REVIEW

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Advances in gastrointestinal tract visualization. Part I

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Abstract: Although endoscopy techniques have undergone impressive development in recent years, there remains a need for better visualization in specific circumstances, e.g. detection of flat colorectal lesions. Less threatening and much less painful alternatives to conventional colonoscopy are also of a particular interest for patients. Many techniques are under investigation, but chromoendoscopy is a technique with proven clinical usefulness. Instead of real-time endoscopic imaging methods, such as narrow band imaging (NBI) and Fuji intelligent chromo endoscopy (FICE), also self-propelled colonoscopy devices *Aer-O-Scope* and *Invendoscope* are briefly discussed. Ideal endoscopy should have the ability to screen large mucosal areas, together with providing high diagnostic accuracy, and also need to be patient friendly. It is very probable that future success in clinical application will appertain to the combination several techniques.

Key words: endoscopy, Narrow Band Imaging (NBI), Fuji Intelligent Chromo Endoscopy (FICE), self-propelled colonoscopy

INTRODUCTION

Although endoscopy techniques have undergone impressive development in recent years, there remains a need for better visualization in specific circumstances, e.g. detection of flat colorectal lesions. During classic endoscopic examination, mucosal lesions are detected and identified by changes in colour and irregularity of surface. Many techniques enhancing the luminal visibility are under investigation, but only chromo endoscopy is a technique with proven clinical usefulness. Colonoscopy is a medical procedure usually causing pain and discomfort for patients, generally due to passing impediments such as alpha loops and difficult colon sections. Sedationless colonoscopy will result in fewer potential complications, higher patient turnover and significant savings in costs, thereby helping to optimize the processes for health care providers.

The aim of the first part of the review is a brief presentation of the newly developed methods for improving real-time endoscopic visualization such as narrow band imaging (NBI) and Fuji intelligent chromo endoscopy (FICE). Prototype **s**elf-propelled colonoscopy devices: *Aer-O-Scope* and *Invendoscope,* and the prototype for an auxiliary imaging device – *Third Eye Rectoscope,* are also described. Different point measurement and still imaging methods, such as fluorescence spectroscopy, optical coherence tomography, confocal laser microscopy, Raman spectroscopy and elastic (light) scattering spectroscopy will be the scope of the second part of the review.

NARROW BAND IMAGING (NBI)

NBI (Olympus Corp., Japan) is a novel endoscopic technique using narrow-band width filters in a red-green-blue (R/G/B) sequential illumination system. The result of such visualization is an image at distinct levels of the mucosa, increasing the contrast between the epithelial surface and the subjacent vascular pattern which significantly enhances the accuracy of diagnosis by better detection and identification of mucosal pathologic changes [1]. The depth of penetration into the mucosa depends on the wavelength used. Blue band for superficial, green band for intermediate and red band – designated for deep mucosa penetration; the blue band filter is composed to correspond to the peak absorption spectrum of hemoglobin to enhance the visualization of capillary vessels on surface mucosa [2]. In contrast to the classic endoscopes using the xenon source of white light, NBI equipped devices capture the reflected light by a charge-coupled device (CCD) chips (colour CCD – nonsequential and monocrome CCD-sequential) in order to reconstruct the image. The depth of penetration differs because the full range of visible spectrum is not covered due to gaps between the narrow bands. As a result, the difference between morphological images reconstructed for each of the three channels (R, G, and B), which corresponds with the surface (capillaries), middle, and deep layers of the mucosa, respectively.

The main advantage of NBI is that it was the first real-time imaging system giving the same contrast enhancement capabilities as chromoendoscopy, but without the necessity of using dye agents [3, 4]. Practical application of NBI is based on the possibility of assessing the superficial mucosal vascular network and analysis of the surface architecture of the epithelium (pit pattern) [5]. The disorganization of the both pit and vascular patterns of the gastrointestinal mucosa seen in high-intensity blue light may enhance the early detection of the premalignant/malignant neoplastic and inflammatory lesions of the esophagus, stomach and large bowel. Therefore, the basic clinical usefulness of NBI is the proper identification and localization of the biopsies in areas of mucosal metaplasia, dysplasia or carcinoma [6]. In the diagnosis of esophageal changes, the NBI provides an opportunity for better visualization of the intrapapillary capillary loops, which are important in the both diagnosis

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process and staging of early squamous cell esophageal cancer [7]. In the diagnosis of Barrett's esophagus, where the detection of intestinal metaplasia is of great importance, NBI helps to identify areas with distorted or disrupted fragments (e.g. severe dysplasia or superficial carcinoma) for precise biopsies. Categorization Barrett's esophagus is also easier when observing the pit pattern in NBI [3]. In the stomach, the difference of surface architecture of the mucosa and different vascular pattern in the fundus and antrum has been described with use the of NBI [8, 9], and, for example, in chronic atrophic gastritis changes in the vascular pattern correlate with the degree of mucosal atrophy [4]. Neoplastic changes may be suspected when lesions with irregular elevation or amorphous pattern are observed, since ulcers may show both regular and irregular pit patterns [4]. NBI visualization of the duodenum is very useful in patients with celiac disease for classification of villous atrophy [4]. The main advantage of NBA in colonoscopy is the opportunity for early detection of flat adenomas and cancers and more precise differentiation between hyperplastic and adenomatous polyps, as well as the possibility of identification dysplastic lesions in patients with inflammatory bowel disease [4]. With the use of NBA, overall detection of adenoma may be improved by > 40% [10]. However, a multi-centre study from Europe comparing NBA with conventional white light colonoscopy found that initially there was improved adenoma detection with narrow-band imaging, but as the trial progressed, these differences disappeared [11].

