

Photoacoustic imaging as a tool for assessing the biomechanical behavior of aqueous veins and perilimbal sclera complex

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Background and Objective

There has been growth in the micro-invasive glaucoma surgeries (MIGS) to manage glaucoma by lowering intraocular pressure (IOP). The inability to predict the outcome of MIGS is a critical barrier to providing safe and effective interventions for patients. To address this critical barrier, our purpose is to advance knowledge on the aqueous humor dynamic mechanisms of the distal drainage in the aqueous veins in the perilimbal sclera. We developed an imaging technology to visualize the aqueous veins and perilimbal sclera in three dimension (3D) that will assist in understanding the biomechanical behaviors of the tissue components and their roles in IOP regulation.

Methods

Photoacoustic (PA) imaging generates acoustic signals from tissue components using their characteristic optical absorption spectra (Fig. 1a). PA imaging can visualize the tissue components in the anterior segment of the eye (Fig. 1b). Using porcine globes, an optical resolution PA imaging system was developed to resolve 3D architectures of the sclera containing collagen and lipid components at 1200 nm (Fig. 1d), and of the aqueous veins perfused with indocyanine green at 790 nm (Fig. 1c). The displacement of the spatial features within the tissue components were tracked during change of IOP. A finite element analysis (FEA) method was developed that computes tissue and vein strain fields from the displacement data.

Results/Discussion

Preliminary results show the capability of the imaging system in resolving tissue components (Fig. 1e) and strain gradients at the vein-sclera interface. Studies are ongoing to establish the relationship between vein strains, IOP, depth and size.

PA imaging and FEA is a potential tool to advance understanding of the biomechanical behaviors of the complex aqueous veins-perilimbal scleral system in IOP regulation. Advancing this knowledge on biomechanics and aqueous humor dynamics will enable clinicians to improve MIGS outcomes by choosing the appropriate surgery for a given patient based on the distal outflow system.

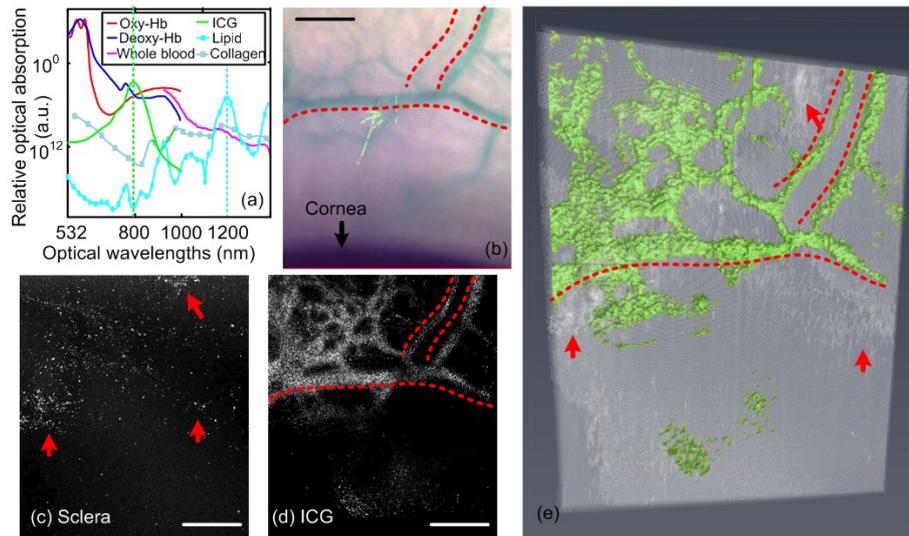


Fig. 1 Resolving aqueous veins and the surrounding scleral tissue using optical contrast enhancement by ICG and PAI. (a) Relative optical absorption spectra of relevant tissue components. (b) Picture of perlimbal scleral tissue in the nasal area of an eye perfused with 5% ICG. (c-d) PA images of scleral tissues and aqueous veins taken at 1200 nm and 790 nm, respectively. (e) Pseudocolor image co-registering (c) and (d) in 3D with aqueous veins in green and sclera in white/gray. Scale bars are 500 μm . The red dashed lines mark the same vessels in (b)(d)(e). The red arrows mark the spatial/texture features within the sclera in (c)(e).

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