ARVO 2020

View Abstract

CONTROL ID: 3359969

SUBMISSION ROLE: Abstract Submission

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ABSTRACT

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

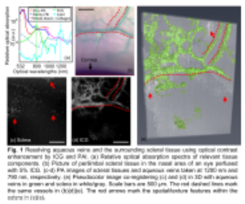
ABSTRACT BODY:

Purpose: 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). Combining high optical sensitivity and deep acoustic penetration, PA imaging is an ideal tool for visualizing the tissue components in the anterior segment of the eye. Using porcine globes, an optical resolution PA imaging system was developed to resolve 3D architectures of the aqueous veins perfused with indocyanine green at 790 nm, and of the sclera containing collagen and lipid components at 1200 nm. The displacement of the spatial features within the tissue components were tracked during change of IOP. A finite element analysis (FEA) model was developed that computes tissue and vein strain fields from the displacement data.

Results: This method has resolved aqueous veins and the sclera (Fig. 1b-d). The system captures a two-component image (Fig. 1e) within 6 seconds. A spatial tracking method tracks the displacement of the spatial features. The finite element mesh is created using the imaged spatial feature points, and can be used to calculate strains in both tissue components. Preliminary results show strain gradients at the vein-sclera interface. Studies are ongoing to establish the relationship between vein strains, IOP, depth and size.

Conclusions: 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.



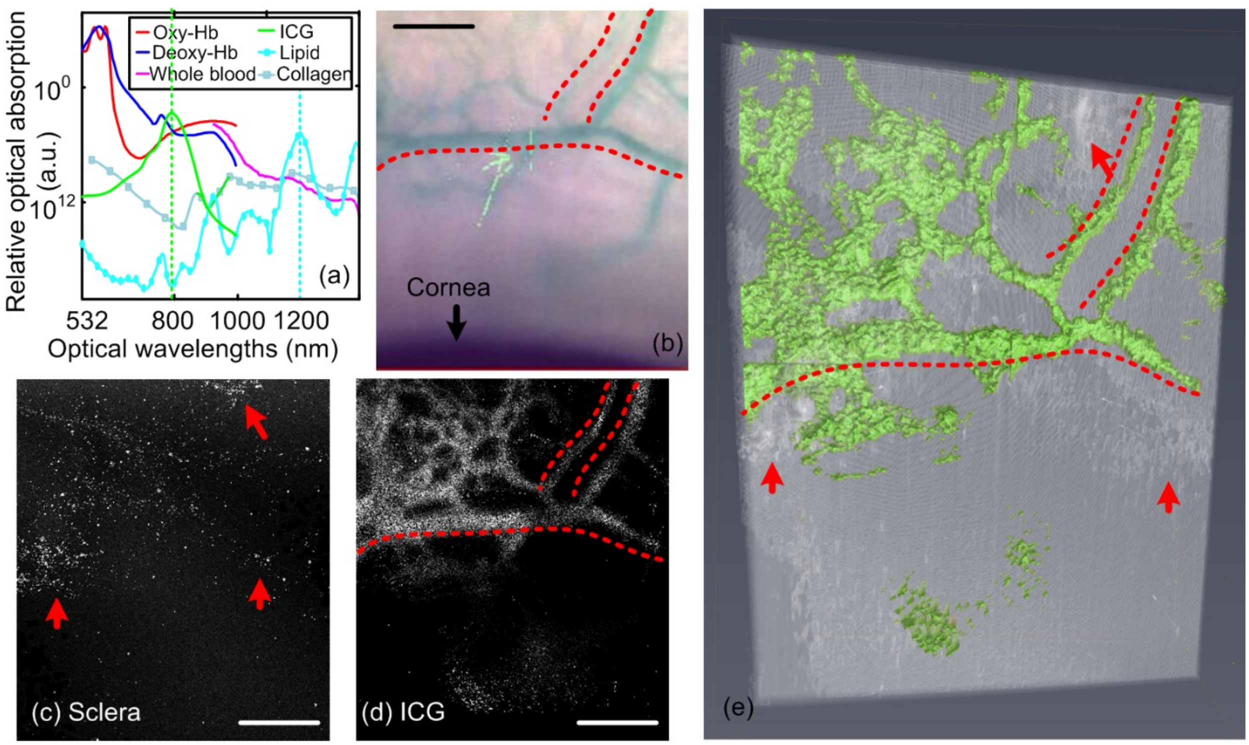


Fig. 1 Resolving aqueous veins and the surrounding scleral tissue using optical contrast enhancement by ICG and PAI. (a) Relative optical absorption spectra of relevant tissue components. (b) Picture of perilimbal scleral tissue in the nasal area of an eye perfused with 5% ICG. (c-d) PA images of scleral 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).