FUJI INTELLIGENT CHROMO ENDOSCOPY (FICE)

The FICE imaging technique (Fujinon Corp., Japan) is based on Spectral Estimation Technology, which allows the production of an image of a given, dedicated wavelength of light from an ordinary endoscopic image arithmetically processed in the video processor. The picture captured by the electronic scope is send to the Spectral Estimating Matrix processing circuit in the processor, where various pixilated spectrums of the picture are estimated. After the spectrums by pixels are estimated, the implementation of imaging on a single wavelength is possible. Single wavelength images are randomly selected, and assigned to red (R550), green (G500) and blue (B470) respectively to compose and display a FICE enhanced colour image. The main advantage of this technique is better characterization of mucosal tissue structures, which enhances both the detection and identification of pathologic changes within the GI tract. Actually, FICE is considered a system which enables physicians to supplement differences in endoscopy experience and to diagnose clinical findings more accurately. The practical significance of FICE in clinical practice is comparable with NBI and based on the possibility to assess the superficial mucosal vascular network, and analysis of the surface architecture of the epithelium (pit pattern). The utility of FICE high-resolution imaging was also tested within the small bowel in patients with celiac disease [12].

AER-O-SCOPE

Expanding possibilities of self-propelled colonoscope technology arise with the implementation of the *Aer-O-Scope* system (GI View Ltd., Israel). *Aer-O-Scope* is a self-propelled capsule endoscope that uses a double-balloon system. This technique is generally operator independent and its propulsion mechanism has been demonstrated on the animal model [13]. This device has a unique multi-directional visualization system, (360° circumferential vision with 25° forward vision and 25° of retrovision) which provides high resolution video images of the colon inner surface that are displayed on a screen for real time viewing.

This unique colonoscope was demonstrated to be effective in an *ex-vivo* pig model using sewn beads to mimic colon polyps [13, 14]. The data on human clinical studies with this novel visualization system are not yet available; however it is predicted to be a safe, less threatening and much less painful alternative to conventional colonoscopy.

INVENDOSCOPY

Invendoscopy (Invendo Medical GmbH, Germany) is another alternative to conversional colonoscopy. This self-propelled colonoscopy system contains a disposable endoscope with a CMOS chip and a hydraulically operated bending section controlled with a joystick. The propulsion mechanism consists of a sheath folded back on itself. A drive mechanism rotates the sheath from inside to the outside, pushing the camera in the colonoscope tip forward. The inverted sleeve technology in combination with the small bending diameter minimizes the forces on the colon walls and prevents looping, minimizing pain and discomfort for the patient. The device is equipped with a centralized 3.2 mm working channel with the support of the deflectable electrohydraulic tip; therefore it can be also used for routine therapeutic procedures such as polypectomy [15].

To date, the results of only one clinical study on the efficacy of this method performed in Germany is available. In this study, the colonoscope could be passed into the cecum in 79% of 24 patients, with a mean time to reach the cecum of 26 minutes. Participants rated the examination on an overall score (1.77 points; range, 1-3), using a self assessed pain scale (pain scale range was from 1 = no discomfort to 6 = severe pain) [15].

THIRD EYE RECTOSCOPE

Technical capacities of the Third Eye Retroscope (TER) – prototype of an auxiliary imaging device (Avantis Medical Systems, California, USA) were presented on a polyp model in 2006. During colonoscopy, this very small device is provided with a catheter which is passed down the working channel of the colonoscope and positioned several centimeters distal to the colonoscope tip. The catheter retroflexes so that a lens faces the colonoscope, and the view images are visible on one screen demonstrating the standard forward view, and on a second screen demonstrating a retrograde view provided by the TER prototype. This novel imaging technique improved the detection rates for implanted polyps located on the proximal aspect of haustral folds from 12% with the forward view to 81% with both views [16]. The data on human clinical studies with this novel visualization system are not yet available.

CONCLUSION

Ideal endoscopy should have the ability to screen large mucosal areas, together with providing high diagnostic accuracy in order to provide the early diagnosis of malignant and premalignant changes of the mucosa. Chromo- and magnifying endoscopes are exciting new tools and offer detailed analysis of the mucosal surface such as pit pattern architecture and vascular network. The latest developments in endoscopy provide significant improvement in imaging technology and are also connected with patient convenience by reducing both pain and the risk of potential complications.

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