In Vivo Fluorescence Lifetime Imaging of Colorectal Polyps

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Abstract

Colorectal cancer (CRC) ranks third in cancer diagnoses worldwide and second in cancer-related deaths, with an increasing incidence rate in young adults under 50. Screening and surveillance tools aid in the early detection of CRC. However, current endoscopic procedures lack biochemical specificity, and non-endoscopic procedures like immunochemical tests are usually limited by poor sensitivity to early, low-grade dysplasia.

Our study used label-free fluorescence lifetime imaging (FLIm) to phenotype colonic polyps (e.g. inflammatory, hyperplastic, non- adenomatous, adenomatous, dysplasia, carcinoma). Utilizing pulse-sampling FLIm, we collected measurements from the patients' colonic mucosa using a 355 nm pulsed laser and three pre-filtered avalanche photodiode detectors (APDs) at 390/40 nm, 470/28 nm, and 540/50 nm spectral bands; therefore, captured lifetime changes in structural proteins like collagen and metabolic cofactors - nicotinamide adenine dinucleotide (NAD(P)H) and flavin adenine dinucleotide (FAD), respectively. We integrated the device with clinical colonoscopes using a 5-meter-long fiber optic probe compatible with the scope's 3.2 mm working channel. This setup allowed FLIm data acquisition in real-time (<1 μs/data point), and enabled to collect data from large surface areas.

We characterized the in vivo autofluorescence properties of polyps from 15 patients, including 134 FLIm measurements of colorectal polyps and their adjacent normal (deemed healthy) mucosa. The lifetime values of mucosa showed 9 - 15% variation across the patient cohort and across the colon anatomy. To resolve inter-patient variation, each lesion lifetime measurement was Z-score normalized using healthy adjacent mucosa as reference. Among the most commonly detected polyp types (tubular adenoma (TA, n = 33), sessile serrated adenoma (SSA, n = 7), hyperplastic polyp (HP, n = 7)), the normalized value suggested significant differences (Mann-Whitney U-test) across the spectral channels. At 390/40 nm, the TA profile showed significant differences to HP and SSA, while SSA showed significant differences to HP and TA at 470/28 and 540/50 nm. These findings suggest a potential role of FLIm in augmenting CRC screening and surveillance, particularly for early-stage lesions.