OPTICAL SPECTROSCOPY FOR REAL-TIME NEURONAVIGATION DURING DEEP BRAIN STIMULATION SURGERIES

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Deep brain stimulation (DBS) surgery is a highly effective treatment for Parkinson's disease (PD) patients who experience diminished response to medication. Precise placement of the DBS electrode within the brain is crucial for optimal therapeutic outcomes. Current techniques, such as preoperative MRI and microelectrode recordings (MER), have limitations. This study explores the potential of optical spectroscopy techniques for real-time guidance during DBS surgeries. The use of optical spectroscopy as a guidance tool in DBS surgeries offers several advantages over current methods. Real-time optical measurements can provide immediate feedback to the surgical team, enabling adjustments and improving accuracy during electrode placement. This can significantly reduce the risk of misplaced DBS leads and enhance overall surgical outcomes. Implementing optical techniques in DBS surgeries has the potential to help the neurosurgeon identify the optimal location for the electrode, thereby minimizing adverse neuropsychological consequences for patients and improving outcomes.

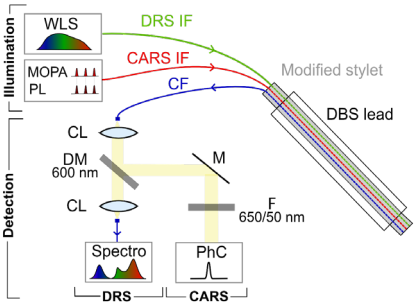

Fig 1. Optical probe and setup for illumination and collection for both CARS and DRS.

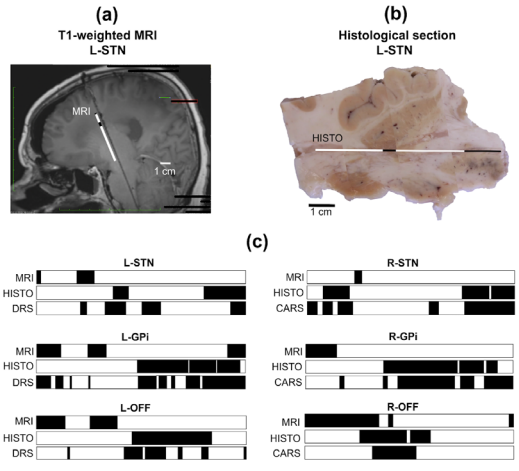

Fig 2. Example of an MRI (a) and histology (b) showing the insertion trajectory to the sub thalamic nucleus (STN) c) Barcodes from MRI, histology (identified as HISTO) and from spectral acquisitions (identified as CARS or DRS).

The study investigated two optical methods, coherent anti-Stokes Raman spectroscopy (CARS) and diffuse reflectance spectroscopy (DRS), for differentiating white matter (WM) and gray matter (GM) in the human brain. These methods utilize minimally invasive optical fibers and have shown promise in non-human primates (Fig. 1). A post-mortem human brain was used, and a custom-built optical probe integrated with a commercial DBS lead was employed for spectroscopic measurements. Preoperative magnetic resonance imaging (MRI) scans were utilized for trajectory planning, and the optical

probe was inserted into the brain along six trajectories targeting specific regions. Principal component analysis (PCA) combined with *k-means* clustering was used to classify each spectrum acquired by the optical probe as either WM or GM. Histological slices and postoperative MRI scans served as references for assessing the accuracy of the optical measurements. The sequence of tissue identified becomes a **barcode**, unique to a given trajectory (Fig. 2). The findings demonstrated that DRS and CARS spectra acquired with the optical probe effectively identified WM and GM during DBS lead insertion in the post-mortem human brain. The optical measurements correlated well with histological analysis, validating their potential for real-time tissue identification in DBS surgeries.

This study shows the feasibility of optical spectroscopy as a valuable tool for real-time tissue identification in DBS surgeries. The ability to differentiate WM and GM during electrode insertion can significantly improve the precision and effectiveness of the procedure. Although the study was conducted on a post-mortem human brain, the results encourage further research to evaluate the optical methods in live human patients and refine the spectroscopic analysis algorithms. Optical guidance holds promise for enhancing the quality of life for individuals with Parkinson's disease by improving the accuracy and efficacy of DBS surgeries.