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Accurate Classification of Diminutive Colorectal Polyps Using Computer-Aided Analysis

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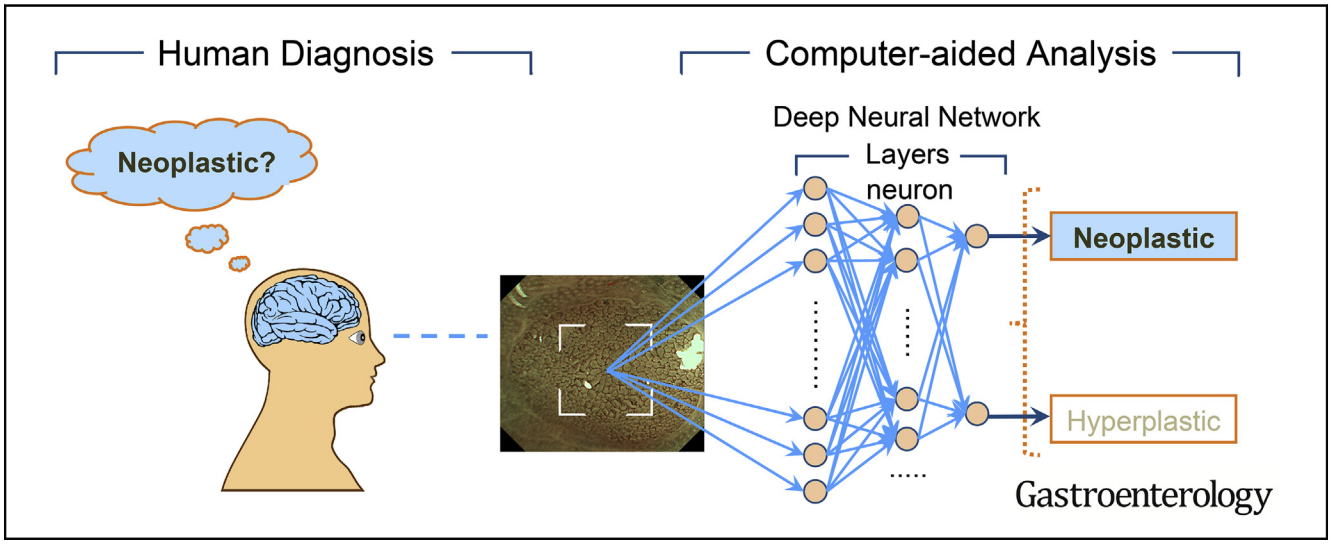

BACKGROUND & AIMS: Narrow-band imaging is an image-enhanced form of endoscopy used to observed microstructures and capillaries of the mucosal epithelium which allows for real-time prediction of histologic features of colorectal polyps. However, narrow-band imaging expertise is required to differentiate hyperplastic from neoplastic polyps with high levels of accuracy. We developed and tested a system of computer-aided diagnosis with a deep neural network (DNN-CAD) to analyze narrow-band images of diminutive colorectal polyps. **METHODS:** We collected 1476 images of neoplastic polyps and 681 images of hyperplastic polyps, obtained from the picture archiving and communications system database in a tertiary hospital in Taiwan. Histologic findings from the polyps were also collected and used as the reference standard. The images and data were used to train the DNN. A test set of images (96 hyperplastic and 188 neoplastic polyps, smaller than 5 mm), obtained from patients who underwent colonoscopies from March 2017 through August 2017, was then used to test the diagnostic ability of the DNN-CAD vs endoscopists (2 expert and 4 novice), who were asked to classify the images of the test set as neoplastic or hyperplastic. Their classifications were compared with findings from histologic analysis. The primary outcome measures were diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic time. The accuracy, sensitivity, specificity, PPV, NPV, and diagnostic time were compared among DNN-CAD, the novice endoscopists, and the expert endoscopists. The study was designed to detect a difference of 10% in accuracy by a 2-sided McNemar test. **RESULTS:** In the test set, the DNN-CAD identified neoplastic or hyperplastic polyps with 96.3% sensitivity, 78.1% specificity, a PPV of 89.6%, and a NPV of 91.5%. Fewer than half of the novice endoscopists classified polyps with a NPV of 90% (their NPVs ranged from 73.9% to 84.0%). DNN-CAD classified polyps as neoplastic or hyperplastic in 0.45 ± 0.07 seconds—shorter than the time required by experts (1.54 ± 1.30 seconds) and nonexperts (1.77 ± 1.37 seconds) (both $P < .001$). DNN-CAD classified polyps with perfect intra-observer agreement (kappa score of 1). There was a low level of intra-observer and inter-observer agreement in classification among endoscopists. **CONCLUSIONS:** We developed a system called DNN-CAD to identify neoplastic or hyperplastic colorectal polyps less than 5 mm. The system classified polyps with a PPV of 89.6%, and a NPV of 91.5%, and in a shorter time than endoscopists. This deep-learning model has potential for not only endoscopic image recognition but for other forms of medical image analysis, including sonography, computed tomography, and magnetic resonance images.

