

The pressure-induced deformation response of the human lamina cribrosa: Analysis of regional variations

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The objective of this study was to measure the pressure-induced deformation response of the human lamina cribrosa (LC) and analyze for variations with age and anatomical region. The posterior scleral cup of 8 eyes from 6 human donors was mounted onto a custom inflation chamber. A laser-scanning microscope was used for second harmonic generation (SHG) imaging of the collagen structure in the posterior volume of the LC at pressures from 5mmHg to 45mmHg. The SHG volumes were analyzed by the Fast-Fourier Iterative Digital Volume Correlation (DVC) algorithm for the three dimensional (3D) displacement field.

The components of the Green-Lagrange strain tensor and the in-plane principal and maximum shear strains were evaluated from the DVC displacement field for the central and peripheral regions of the LC and the nasal, temporal, inferior, and superior quadrants surrounding the central retinal artery and vein. Among the major findings were that older age was associated with lower strains, the maximum shear strain was larger in the peripheral than central region, and the maximum principal strain was lower in the nasal quadrant. The elliptical shape of the LC was also predictive of the biaxial strain ratio. Age-related and structure-related variations in the pressure-induced strains of the LC may contribute to the susceptibility and severity of optic nerve damage in glaucoma, and regional variations may explain the progression of axonal damage and tissue remodeling observed in the LC in glaucoma.

STATEMENT OF SIGNIFICANCE: Glaucoma causes vision loss through progressive damage of the retinal ganglion axons at the lamina cribrosa (LC) , the connective tissue structure that supports the axons as they leave the eye. Mechanical characterization of the LC is challenging because of the complex 3D shape and inaccessibility of the tissue. We present a new method using digital volume correlation to map the 3D displacement and strain fields in the LC under inflation. We report for the first time significant regional variations in the strains that are consistent with the pattern of optic nerve damage in early glaucoma. Thus regional strain variations may be predictive of the progression of axonal damage in glaucoma.

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