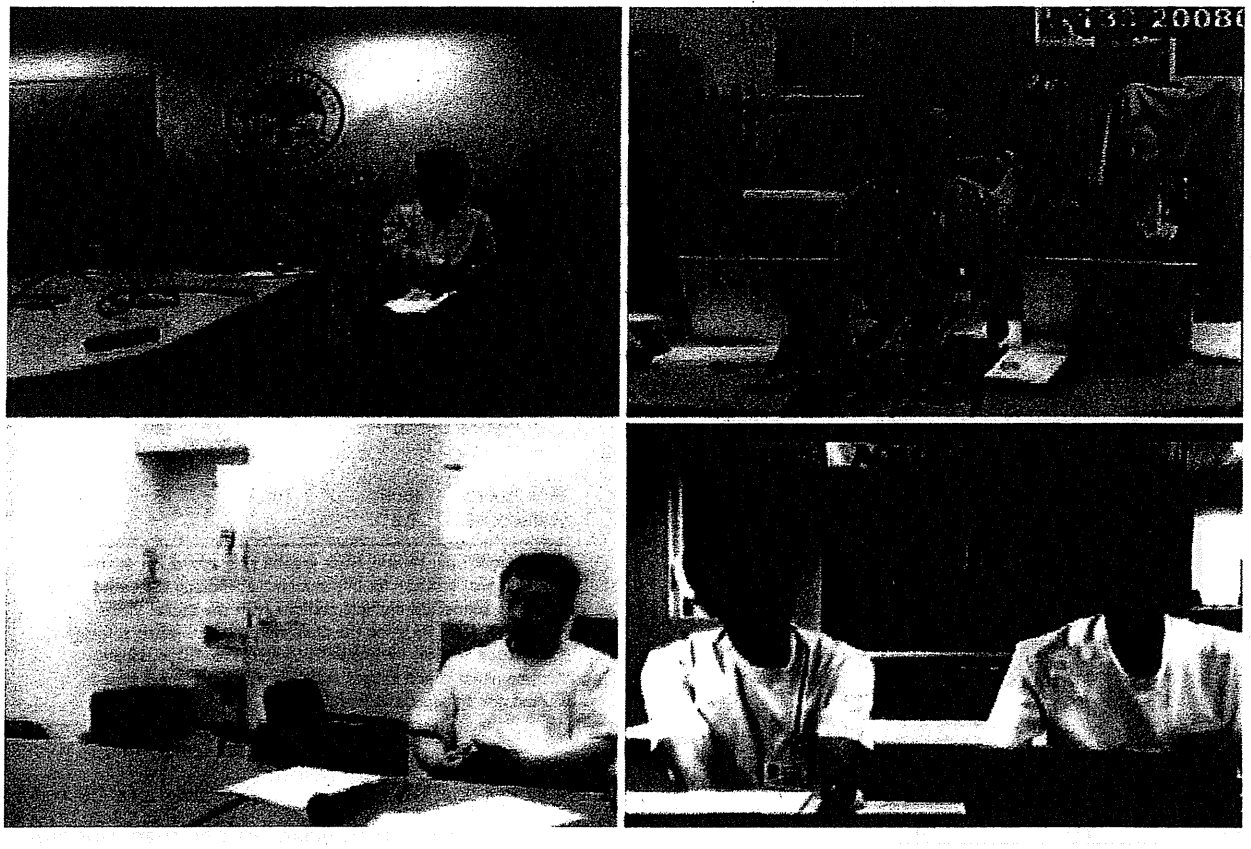

Figure 1. Screen capture of a composite image from the 4 participating centers. The original program was transmitted at 720 × 480 pixels digital video resolution with 30 frames per second.

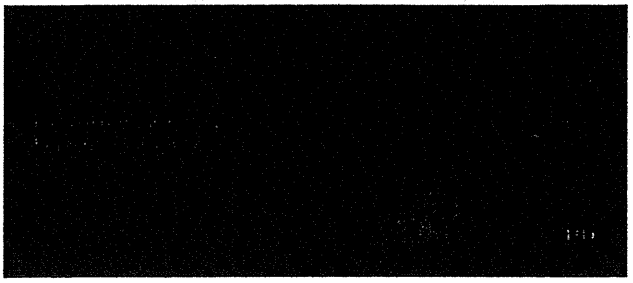

Figure 2. Screen capture from a video lecture display during one of the programs.

The majority of participants reported a definite interest in participating in future, similar sessions—mean rating of 4.7 ± 0.5 (range 3-5). Participants highly rated the technical quality of the endoscopic images and audio and video teleconferencing, with a mean rating of 4.7 ± 0.5, 4.5 ± 0.6, and 4.7 ± 0.5, respectively.

DISCUSSION

Progress in endoscopy requires the dissemination of information about technique and technology. The global availability of, demand for, and practice of endoscopy poses an increasing challenge to effectively and efficiently disseminate the art and science of endoscopic techniques and technologies. It is important to meet this challenge; otherwise, the potential benefit of endoscopy to more patients cannot be realized. Over the years, we have provided resources for learning endoscopy through self-study multimedia programs, publications, and lectures. Recently, we explored an interactive education mechanism—one that would allow us to interactively teach and learn endoscopy through real-time sharing of high-resolution endoscopy images and videos with other endoscopy centers at a minimal cost.