EDITOR'S NOTES

BACKGROUND AND CONTEXT

Narrow-band imaging (NBI) is an image-enhanced form of endoscopy used to observed microstructures and capillaries of the mucosal epithelium that allows for real-time prediction of histologic features of colorectal polyps.

NEW FINDINGS

The authors developed a computer-aided system of deep neural networks to identify neoplastic or hyperplastic colorectal polyps less than 5 mm and this model classified polyps with high accuracy.

LIMITATIONS

This computer-aided analysis was based on only magnifying narrow-band images of high-quality.

IMPACT

The deep-learning model has potential for not only endoscopic image recognition but for other forms of medical image analysis, including sonography, computed tomography, and magnetic resonance images.

Keywords: Colon Cancer Detection; Machine Learning; Cost-effectiveness; Magnifying.

Background and Aims

Colorectal cancer (CRC) is one of the most common malignancies worldwide and is currently the third leading cause of cancer death in Taiwan.[1] Most CRCs arise from preexisting adenomas, and the adenoma–carcinoma sequence offers an opportunity for the screening and prevention of CRC.[2] Colonoscopy with adenoma resection can reduce the incidence of CRC by as much as 80% and the associated mortality by 50%.[3,4] However, endoscopic resection of hyperplastic polyps exacerbates medical costs, including those for resection and unnecessary pathologic evaluation, because malignant transformations are rare. Therefore, accurate diagnosis before endoscopic resection is important to avoid inappropriate resection, and, further, optical diagnosis has the potential to improve the cost-effectiveness and efficiency of colonoscopy.[5]

Narrow-band imaging (NBI) is a type of equipment-based image-enhanced endoscopy that has been used to observe the microstructures and capillaries of the mucosal epithelium and allows real-time histologic predictions based on colorectal polyps.[6] The NBI International Colorectal Endoscopic classification is a diagnostic criterion for hyperplastic and adenomatous polyps using NBI.[7] An optical diagnosis of NBI in clinical practice requires expertise to differentiate polyp histology with high accuracy. Recent studies have reported that the results of optical diagnosis in a nonacademic setting were disappointing.[8,9]

To overcome this limitation, computer-aided diagnosis (CAD) has been developed.[10–12] Although these computer-aided systems have excellent potential as diagnostic aids in colonoscopic examination, access to the technology is limited because of institution-specific and localized software implementations. We developed and validated a novel system of computer-aided diagnosis with a deep neural network (DNN-CAD) to analyze magnifying NBI of diminutive colorectal polyps.

Materials and Methods

The study was approved by the Ethics Committee of Tri-Service General Hospital, Taipei, Taiwan, and was conducted at the hospital's endoscopy center. All authors had access to the study data and reviewed and approved the final manuscript. Instruments used in this study included colonoscopes with an optical magnification function (CF-H260AZI, PCF-Q260AZI, CF-HQ290AZI; Olympus Optical Co, Ltd, Tokyo, Japan), and the EVIS LUCERAELITE Video System Center CV-290 (Olympus Medical Systems). Polyps detected by white-light colonoscopy were observed with NBI at the maximum magnification power.

Setup of the Image Classifier With a Deep Neural Network

The medical–engineering collaborative project between Tri-Service General Hospital and the Computer Science Department of National Chiao Tung University, initiated in 2016, resulted in marked improvements of our original software. The algorithm of the retraining model using TensorFlow (https://www.tensorflow.org/),[13] comprises 4 steps: (i) image collection, (ii) model learning, (iii) creation of a classifier, and (iv) diagnostic output.

In 2016, 2 endoscopists with more than 10 years of colonoscopy experience reviewed colonoscopic images with NBI and full magnification from the picture archiving and communications system database in Tri-Service General Hospital and, as the training set for TensorFlow, selected appropriate regions of interest (ROI) that contained high-quality images for visual inspection. Multiple ROIs in the same polyp were collected to reduce the selection bias; ROI were then cropped from the endoscopic images captured from the video signal with a resolution of 1920 × 1080. These images were classified as hyperplastic or neoplastic polyps according to the NBI International Colorectal Endoscopic classification system (Figure 1). The histologic reports regarding these polyps were also collected. If the NBI International Colorectal Endoscopic classification of a polyp was not compatible with the histologic report, the histologic image was retrieved and reevaluated. Three gastrointestinal pathologists—two attending staff members (H.S.L., Y.J.P.) and 1 senior fellow (M.J.L.)—provided histologic assessments to determine the type of lesion. The final diagnosis was based on NBI images and adjusted by the histologic report. To set up the DNN-CAD, 1476 images of neoplastic polyps and 681 images of hyperplastic polyps were collected as the training set.

Abbreviations used in this paper: **CAD, computer-aided diagnosis; CRC, colorectal cancer; DNN-CAD, computer-aided diagnosis with a deep neural network; NBI, narrow-band imaging; NPV, negative predictive value; PIVI, Preservation and Incorporation of Valuable Endoscopic Innovations; PPV, positive predictive value; ROI, regions of interest.**

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