Quantitative Characterization of Peripheral Nerve Structural Features using Optical Coherence Tomography

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Summary: Peripheral nerve structural features are quantitatively characterized using intensity- and polarization-sensitive optical coherence tomography.

Here we present the application of multi-functional spectral domain optical coherence tomography in peripheral nerve imaging. Using intensity- and polarization-sensitive OCT, we have acquired high resolution cross sectional images of a 5 mm section of a rat sciatic nerve in vivo. The nerve was excised and attached to a micrometer to induce stretch on the nerve and was imaged identically to the nerve in vivo. All image data sets of 200 images were used to reconstruct 3D representations of the tissue, allowing for a more thorough analysis of the structural features of peripheral nerves.

Figure 1. 2D cross-sectional images and 3D reconstructions of the rat sciatic nerve. Left. 2D intensity cross-sectional image. Middle Left. 3D intensity reconstruction of a 5mm section of the sciatic nerve. Middle Right. 2D polarization cross-sectional image. Right. 3D polarization reconstruction of the same 5mm segment of the sciatic nerve.

From the in vivo 2D images, we quantitatively distinguished the sciatic nerve from the surrounding muscle tissue using the extinction coefficient, calculated from intensity images and birefringence, calculated from polarization images, of each tissue. Our results show that the sciatic nerve has a higher extinction coefficient and lower birefringence compared to the surrounding muscle tissue. Using the 2D ex vivo images, we determined the epineurium thickness of the sciatic nerve for un-stretched and stretched nerves to determine whether there is a change in thickness with stretch. Our results show that the epineurium thickness remains unchanged as the nerve is stretched. The 3D reconstructions were used to quantify the frequency of Fontana’s bands for un-stretched and stretched nerves, as a measure of the amount of stretch a nerve is experiencing, and whether there is an overall change in birefringence with stretch. Our results show a decrease in the number of bands per millimeter for stretched nerves compared to un-stretched nerves. Most notably, we report no change in birefringence between the two tension states of the nerve.

The sciatic nerve of the rat is similar in size to the digital nerves of humans and therefore, provides potentially translational information regarding the structural features of human peripheral nerves. Quantitative information about the structure and properties of nerves is essential in accurate assessment of nerve injury. By showing that there is no change in birefringence due to nerve stretching, we can more confidently attribute changes in nerve birefringence to the existence of some type of peripheral nerve injury. Lastly, knowledge of the epineurium/mesoneurium boundary as well as the epineurium thickness will increase the accuracy and precision of microsurgical treatments of peripheral nerve injury.