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*Endoscopic optical coherence tomography and angiography for gastroenterology applications*

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# Endoscopic optical coherence tomography and angiography for gastroenterology applications

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## Abstract

Endoscopic optical coherence tomography (OCT) angiography enables volumetric coregistered architectural and microvasculature imaging of the human gastrointestinal tract *in vivo*. In this talk, we will discuss technical advances and clinical gastroenterology applications with the endoscopic OCT angiography technique.

**Keywords:** optical coherence tomography, angiography, endoscopic imaging, gastroenterology, gastrointestinal

## I Introduction

Optical coherence tomography (OCT) can provide noninvasive imaging of the tissue architecture without requiring exogenous contrast agents [1]. Leveraging from the Fourier domain detection techniques and miniature imaging catheters, endoscopic OCT enables volumetric imaging of the human gastrointestinal (GI) tract *in vivo* [2, 3]. Although there have been several previous studies investigating the diagnostic potential of endoscopic OCT for various GI diseases, for example, Barrett's esophagus (BE) and BE associated dysplasia [4, 5], and esophageal squamous cell carcinoma [6], the accuracy for detecting the presence of neoplasms has been limited. On the contrary, angiogenesis has been reported as an essential step toward the tumor formation and spreading, which might occur earlier than tissue architectural changes [7]. By detecting the variations of OCT signal intensity between consecutive OCT frames (B-scans), OCT angiography (OCTA) enables volumetric imaging of the subsurface tissue microvasculatures [8]. However, the translation of OCTA to gastroenterology application is challenging due to the limited OCT imaging speed and the lack of proper imaging catheter design. We have

recently developed an ultrahigh speed endoscopic OCT system with a 600 kHz axial scan rate. In combination with a micromotor imaging catheter, this technology allows depth-resolved, *en face* visualization of the tissue architectures and three-dimensional visualization of the subsurface microvasculature of the human GI tract [9]. We have collected co-registered OCT and OCTA datasets from a variety of upper and lower GI tract diseases, including BE and BE associated dysplasia, gastric antral vascular ectasia (GAVE), and inflammatory bowel disease. The representative cross-sectional and *en face* OCT and OCTA images showing characteristic features of these pathologies are presented. We also report two novel catheter designs enabling OCT and OCTA imaging.

## II Methods

A prototype ultrahigh speed endoscopic OCT system for clinical gastroenterology application using a MEMS-tunable VCSEL light source and a micromotor imaging catheter was used in this study. The details of this new technology have been described in detail [9]. Briefly, the MEMS-tunable light source with the central wavelength at 1.3  $\mu\text{m}$  was driven with a 300 kHz sinusoidal signal, allowing a 600 kHz axial (depth) scan rate and the

micromotor imaging had a frame rate of 400 frames per second. The axial and transverse OCT image resolution was  $\sim 8\ \mu\text{m}$  and  $\sim 20\ \mu\text{m}$ , respectively. Each OCT/OCTA acquisition imaged an area of 10 mm (circumferential) x 16 mm (longitudinal) in  $\sim 8$  seconds.

The study was performed at the Veterans Affairs Boston Healthcare System (VABHS) under institutional review board approved protocols at the VABHS, Harvard Medical School, and MIT. Written informed consent was obtained prior to endoscopic OCT imaging.

### III Results

Figure 1 shows an example coregistered *en face* OCT and OCTA images from a nodular region (arrow, inset Fig. 1A) identified in the endoscopy session of a 58-year-old man with dysplastic BE. The mucosal nodule was resected endoscopically and histopathology confirmed the nodule as focal HGD (inset, Fig. 1C). A loss of normal layered esophageal mucosal architecture was observed on OCT (Fig. 1B). *En face* structural OCT exhibited a non-uniform, irregular, and distorted mucosal pattern with enlarged and elongated crypts (arrows, Fig. 1A). In addition, some BE glands with irregular size and shape were identified (stars, Fig. 1A). *En face* OCTA showed increased vascularity with abnormal/disorganized branching and various sizes (arrows).

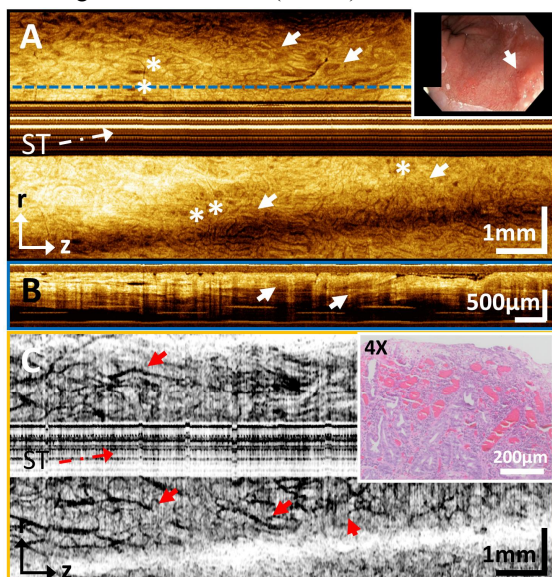


Figure 1. *En face* OCT and OCTA of BE with high-grade dysplasia (HGD) at a depth of  $170\ \mu\text{m}$ . (A) *En face* OCT image shows an abnormal surface mucosa pattern (arrows) with

irregular and dilated glands (red star). (B) Cross-sectional OCT image. (C) *En face* OCTA shows a complex and abnormal vascular pattern. Inset (A): Endoscopic image of the imaged site. Inset (C): Histopathology of the resected nodule specimen from the imaged region. Scale bars:  $200\ \mu\text{m}$ .

### IV Conclusions

The ability to visualize volumetric tissue architecture and microvasculature promises to improve detection of pathology and assessment of treatment efficacy. Preliminary results indicate that endoscopic OCT and OCTA can be a viable adjunct to other advanced endoscopic imaging techniques.

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