Accurate Brain Tumor Biopsy Using 3D [1]H-MRS Neuronavigation

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Introduction: [1]H-Magnetic Resonance Spectroscopy ([1]H-MRS) is a tool that permits diagnosing types of intracranial tumors based on metabolite markers [1]. NMR (ex-vivo) of brain tumor samples has shown that the aggressiveness of a tumor may be determined based on its spectral profile [2]. Due to the heterogeneous nature of the tissue in brain tumors, it is thought that the metabolite profile differs in regions of greater aggression. In a parallel study in our group, it has been proposed that utilizing 3D [1]H-MRS may permit *in vivo* grading of the meningioma subset of intracranial tumors by examining specific voxel regions within the tumor. To correlate the 3D [1]H-MRS voxel spectra with genetic and ex vivo NMR data from meningioma tumors, it is imperative for the neurosurgeon to excise the tissue of interest precisely. The goals of this project are to identify the 3D [1]H-MRS tissue of interest for surgical navigation and to facilitate accurate excision of tissue for further spectral and genetic correlation.

Methods: 10 patients demonstrating meningioma were enlisted in the study, following standard IRB approval and informed consent. 5 patients were included in the control group. For each patient, published Alzheimer's Disease Neuroimaging Initiative calibration methods [3] and freely available correction and analysis software were used to geometrically calibrate the scanner and ensure geometric accuracy prior to scanning. High-order shimming was next performed in the area of the tumor. 3D CSI (PROBE-P) was used to obtain the MRS information from those patients with meningiomas. LCModel quantified the metabolite peaks from the [1]H-MRS data [4]. CSI voxels were selected based on their metabolite profiles and the voxel coordinates were determined with regard to the structural image. An in-house MATLAB (Mathworks, Inc) program was written that allows mapping of the regions of interest (ROIs) onto the structural brain DICOM images based on the image coordinates. These mapped ROIs were converted into DICOM masks and sent to the surgical planning station (STEALTH, Medtronic, Inc.). The planning station overlaid the masks onto the native structural images typically used for surgical navigation. The spectroscopic mask ROIs were highlighted in color for the surgeons in the operating room, using a custom coloring scheme.

Results: The first five operations were performed using estimation of location of the tissue of interest by the neurosurgeon based on two dimension images, without the benefit of the navigation system. The subsequent five operations utilized the STEALTH overlay of the ROIs (Fig. 1) created in the MATLAB code GUI (Fig. 2). This permits precise excision of the tumor regions by the neurosurgeon. The excisions were documented by screenshots (Fig. 3) when the surgeon placed the marker within ROI.

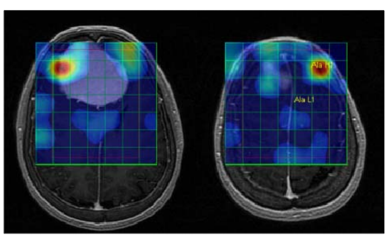

Figure 1. Heatmaps are generated with the use of the quantitative data coming from LCModel. Alanine hotspots are shown in the images.

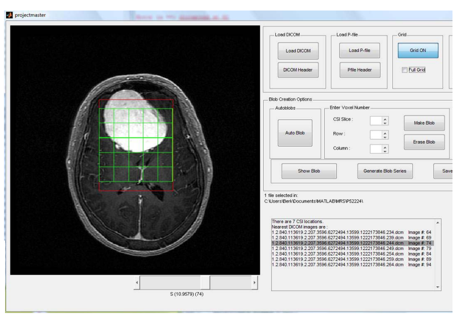

Figure 2. MATLAB software GUI permitting STEALTH blob overlay formation.

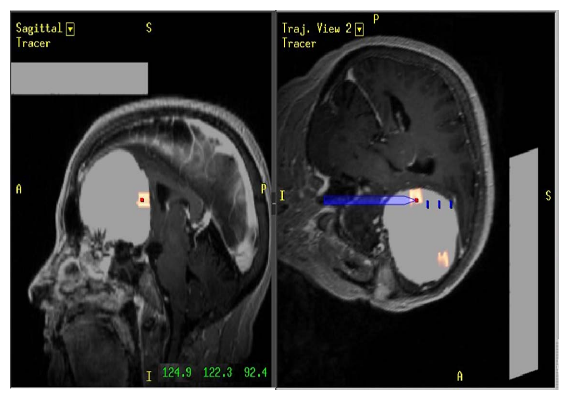

Figure 3. STEALTH screen during the operation. Blue arrow shows where the neurosurgeon is working to remove the ROI.

Discussion: The neuronavigation overlays made the location of the regions of interest obvious for the neurosurgeons. The precise, navigated removal of tissue added greater validity to the 3D 1H-MRS meningioma grading study. Specific metabolite hot spots were created and overlaid onto the structural images. These hotspots illuminated the biopsy regions during the surgery acting as markers like the markers used in fMRI. The biopsied regions were correlated with histopathology. Without neuronavigation, the volumes of interest were located solely by verbal and visual cues in the operating theater, and there was no systematic way to validate the location.

References:

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