

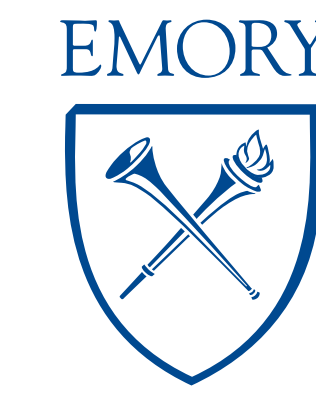
Optic Nerve Sheath Mechanics in VIIP Syndrome

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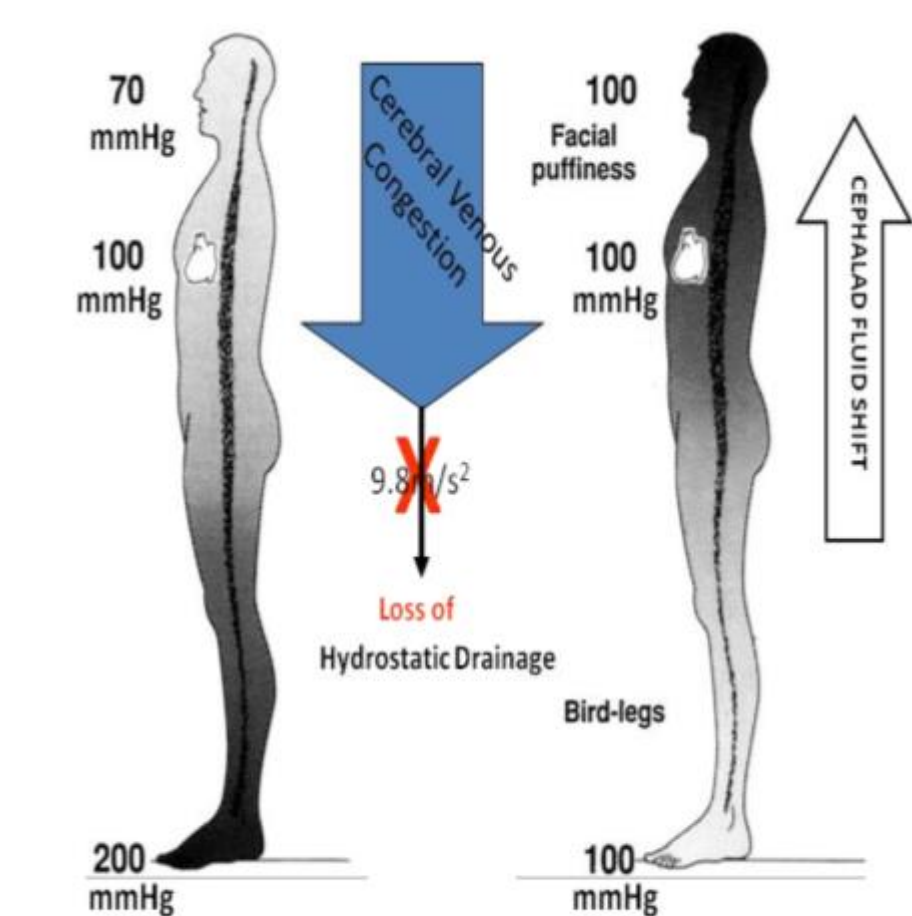
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BACKGROUND – VIIP Syndrome

Visual Impairment and Intracranial Pressure (VIIP) syndrome is a constellation of ophthalmic changes that occur in astronauts following long-duration spaceflight. Understanding the mechanisms that lead to the ocular changes involved in VIIP is of critical importance for space medicine research.



