Computer-aided diagnosis of colorectal polyp histology by using a real-time image recognition system and narrow-band imaging magnifying colonoscopy

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Background and Aims: It is necessary to establish cost-effective examinations and treatments for diminutive colorectal tumors that consider the treatment risk and surveillance interval after treatment. The Preservation and Incorporation of Valuable Endoscopic Innovations (PIVI) committee of the American Society for Gastrointestinal Endoscopy published a statement recommending the establishment of endoscopic techniques that practice the resect and discard strategy. The aims of this study were to evaluate whether our newly developed real-time image recognition system can predict histologic diagnoses of colorectal lesions depicted on narrow-band imaging and to satisfy some problems with the PIVI recommendations.

Methods: We enrolled 41 patients who had undergone endoscopic resection of 118 colorectal lesions (45 non-neoplastic lesions and 73 neoplastic lesions). We compared the results of real-time image recognition system analysis with that of narrow-band imaging diagnosis and evaluated the correlation between image analysis and the pathological results.

Results: Concordance between the endoscopic diagnosis and diagnosis by a real-time image recognition system with a support vector machine output value was 97.5% (115/118). Accuracy between the histologic findings of diminutive colorectal lesions (polyps) and diagnosis by a real-time image recognition system with a support vector machine output value was 93.2% (sensitivity, 93.0%; specificity, 93.3%; positive predictive value (PPV), 93.0%; and negative predictive value, 93.3%).

Conclusions: Although further investigation is necessary to establish our computer-aided diagnosis system, this real-time image recognition system may satisfy the PIVI recommendations and be useful for predicting the histology of colorectal tumors.

Colorectal tumors are among the most common tumors worldwide. Most adenomas are considered premalignant lesions,[1] and the number of adenomas is a good determining factor for predicting the long-term risk of advanced neoplasia.[2-4] A recent report showed that colonoscopy and sigmoidoscopy are associated with a reduced incidence of cancer.[5] It is necessary to establish cost-effective examinations and treatments for small colorectal tumors that consider the treatment risk and surveillance interval after treatment. The Preservation and Incorporation of Valuable Endoscopic Innovations (PIVI) committee of the American Society for Gastrointestinal Endoscopy published a statement on establishing endoscopic techniques that practice the resect and discard strategy.[6] Therefore, it is necessary to provide endoscopic treatment that is consistent with the PIVI recommendations. Recently, combining the narrow-band imaging (NBI) system and magnifying endoscopy allows simple and clear visualization of the microscopic structures of the superficial mucosa and its capillary patterns.[7] NBI magnifying endoscopy may be useful for providing a precise endoscopic diagnosis of a histological diagnosis. Various NBI classifications such as the Hiroshima classification,[8] which correlates with the histologic

Abbreviations: NBI, narrow-band imaging; NPV, negative predictive value; PIVI, Preservation and Incorporation of Valuable Endoscopic Innovations; PPV, positive predictive value; ROI, region of interest; SIFT, scale-invariant feature transform; SVM, support vector machine.

DISCLOSURE: *All authors disclosed no financial relationships relevant to this article.*

0016-5107/$36.00
http://dx.doi.org/10.1016/j.gie.2015.08.004

Received March 25, 2015. Accepted August 2, 2015.

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features, is clinically useful for determining treatment options for colorectal tumors.[9-11] However, an NBI-based diagnosis requires training and experience, and an objective diagnosis is necessary. Therefore, we are developing a computerized system[12] that provides a more objective diagnosis, which allows nonexpert endoscopists to achieve a high diagnostic accuracy. We report an improved software program that can evaluate colorectal lesions using real-time colonoscopy. We evaluated the use of this real-time image recognition system by using NBI magnifying colonoscopy with a support vector machine (SVM) output value to satisfy some problems in the PIVI recommendations.

