PREDICTING MICROGRAVITY INDUCED VISION CHANGES USING A CRANIAL VENOUS CIRCULATORY MODEL

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Understanding and mitigating astronaut vision impairment following short and long term space flight is an ongoing goal for NASA. The eye interacts with multiple fluid systems that may lead to the observed vision impairment including the circulatory system, the cerebrospinal fluid (CSF) system, and the aqueous humor regulatory system. These systems apply forces acting on the eye through venous pressure, intracranial pressure (ICP), and intraocular pressure (IOP), respectively. We theorize that combined changes in IOP, ICP, and venous pressure may occur during spaceflight that cause changes in the eye geometry resulting in changes in visual acuity. In addition, the loss of hydrostatic gradients in microgravity may lead to fluid shifts that further modify forces acting on the eye. We also theorize that long term modifications to the eye geometry to compensate for pressure changes may lead to irreversible deformation of tissues resulting in clinically observed phenomena (e.g. choroidal folds).

On this project we are combining computer modeling and human subject testing to determine how changes in hydrostatic gradients, fluid distribution, and cranial venous anatomy can influence microgravity-induced visual changes. To this end, we are developing a numerical model that predicts alterations in the hemodynamics of the cranial venous system produced by changes in hydrostatic gradients and fluid shifts. While models describing the cranial venous system exist in the literature, incorporation of hydrostatic gradient and fluid shift effects is novel. Our computer model consists of two parts: a system model and a structural model. The system model will describe flow and pressure in the circulatory system, the cerebral spinal fluid regulatory system, and the eye's aqueous humor regulatory system. The structural model will use a separate decoupled finite element model to describe the eye globe and structures contained within. Both the system level model and the structural model will account for changes in tissue properties that may be induced in microgravity, as well as effects of microgravity exposure duration. We plan to validate the computer model with magnetic resonance imaging (MRI) measurements of venous flow, venous volume, venous pressure, intracranial compliance, CSF volume and flow pulsatility during cephalad fluid shifts both supine and prone. We will also use measurements of intraocular pressure obtained outside of the MRI magnet. As a part of our modeling effort, we also plan to study anatomic variants that could alter the responses to a fluid shift. This model and supporting data will provide a means to develop hypotheses about how microgravity produces visual changes over time and may allow predictions about which subjects may be at risk for visual deficits associated with microgravity.

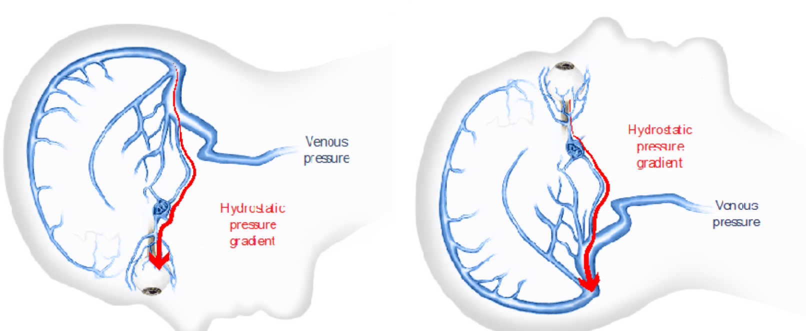

Figure 1. The ocular pressure changes that develop in microgravity involve an interaction between alterations in intracranial venous pressure and the loss of hydrostatic pressures.

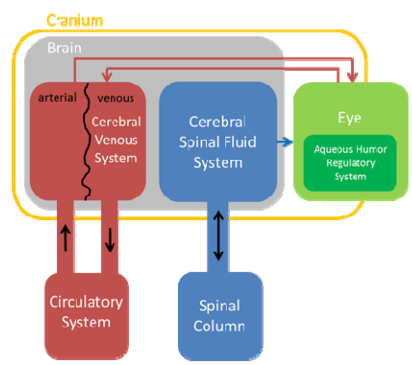

Figure 2. Schematic of the Cerebral/Cranial Venous Physiology Model