A Framework for Modelling Connective Tissue Changes in VIIP Syndrome

C. R. Ethier¹, L. Best², R. Gleason¹, L. Mulugeta³, J. G. Myers², E. S. Nelson² and B. Samuels⁴

¹Department of Biomedical Engineering, Georgia Institute of Technology/Emory University, Atlanta, GA
²NASA Glenn Research Center, Cleveland, OH
³Universities Space Research Association, Houston, TX
⁴Department of Ophthalmology, U. Alabama at Birmingham, Birmingham, AL

BACKGROUND AND HYPOTHESIS

Visual Impairment and Intracranial Pressure (VIIP) syndrome:
- A spectrum of ophthalmic changes including posterior globe flattening, choroidal folds, distension of the optic nerve sheath, kinking of the optic nerve and potentially permanent degradation of visual function.
- Slow onset and chronic condition.
- Similarities to certain ophthalmic findings in patients with raised intracranial pressure.

Hypothesis: (i) biomechanical factors play a role in VIIP, and (ii) connective tissue remodeling must be accounted for if we wish to understand the pathology of VIIP.

This work addresses 2 knowledge gaps: VIIP1. We do not know the etiological mechanisms and contributing risk factors for ocular structural and functional changes seen in-flight and postflight, and CV7. How are fluids redistributed in flight?

METHODS AND APPROACH

Modeling/Characterization of Ocular Biomechanics

Fluids Transport Models

Linkage/Tissue Remodeling Models

Figure 1. MRI images showing tortuous optic nerve sheath in VIIP syndrome (left) vs. a control eye (right).


Figure 2. Finite element modeling of ocular biomechanics. Top & bottom left: A patient-specific human optic nerve head, reconstructed from serial histologic sections, is embedded in a generic corneo-scleral shell, left: A patient-specific human optic nerve head, reconstructed from serial histologic sections, is embedded in a generic corneo-scleral shell, Bottom left: A patient-specific human optic nerve head, reconstructed from serial histologic sections, is embedded in a generic corneo-scleral shell, Bottom right: Courtesy of Dr Ian Campbell, Georgia Tech.

Validation of our implementation of the Kiel et al. equations for ocular fluid transport; Make measurements of optic nerve sheath physical parameters (see poster by Raykin et al.); Implement remodeling algorithm in FEBio (www.febio.org); Couple compartment model with ocular finite element model.

ACKNOWLEDGEMENTS

NASA grant NNX13AP91G [Microgravity-driven Optic Nerve/Sheath Remodeling Simulator (MONSTR Sim)]. We thank De Von Griffin for administrative support.