Herein, we describe a potential use of the super-broadband Internet connection for transmitting information (intensive endoscopic movies) for the purpose of teaching diagnostic and therapeutic endoscopy techniques that require images with fine details. We report that the infrastructure that is currently available to most academic centers worldwide can support such an effort by using advanced networks, such as Internet2, and the DVTS. The effort appears to be promising, as evidenced by participants' increasing understanding of a spectrum of concepts of IEE. The use of advanced networks and the DVTS is also highly efficient. It would have been otherwise costly and time prohibitive for the numerous speakers of the 4 IEE

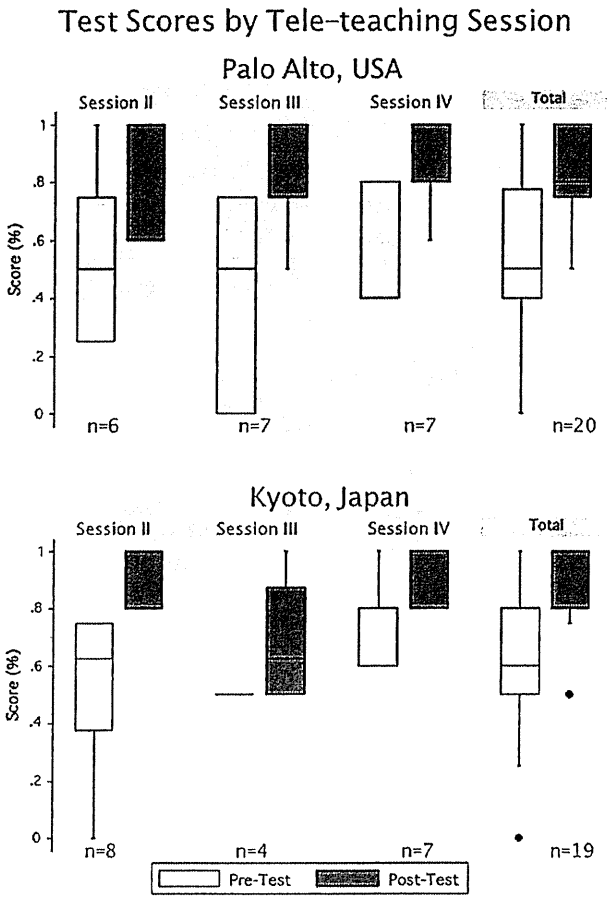

Figure 3. Distribution of participants' prelecture and postlecture scores, according to session number and site location. The height of the "box" displays the interquartile range (IQR), with the 25th and 75th percentiles representing the lower and upper edges of the box, respectively. The middle horizontal line across the box is the median. Error bars extend from the box to show the minimum and maximum data points (whiskers). The lower whisker represents the 25th percentile minus 1.5× IQR, and the upper whisker represents the 75th percentile plus 1.5× IQR. Values outside of the whiskers are defined as outliers.

sessions to travel to the participating sites of this study. Comparatively, the annual Internet2 university membership dues and network participation fee is $60,000,[9] and the DVTS is free software. The hardware consists of an off-the-shelf digital video camera, audio gear, and a computer with Firewire-400 port and display monitor. Furthermore, once the technology infrastructure is in place, it can support numerous applications, such as distance learning, real-time clinical consultation, and live case demonstrations.[7,10]

We recognize a number of potential limitations of the use of advanced networks, such as Internet2 and APAN, and the DVTS. Namely, the robust technology has intensive bandwidth requirements. We used infrastructures of a super-broadband Internet line that was already available in our respective institutions. Though this infrastructure exists at most academic centers worldwide, the deployment and application of its resources may not be readily available. In addition, the current operation of the DVTS requires a supporting technician, rather than operating as a turn-key system. Although the line used is super broad, there was a limitation because of the lag time required for the data to be transmitted from one site to another. Albeit minimal, this lag time was appreciated only during conversation.

TABLE 1. Study technology characteristics of advanced networks using the Digital Video Transport System

Technology	Kyushu University* Fukuoka, Japan	VA Palo Alto,Stanford University, Palo Alto, California, USA	Kyoto University, Kyoto, Japan	Hanyang University, Seoul, South Korea
Bandwidth				
Local	100 Mbps	1 Gbps	100 Mbps	1 Gbps
Remote	10 Gbps	1 Gbps	10 Gbps	1 Gbps
Transmission distance (km)	0	9000	500	550
Time latency (milliseconds)	about 0.01	100	5	10

Mbps, Megabit per second; *Gbps*, gigabit per second; *km*, kilometer.
*The Research Institute for Information Technology at Kyushu University connected multiple stations with the Digital Video Transport System by using the QuallmageQuatre server software (Information Services International-Dentsu, Ltd; Tokyo, Japan). Uncompressed digital images were distributed to the 3 sites without any analog conversion.

In summary, we have described our preliminary experience of using a new communication tool and system to potentially disseminate endoscopy effectively and efficiently. Further efforts to explore the use of the already available super-broadband Internet network for televideo endoscopy teaching are needed.

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