MATERIALS AND METHODS

Specimen preparation and instruments

We examined 118 lesions (88 lesions, ≤5 mm; 12 lesions, 6–9 mm; and 18 lesions, ≥10 mm) obtained from 41 patients (29 male and 12 female, 67.3 ± 7.9 years of age) who underwent EMR, endoscopic submucosal dissection, and biopsy for colorectal lesions. The patients were treated at Hiroshima University Hospital between October 2014 and March 2015. Patients with sessile serrated adenomas and traditional serrated adenomas were excluded. Pathologic examinations were performed by using hematoxylin and eosin–stained sections by a single GI pathologist blinded to the endoscopic and real-time image recognition system diagnosis. Pathology was used as the criterion standard.

The intervals for postpolypectomy surveillance that would be recommended by using the real-time image recognition system instead of endoscopic predictions of histology were compared with those that would be recommended by using the pathologic findings. The recommended follow-up intervals from the U.S. Multi-Society Task Force and American Cancer Society guideline[13] were used.

The study received full approval from the Ethics Committee of Hiroshima University, was performed at the Department of Endoscopy and Medicine, Hiroshima University, Hiroshima, Japan, and was conducted in accordance with the guidelines of the Declaration of Helsinki. Patients and/or their family members provided informed consent for the endoscopic examination and pathologic study of resected specimens.

Instruments used in this study included a magnifying videoscope system (CF-H260AZI; Olympus Optical Co, Ltd, Tokyo, Japan), which provides a magnifying power of up to 80× (optical magnification), and the EVIS LUCERA ELITE Video System Center CV-290 (Olympus Medical Systems, Tokyo, Japan). Lesions detected by conventional colonoscopy were observed by using NBI at the optical maximum magnification, and the obtained NBI magnifying images were analyzed in real time by using our newly developed image recognition system.

COLONOSCOPY PROCEDURE AND NBI CHARACTERIZATION OF THE LESIONS

An endoscopist with 6 years of colonoscopy experience focused images at the optical maximum magnification, analyzed the NBI magnifying images in focus without motion blur of the colorectal lesions in real time, and obtained still NBI magnifying colorectal lesion images. Another endoscopist with more than 20 years of colonoscopy experience who was blinded to the histologic findings and real-time image recognition system findings classified the still NBI magnifying images as type A or type B–C with a high or low confidence prediction according to the Hiroshima classification system after the procedure. In our study, high- and low-confidence predictions were made in 95.8% (113/118) and 4.2% (5/118) of lesions, respectively. The Hiroshima classification divides microvessels and the surface structure in a narrow-band image into types A, B, or C. This classification system reportedly correlates with histological diagnoses.[8] Type A corresponds to nonneoplastic lesions, whereas type B–C corresponds to neoplastic lesions.

Real-time image recognition system

For the quantitative analysis of colorectal lesions, we developed a custom software program that can display features of endoscopic images and quantify each image according to the corresponding features on the training image. To develop the image recognition system, we prepared a set of 2247 cutout training images (504 type A and 1743 types B–C3 images) from 1262 colorectal lesions that were collected before this study at the optical maximum NBI magnification in the same manner as in this study at Hiroshima University Hospital. The set did not include images that were considered unsuitable for evaluation (exclusion criteria were out-of-focus images, motion blurred images, and those with halation). We used a bag-of-features representation in which an image is represented by a histogram of visual words that are produced by a hierarchical k-means clustering of scale-invariant feature transform (SIFT) descriptors as local features. In this study, SIFT descriptors, in which each descriptor is a 128-dimensional vector, were computed at points on a regular grid of 5 pixels with dense spacing and also at 2 different scales (5 and 7 pixels) of local patches, which were centered at each grid point. A regular grid was used because the texture of each narrow-band image filled the whole image. An SVM with a linear kernel was used as the classifier (Fig. 1).

By using an SVM and logistic regression, we calculated the SVM output value for the real-time recognition system. The simple logistic function was defined by the following formula: $P(t) = 1/(1 + e^{-t})$, where P denotes the SVM output value, t denotes the distance from the boundary line for type A or B–C, and e is the exponential function.