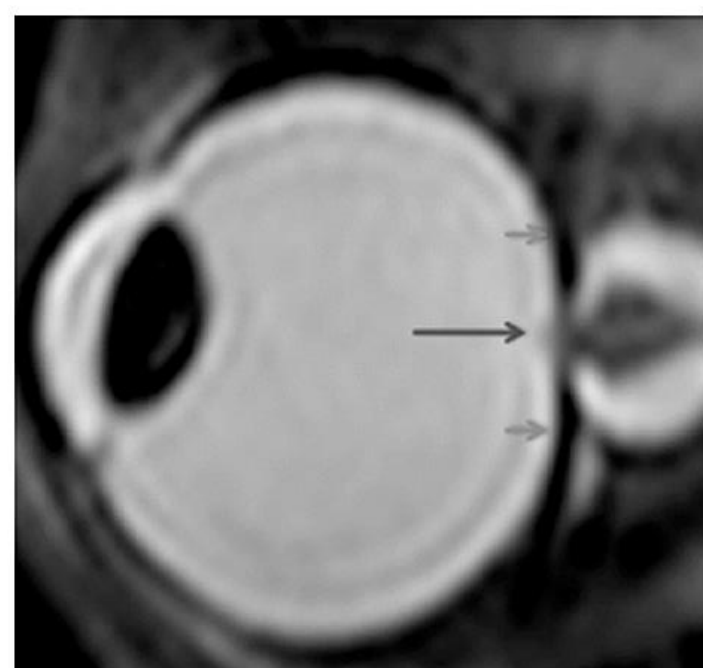
Cephalad fluid shift hypothesis

in microgravity, the pressure gradient in the body is significantly reduced, resulting in higher pressures in the head (increased intracranial pressures, ICP)

humanresearchroadmap.nasa.gov

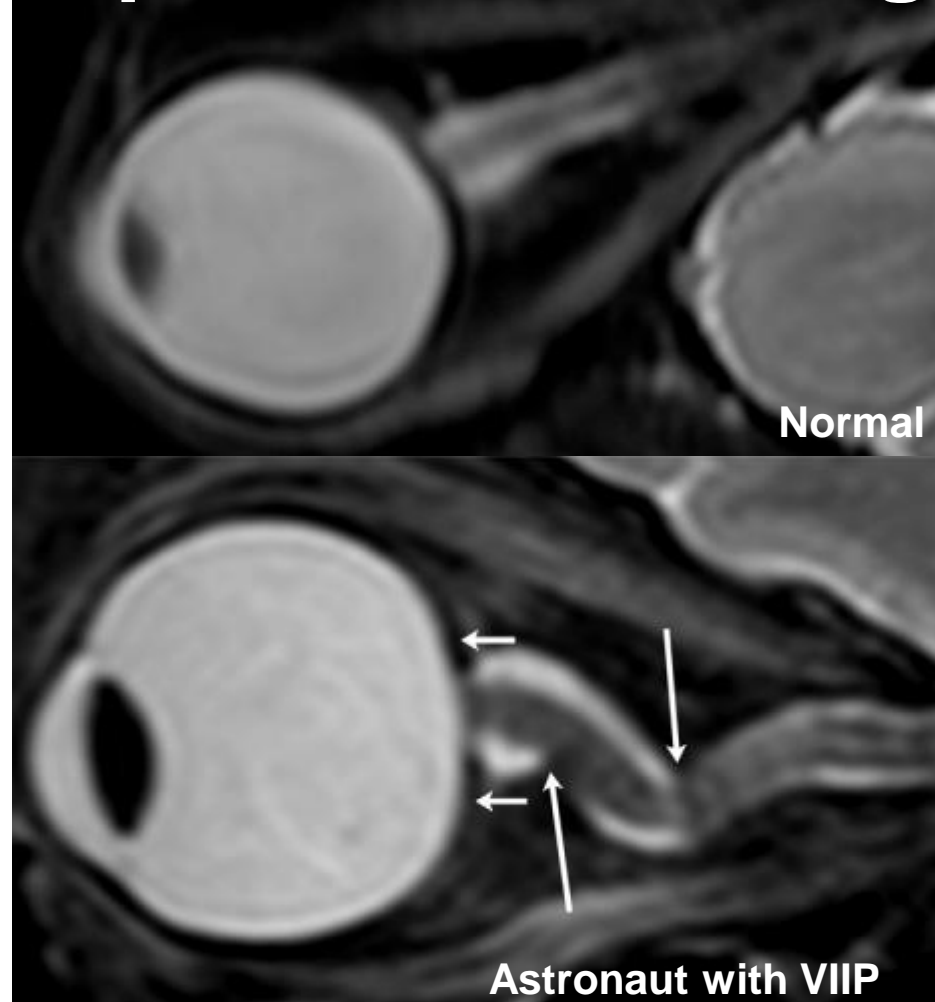
Some astronauts present with optic nerve distension and/or a kink in the optic nerve after return to earth strongly suggesting that axial distension and tissue remodeling in response to ICP increases may be taking place.

