Ex vivo Thin slice Magnetic Resonance Histological Imaging

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Introduction: Correlating MRI with histology results is challenging because co-registration of tissue samples with MR images can be difficult using traditional volume coils. In addition, the MR slice is much thicker than the sliced tissues samples. Here we present a novel histological slide RF coil that is able to image histological tissue sections with adequate resolution and signal-to-noise ratio to compare histologically stained tissue with the MR images of the same slice.

Methods: The coil design was optimized with computer modeling using XFDTD 6.0 (Remcom, State College, PA). The coil was designed to fit two standard histological glass slides (25 x 75 x 1.0 mm) laid on each other. Histological brain tissue sections were taken from wild-type C57BL/6J mice. The mice were euthanized and their brains excised. Whole brains were placed in ice cold 4% paraformaldehyde for one hour to fix the tissue, and placed in 10% and 20% sucrose gradients for cryogenic protection. Sections were then cut at 60μm using a Leica cryostat and placed onto the slides for imaging. To maintain hydration a few drops of dH_2O and a hydrophobic barrier was used on the edges of the slides. For T_2 mapping, multi-echo T_2 weighted images were taken with 2.3 x 2.3 mm FOV, 128 x 128 matrix, 2500ms TR, 9.20ms TE, 8 echoes, 128 averages. RARE images with the same geometric parameters were acquired with 2500ms TR, 12.0ms TE, and 64 averages for a total time of 23m.

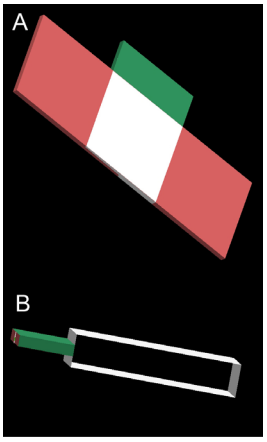

Figure 1. A: Top view of the coil. The two glass slides (red) fit between the copper strips (white). A dielectric piece of Teflon (green) between the extended coil plates acts as a distributed capacitor. The terminals of the copper strip are B: Side view of the coil and terminal.

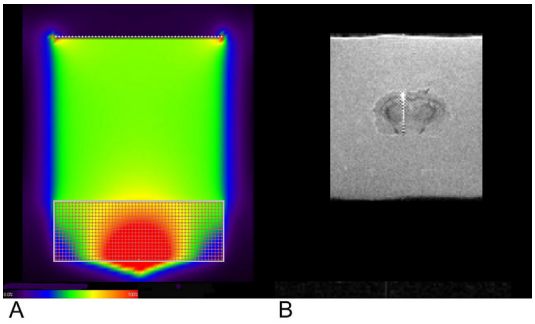

Figure 2. A: Calculated B1 field of the coil. The box on the bottom represents the Teflon-filled terminal. The field is homogenous over the entire imaging region in the coil. B: A RARE image of a 60μm section of mouse brain tissue. The homogeneity of the field of view is as predicted in the model.

Results: The challenge for imaging histological slices is the vast difference in aspect ratio between planar size and thickness of the slice. This requires a RF coil producing highly uniform B1 field in a two-dimensional plane with minimal thickness. As shown in Fig. 1, this is achieved with a single loop of 25.4 mm wide copper strip so that the histological slides fit tightly in the coil. Due to the small dimension of the coil, non-uniform current near the feeding points to the circuit significantly reduced B1 field inhomogeneity. This problem was overcome by placing a Teflon strip (25.4 x 25.4 x 0.36mm) between the extended (25.4mm) copper strip terminals (outlined by the box in Fig.2). The B1 uniformity of the coil determined by the numerical calculation (Fig. 2a) was demonstrated with imaging (Fig. 2B). The experimental image shows a homogeneity field across the entire field of view. T_2 mapping with the coil was carried out using a 60μm slice shown in Figure 3. The atlas on the left of T_2 weighted image shows the white matter tracks of internal capsule, corpus callosum and optic tract in red. These white matter tracks are seen as hypo-intensities in the T_2 image. The T_2 parametric map (Fig. 3B) demonstrates that hypo-intensities are in spatial correlation with patches of high iron content (arrows in Figure 3B).

Discussion: These results demonstrate the feasibility of using a micro imaging histology coil to image thin slices of tissue. Previous work has used MR to image tissue slices as thin as 500μm (1). With our coil, we provide MR images of a 60μm coronal brain slice with high resolution and signal-to-noise compared with those acquired with traditional histology. This work will enable the micro imaging of pathologically diseased tissue to obtain a precise one-to-one comparison to stained tissue sections. The novel design of using distributed capacitance results in an optimal RF field homogeneity in the close vicinity of coil conductor, which is desirable for SNR enhancement in micro-imaging.

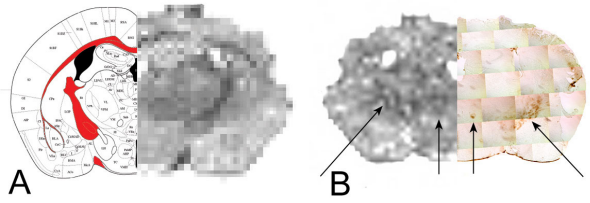

Figure 3. A: T_2 image and mouse brain atlas of the same slice [Bregma -1.06mm]. B: T_2 parametric map and Perl's stained mosaic of the same slice as in A. The Perl's stain is specific for high cellular iron (Fe^{+3}) and these regions are seen as dark brown on a lighter background. The globus pallidus and medial terminal nucleus of the accessory optic track (arrows) are high iron regions. The parameter map shows these regions as hypo-intensities.

References:

1 – Shepherd, T. M., Blackband, S. J. and Wirth, E. D. Magnetic Resonance in Medicine 2002; 48: 565 – 569.