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High-speed three-dimensional imaging of the pulmonary alveoli

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Investigating the structure and function of pulmonary alveoli in vivo is crucial for understanding the normal and diseased lung. In particular, understanding the three-dimensional geometry and relationship of the terminal alveoli to their neighboring alveoli, alveolar ducts and acini during respiration would be a major advance. However, the lung is an inherently difficult organ to image in vivo and the peripheral lung has many compounding challenges not limited to its highly scattering micro architecture, large motion artifacts and difficult access through the bronchial tree.

In this study, we image the alveoli of fixed pig lungs using a high-speed high-resolution optical frequency domain imaging (OFDI) system that is endoscopically compatible for future in vivo imaging of human alveoli. Core imaging components include a rapidly swept wavelength source centered at 1310nm resulting in an A-line depth scan rate of 62,500Hz, a polarization diverse dual balanced receiver, and a high speed data acquisition system. Whole lungs were excised from normal piglets and inflation fixed at 15cm H₂O pressure using a modified Heitzman fixation technique. Lungs were air dried in a heated oven and sectioned into 500µm slices. Three-dimensional datasets were acquired from lung slices with 512x512x1024 voxels and a voxel dimension of 5x5x8µm. Datasets were acquired at 122 frames per second and 0.23 volumes per second - indicating the potential to acquire a three-dimensional volume within a single human respiratory cycle.

OFDI images reveal clear delineation of alveolar septal walls, demonstrating that high-speed three-dimensional visualization of air filled alveoli is feasible. The fixed lung data provides a strong foundation for investigating

the 3D structure and function of alveoli in vivo and suggests great promise for advancing our knowledge of the functional unit of the lung.

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