Optic nerve distension



Mader et al, Ophthalmology, 2011

Optic nerve kinking



Kramer et al. Radiology, 2012.

The goal of this work is to characterize the mechanical properties of the ONS to better understand its biomechanical response to increased ICP.

METHODS



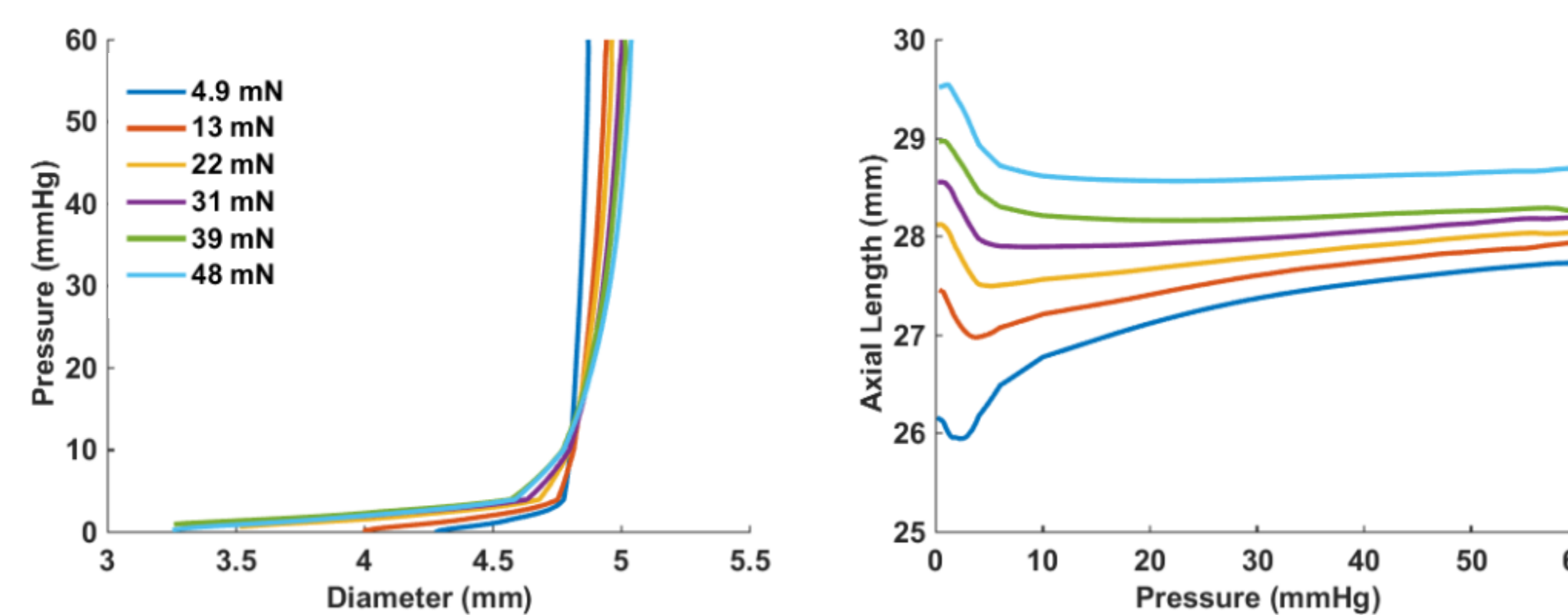
- Fresh porcine eyes obtained from local abattoir
- The optic nerve sheath (ONS) was isolated from the optic nerve proper then cut away from the globe and attached to a pressure control system (to simulate ICP)

