High-Resolution Optical Coherence Tomography Measurement of Ciliary Mucosa Thickness

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Introduction

Given the constant exposure to particles and pathogens, mucociliary clearance (MCC) emerges as a crucial defense mechanism in the human respiratory system. Primary ciliary dyskinesia (PCD), a genetic disorder, disrupts MCC, leading to recurrent respiratory infections. Due to the complex nature of PCD diagnosis, which requires various analyses, PCD is severely underdiagnosed, motivating research at the Institute of Applied Physics (IAP). Recent observations suggest a potential connection between ciliary wavelength and mucus thickness. To explore this further, this master's thesis aims to integrate Optical Coherence Tomography (OCT) into the existing high-speed reflection microscopy setup at the IAP, enabling simultaneous measurements to analyze the relation between average mucus thickness and mucociliary activity.

Materials and Methods

A swept-source OCT system featuring a central wavelength of 1040 nm and an axial resolution of 4.3 µm was integrated into the high-speed reflection microscope(Fig.1). Simultaneous measurements were performed on cultured ex vivo human nasal epithelial samples from healthy donors.

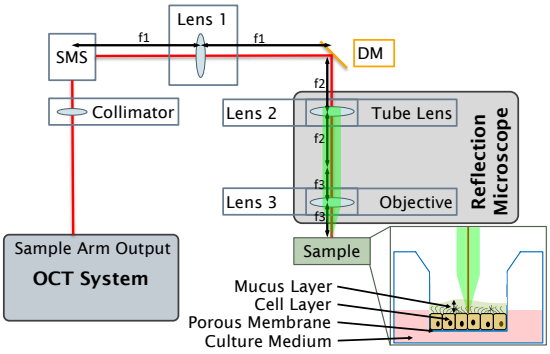

Fig. 1 Schematic representation of the integrated OCT system and the cultured muociliary epithelium sample. SMS: Scanning mirror system; DM: Dichroic mirror

To determine the mucus layer thickness in the recorded volumetric OCT scans, two subpixel detection algorithms were employed. These algorithms precisely identified the top surface of the porous membrane and the mucus surface in the OCT image. The mucus layer thickness was then determined by computing the depth difference between the precisely identified top surface of the porous membrane and the mucus surface, followed by subtracting the known cell layer thickness.

Results

The integrated OCT system in the reflection microscope setup allowed analysis of multiple mucociliary epithelium samples. Fig. 2 illustrates the determined mucus layer thickness from a selected sample with an average thickness of 51.4 µm.

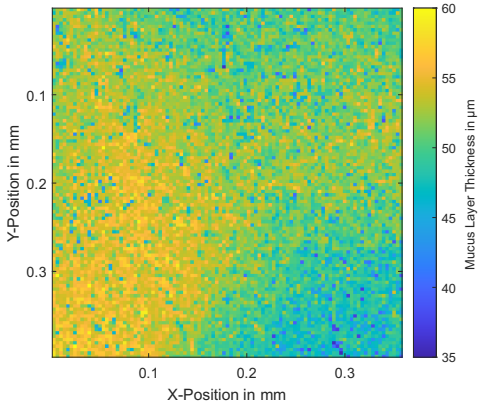

Fig. 2 Determined mucus layer thickness from a volumetric OCT scan.

Discussion

The determined averaged mucus layer thicknesses, in the range of 8.5 µm to 129 µm exhibit consistency with reported values in the literature. The comparison of the computed average mucus layer thickness with the ciliary wavelength measurements from the reflection microscope has provided valuable insights, revealing a trend of higher ciliary wavelength with increased average mucus layer thickness in some samples. To enhance the reliability of the analysis regarding the correlation between average mucus layer thickness and ciliary wavelength, additional measurements are essential in future studies.

References

Y. Ling et al., "Ex vivo visualization of human ciliated epithelium and quantitative analysis of induced flow dynamics by using optical coherence tomography", Lasers in surgery and medicine, 2017.

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