LMS Seminar

28 March 2024 at 2:00 pm - Room Jean Mandel

Biomechanics of the Optic Nerve Head and Applications to Glaucoma

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ABSTRACT

The optic nerve head is a small region in the posterior eyewall, where the axons of the retinal ganglion cells gather to exit the eye and form the optic nerve. The lamina cribrosa is a connective tissue structure in the optic nerve head composed of a stack of perforated plates that resemble a collagen beam network structure when viewed en face. The collagen beams support resident astrocytes and axons of the retinal ganglion cells as they exit the eye. Variations in the mechanical properties of the lamina cribrosa may contribute to the susceptibility and progression of glaucoma. Mouse models of glaucoma have been used to study the biomechanical effects of glaucomatous axon damage. The mouse optic nerve head does not have a connective tissue lamina cribrosa. It contains instead a network of astrocytes with long processes organized into structures that are evocative of the collagen beam structure of the human lamina cribrosa. In this presentation, I will describe our efforts to understand the structure-properties relationship of the optic nerve head tissues of human and mouse eyes. We developed a method using spectral domain optical coherence tomography (SD-OCT) and digital volume correlation (DVC) to measure in vivo the strain response of the optic nerve head tissues to changes in the intraocular pressure (IOP) in glaucoma patients by surgery or glaucoma medication. We recently adapted the method to measure the remodeling strain of the tissues years after IOP lowering. For mouse eyes, we developed ex-vivo inflation tests with optical imaging and 3D digital image correlation (3D-DIC) to measure the mechanical behavior of the lamina cribrosa and astrocytic lamina under physiological conditions. We also developed methods to quantitatively characterize the beam/pore network microstructure of the lamina cribrosa and astrocytic lamina. This has led to a greater understanding of how the lamina structures remodel with glaucoma.

BIOGRAPHY

Thao (Vicky) Nguyen is the Marlin U. Zimmerman Faculty Scholar and Professor in the Department of Mechanical Engineering at Johns Hopkins University. She also holds secondary appointments in Materials Science and Ophthalmology. She received her S.B. in 1998 from MIT, her M.S. in 2001, and Ph.D. in 2004 from Stanford University, all in mechanical engineering. Her research focuses on the biomechanics of soft tissues, active polymers, and biomaterials. Dr. Nguyen has received numerous awards and honors for her work, including the 2008 Presidential Early Career Award for Scientists and Engineers (PECASE) for her work on modeling the thermomechanical behavior of shape memory polymers. In 2013, she received the National Science Foundation Career Award for studying the micromechanisms of growth and remodeling of collagenous tissues, the Eshelby Mechanics Award for Young Faculty, and the Sia Nemat-Nasser Early Career Award from the American Society of Mechanical Engineers (ASME) Materials Division. She also received the 2015 T.J.R. Hughes Young Investigator Award from the ASME Applied Mechanics Division and the 2024 Van C. Mow Medal from the ASME Bioengineering Division for her study on ocular biomechanics and glaucoma. Dr. Nguyen was elected Fellow of ASME in 2022 and Fellow of the American Institute for Medical and Biological Engineering (AIMBE) in 2023. She served as a member of the Board of Directors of the Society of Engineering Science (SES) from 2017-2021 and was elected the President of SES for 2020. She has also held many leadership positions in ASME and is currently the Editor-in-Chief of the ASME Journal of Biomechanical Engineering.