METHODS – Mechanical Testing

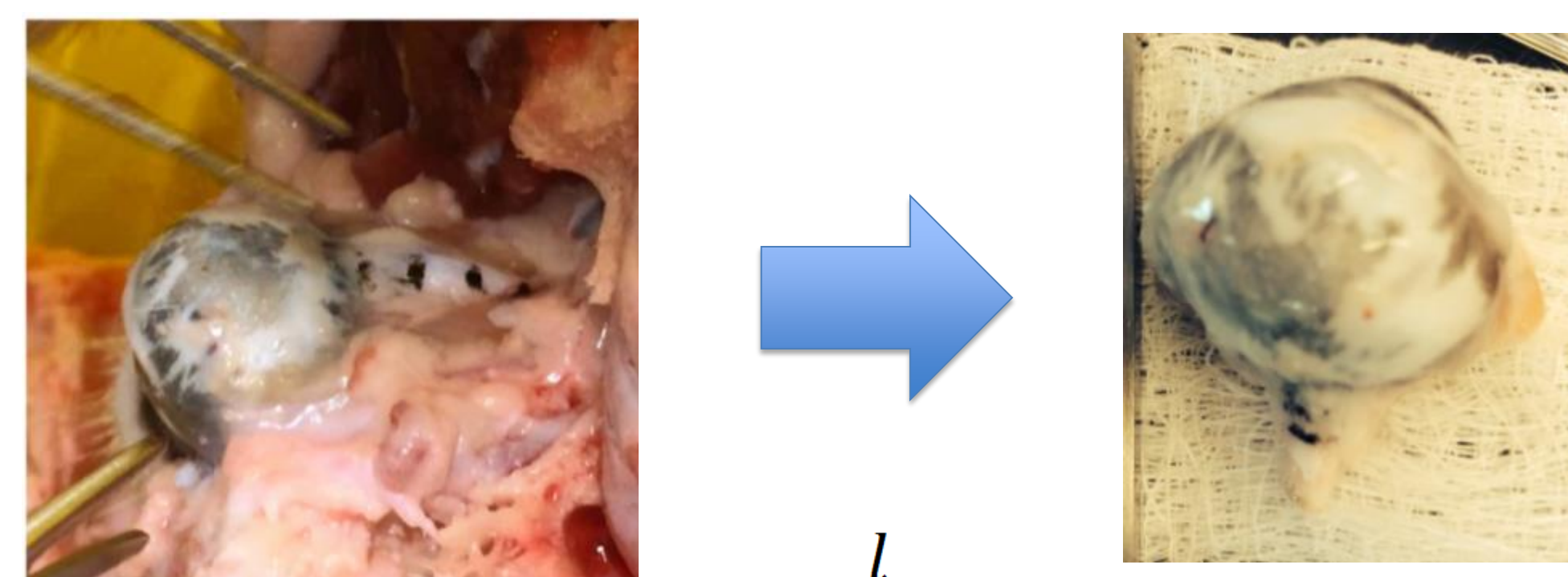
- Developed custom mechanical testing system
 - Allowed for unconfined lengthening, twisting, and circumferential distension
- ICP was cycled between 0-60 mm Hg
- Outer diameter and length of the ONS were recorded
- Tests were performed under variable fixed axial loads

