Non invasive detection of action potentials in a bulk neural tissue from intrinsic mechanical properties of neurons.

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Abstract

During action potentials, physical properties of neurons membrane change drastically since an important part of its components are charged molecules. Mechanical deformations triggered by neural activity are notably expected in the tissue. These changes can be monitored via neurons optical properties, using phase imaging. Their detection would be interesting in neuroimaging, since no chemical or genetic manipulation, (that becomes increasingly difficult with organism "complexity") would be needed to follow non-invasively single neuron activity.
Previous studies have demonstrated that optical properties of nerves and giant axons do change during activity, notably birefringence properties and optical path. Nevertheless, at our knowledge, such effects have never been observed in mammalian cortex neurons with cellular resolution in real time. Moreover, the biological origin of these optical changes are still being discussed.

To be able to detect action potentials from such intrinsic mechanical deformations, it is first important to better understand the spatial and temporal characteristics of such mechanical deformations associated with action potentials.

Towards this goal, we report here the elaboration of a multimodal setup combining Full Field Optical Coherence Tomography and Structured Illumination Microscopy. It enables to simultaneously perform phase imaging and calcium imaging with a submicron transverse resolution at several hundred frames per second. We should therefore be able to follow the entire dynamics of action potentials. The mechanical deformations can be inferred from the optical phase measurement in the axial direction, with a nanometer resolution. This setup can also perform optical sectioning, so, in principle, we will be able to investigate such electromechanical coupling inside tissues, as well as in cultures.
Today, we are characterizing the setup, and we are trying to perform some measurements in neuronal cultures. Depending on the advancement of the experiments, I would insist more on the setup, or on the results we might obtain before December.

Keywords: Optical Phase Imaging, Intrinsic detection of action potentials, Electromechanical Coupling

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