MRI Visualization of Electrode Recording Cylinder Trajectories

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Introduction

The implantation of microelectrodes in the brain is a valuable method for recording neuronal activity *in vivo* (Hubel, 1956; Evarts, 1968; Baker et al., 1999)). The success of this method depends on accurate placement of the microelectrodes. This can be challenging, particularly for targeted brain regions that are below the cortical surface, because stereotaxic locations can very between individuals. In the past, post-mortem histology was the most common technique available to verify the accuracy of microelectrode placement. Recently, magnetic resonance imaging (MRI) has gained widespread acceptance for this purpose, but typically provides only a qualitative account of anatomical structures that lie below the recording cylinder. Here we present a technique that uses MRI to quantitatively determine electrode trajectories and their intersection with desired anatomy. This technique is intended to guide electrode placement specific to the anatomy of an individual subject.

Materials and Methods

After the surgical implantation of two recording cylinders, a 3D magnetization-prepared rapid acquisition gradient echo (MPRAGE) MRI at 1.5T was used to obtain high-resolution (0.7mm isotropic voxel) images of the cylinders and brain of a fully sedated macaque. Each recording cylinder was fitted with a 7cm-long plastic tube filled with $CuSO_4$-doped water to aid in the segmentation of the recording cylinders from brain matter. Using custom software, the image slices where the cylinders could be clearly distinguished from surrounding anatomy were user-identified, and for each slice the cylinder cross sections were fit to an ellipse. The centers of the ellipses were fit to a line describing the center axis of the recording cylinder. Because the intersections of a cylinder and any two parallel planes yields identically shaped ellipses, the mean minor and major axes were computed from all the ellipses. These measurements were used to determine the interior projection of the recording cylinder through deeper slices of the brain volume. This projection was then used in conjunction with Caret (Van Essen et al., 2001) and AFNI (Cox, 1996) brain mapping software to aid in the placement of individual electrodes within targeted anatomical regions.

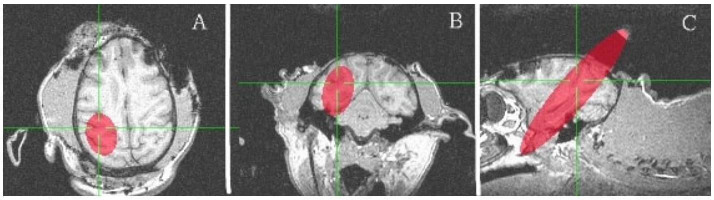

Figure 1: The projection of the MT recording cylinder overlaid on axial, coronal and sagittal slices (A, B, and C, respectively).

Results / Discussion

Phantom studies were conducted and determined that our projection method estimates the coverage of the recording cylinders with an error of less than 7%, as measured by the overlap of estimated and actual cylinder trajectories. This error derived primarily from a shift in the estimate of the center axis by ~1 mm over a depth of ~6 cm. The magnitude of the error was essentially unaffected by inter-operator bias. **Figure 1** shows the projection of a recording cylinder overlaid on axial, coronal and sagittal slices from the macaque MRI, respectively. The cross hairs indicate the location of the intended target: namely the medial temporal area (MT) of extrastriate visual cortex, identified using Caret and AFNI. These images confirmed that an electrode placed in the upper, lateral quadrant of the recording cylinder would reach area MT. **Figure 2** shows a 3D volume rendering, performed in AFNI, showing the 3D projection of the cylinders through the anatomy. By determining electrode trajectories on an individual basis, this method removes the intersubject variability inherent in using atlas stereotaxic coordinates. Future work will include performing pre-surgical imaging to determine the optimal stereotaxic location for the surgical implantation of the recording cylinder, reducing the risk of additional surgeries.

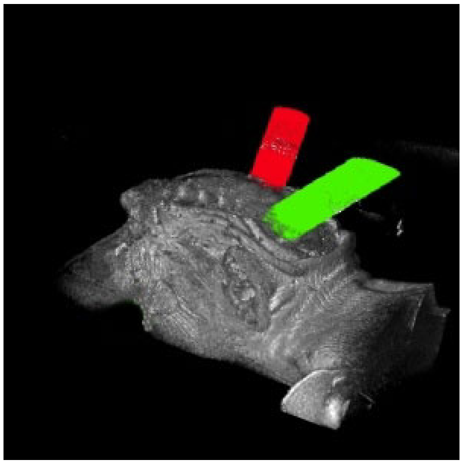

Figure 2: 3D volume rendering of the computed trajectories of two surgically implanted recording cylinders (red and green) derived from the macaque MRI.

References

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