RESULTS

Response of the ONS to pressure



In vivo axial stretch measurements



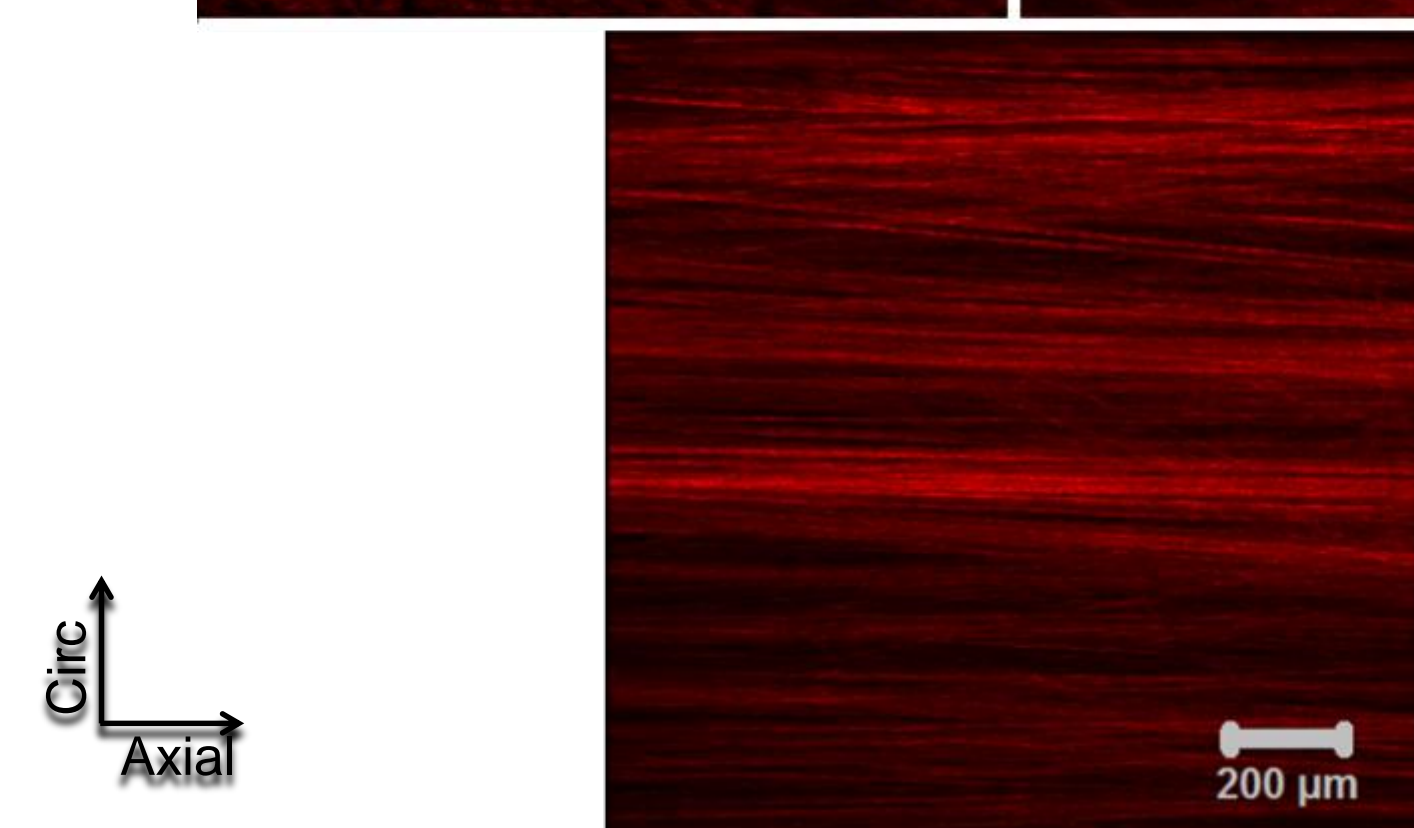
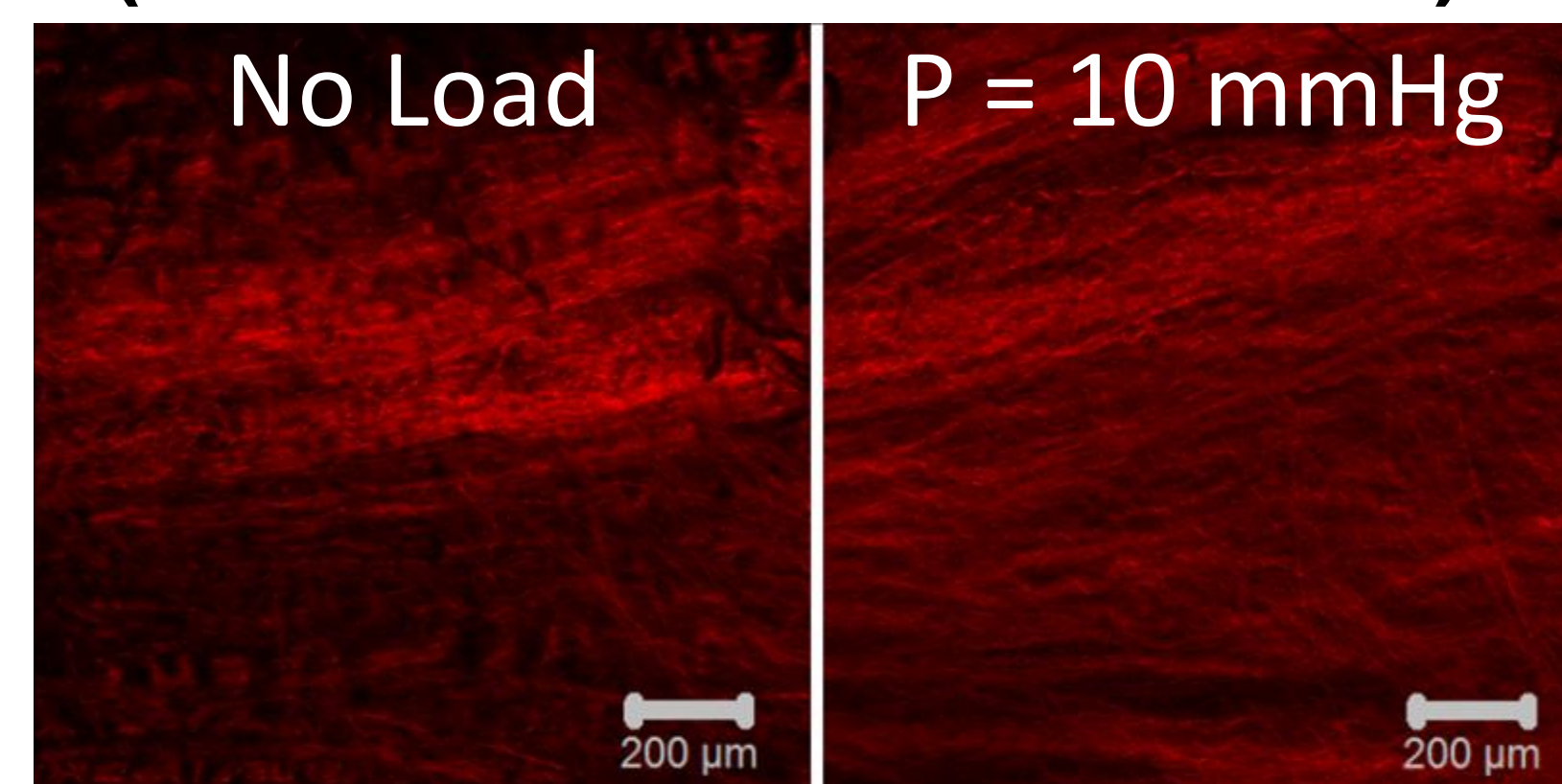
In Vivo

