

Revealing Axonal Regrowth in the Optic Nerve Through Electrical Impedance Tomography

Pooyan *Pahlavan*⁽¹⁾, Ege Iseri⁽¹⁾, Kimberly Kinga Gokoffski⁽¹⁾, and Gianluca Lazzi⁽¹⁾
(1) University of Southern California, Los Angeles, CA 90007, (ppahlava@usc.edu)

Axonal regeneration in the optic nerve is critical for restoring vision in patients suffering from neurodegenerative conditions or injuries such as glaucoma or optic neuritis. While electrical stimulation (ES) has been shown to promote regeneration of retinal ganglion cell (RGC) axons, tracking the regrowth process remains a significant challenge. Electrical Impedance Tomography (EIT) offers a potential solution by enabling non-invasive monitoring of tissue conductivity changes associated with axonal regeneration.

To investigate the potential of EIT, we developed a two-tiered computational framework. First, a detailed 3D model of the rat optic nerve and surrounding tissues was created, incorporating accurate anatomical structures and dielectric properties derived from cadaveric measurements and literature. The electrodes used in this study consist of a set of pads arranged as a ring around the optic nerve, designed to maximize coverage and sensitivity to conductivity changes along its length. This high-resolution model was used to simulate conductivity changes expected during axonal regeneration under ES, enabling realistic predictions of the resulting impedance data.

Second, the simulated data from the detailed model was processed using a simplified computational framework designed for efficient reconstruction of conductivity changes. This model, with a reduced geometric complexity, enabled practical interpretation of the impedance data by solving the inverse problem of identifying spatial conductivity variations along the optic nerve. By systematically testing various electrode configurations and current injection protocols, we optimized the system to enhance sensitivity to the subtle conductivity gradients associated with axonal growth. The integration of these two models allowed us to evaluate the feasibility of EIT as a tool for tracking regeneration while maintaining computational efficiency.

Preliminary results demonstrate that EIT can detect conductivity gradients associated with axonal regrowth, providing real-time insights into the progression of regeneration triggered by ES. Further work aims to refine electrode designs and optimize EIT data processing algorithms for clinical application. This approach may pave the way for real-time monitoring of therapeutic efficacy in optic nerve regeneration treatments.