Catheter-based High-resolution Optical Coherence Tomography

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Abstract

Coronary artery disease and gastrointestinal (GI) cancers are among the top killers worldwide and in Singapore. Acute myocardial infarction (AMI, = heart attack) is one of the leading causes of global morbidity and mortality. Due to the high prevalence and high risk of AMI, identification of vulnerable plaque associated with AMI is critical for early detection and subsequently interventional treatment. Esophageal, gastric and colorectal cancers are among the commonly diagnosed cancers worldwide and early diagnosis of cancers is vital for the effective therapeutics. Neoplasia of the GI tracts which easily develops into cancer usually arises from the epithelium of the mucosa. It is impossible to take biopsy from coronary arteries. Even though biopsies can be routinely taken from GI tissues, the ability to detect early neoplastic changes in GI tracts at early stages is still limited. Therefore, a nondestructive imaging tool such as intracoronary/transendoscopic optical coherence tomography (OCT) is critical for improving diagnostic accuracy.

Owing to the histology-grade resolution and the non-invasive property, micro-OCT (μOCT) has become a promising alternative imaging tool to obtain depth-resolved real-time images. However, μOCT is still limited toward clinical translation to visualize GI tracts and coronary arteries to date due to the lack of a miniature and flexible probe to reach the target area of internal organs. In this dissertation, we proposed and fabricated a μOCT endomicroscopy system with a miniature and flexible probe, and then verified its feasibility for *ex vivo* visualization of the cellular-level morphological information in GI tracts and coronary arteries.

One of the major technical difficulties with μOCT to image tissue *in vivo* is well-known trade-off between the lateral resolution and depth-of-focus (DOF). A high lateral resolution with 1-3 μm usually shortens the DOF to tens of micrometers, which precludes practical applications of μOCT endomicroscopy when imaging through a relatively thick tissue depth. To moderately extend the DOF, a fiber-optics probe with annular apodization design was adopted in this study. Besides, we also employed a

rigid sheath surrounding the probe to mitigate the issue of limited DOF so that area of interests was properly maintained around the relative small focal region.

The dispersion caused by the optical components is another issue affecting the axial resolution and the image quality. To alleviate the effect of chromatic dispersion, we proposed a common path design, so that the sample and reference arms share almost the same path. In addition, the polarization mismatch between the sample and reference arms can be eliminated during the rotation of the probe for circumferential scanning.

The novelty of this study includes: 1) the annular apodization design of the probe that moderately extends the DOF without compromising lateral resolution; 2) usage of a rigid sheath to mitigate the limited DOF; 3) the common path design to minimize the dispersion and polarization mismatch; 4) We are the first in the world to demonstrate cellular resolution imaging of GI tissue and coronary atherosclerosis using a fiber-optic catheter. These results demonstrate μOCT endomicroscope is potentially an *in vivo* histological diagnostic tool for screening precancerous lesions and for the assessment of plaque vulnerability.