$$\lambda_z = \frac{l}{L} \approx 2.0$$

L: undeformed length
l: stretched length

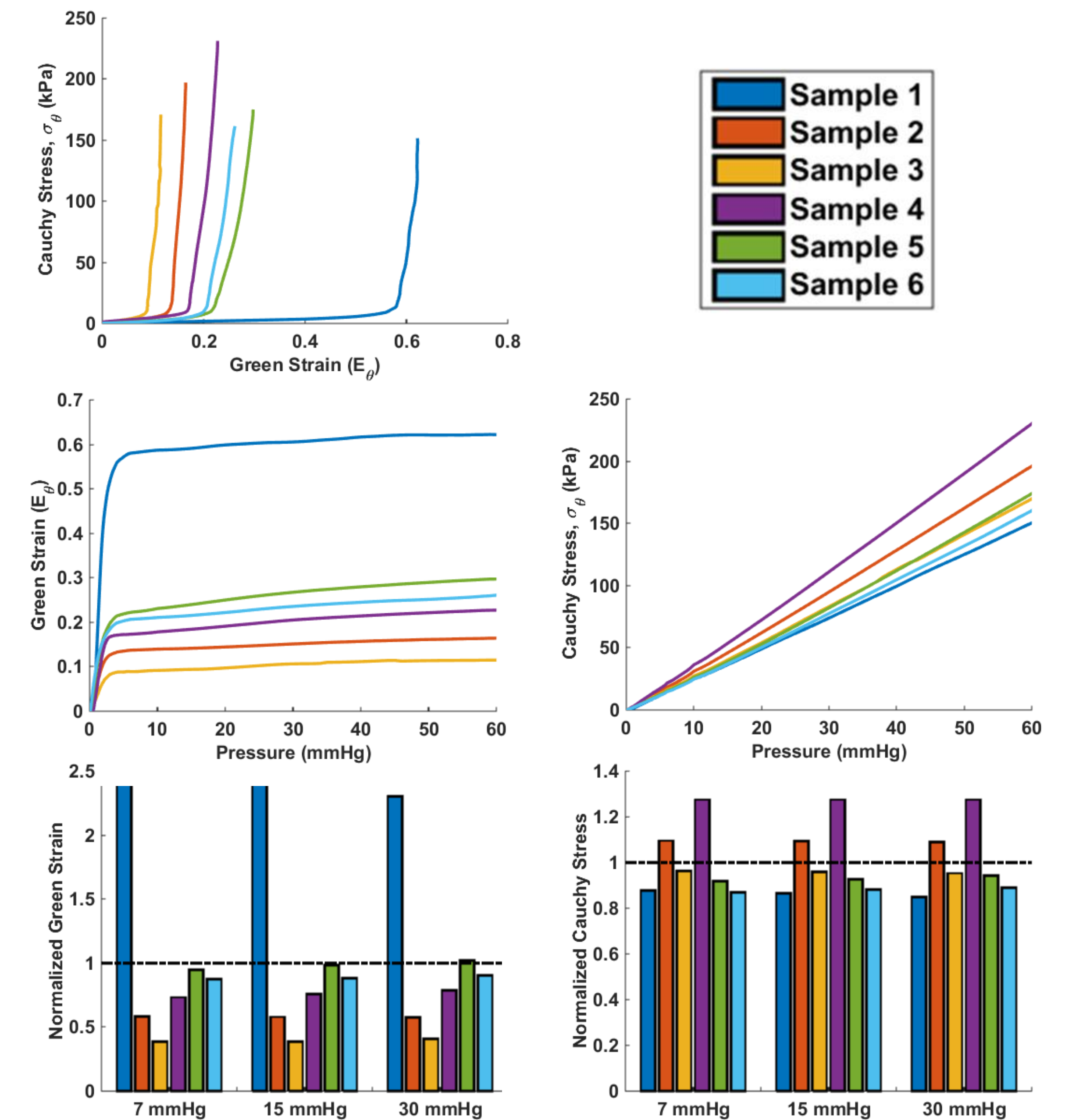
Excised

Axial alignment of collagen fibers in the ONS (Second Harmonic Generation)



RESULTS

Mechanical Properties



CONCLUSIONS

- The ONS is a mechanically complex structure
- “Crossover” point at 11 mmHg
 - Diameter remains constant at this pressure regardless of the axial load that is applied
 - Corresponds to in vivo ICP levels for pigs
 - The observed helical and axial orientation of the collagen fibers may explain this behavior
 - Such mechanical behavior would avoid compression of the optic nerve during change in gaze angle
- Despite large variations in strain, the stress remained nearly constant between samples
- Remodeling of the ONS may be targeted at maintaining this homeostatic stress target

Including these observations into computational models of the optic nerve will help improve their accuracy and enable prediction of possible risk factors of VIIP.