RF Ablation Current Visualization at 0.5T

G. Scott[1], K. Vigen[2], A. Chen[1]
[1]Electrical Engineering, Stanford University, Stanford, California, United States, [2]University of Wisconsin, Madison, Wisconsin, United States

Introduction: RF ablation is a clinically proven procedure for minimally invasive therapies such as cardiovascular electrophysiology and cancer tumor ablation. MRI appears to be well suited to provide interventional thermal monitoring for these procedures[1]. Clinical scanners use fields with Larmor frequencies well above typical ablation frequencies near 500kHz. If ablation could be performed at the Larmor frequency, then direct monitoring of the ablation pathways becomes possible. We present images of RF ablation electrode currents performed on a GE Signa SP 0.5T scanner showing the ability to visualize RF ablation currents.

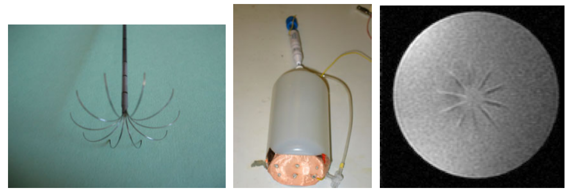

Figure 1: The Leveen RF ablation electrode (left). Copper taped exterior to the phantom provides the ground pad RF return path (center). The tines are visible in the MR magnitude image (right).

Methods: We used a Boston Scientific MRI compatible Leveen electrode for both phantom tests (Fig 1) and with a pork sample that had layered muscle and fat. To perform current density imaging[2], we constructed a second RF transmitter channel to supply RF current at the Larmor frequency but with 0, 90, 180, and 270 degree phase shifts[3]. This system uses the sampled RF output channel of the GE Signa system for its input. A pulse sequence logic control triggered the gating of this second channel which was fed to an AR Kalmus 200 W amplifier. Current was injected synchronously while the MRI scanner played out a 12 ms rotary echo hard pulse. The rotary echo fully refocused hard pulse flip angles leaving a net rotation due only to the superimposed RF magnetic fields from current. This rotating frame angle was converted into a phase image by a 90 degree plane rotation spin echo sequence (TE 16ms, TR 150ms or 300ms, FOV 16cm) Phase images were post-processed by differential curl operations to compute current density.

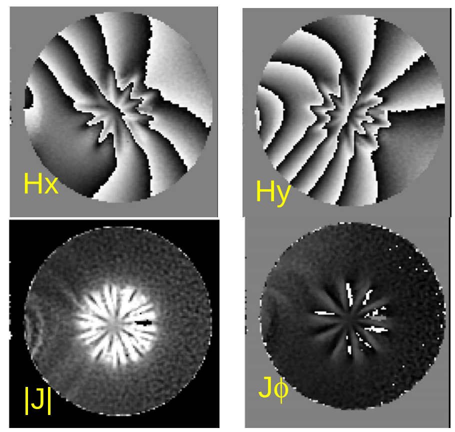

Figure 2: Phantom tests at 0.5T. The rotating frame field maps Hx, and Hy are post processed to get current density magnitude & phase. The return wire is to the left of the phantom and creates a small wave like artifact in the left side of the current density image.

Results: Figure 2 shows our phantom test with the electrode. The rotating frame field phase maps for Hx and Hy encode the information to reconstruct RF current flowing parallel to Bo. The current density magnitude and phase show very high local current density by the electrodes. We then repeated the test on the pork sample (Fig. 3). The electrode tines and shaft are clearly visible as signal voids. Current density amplitudes are reconstructed at three slices in Figure 4. Even at 21 MHz, fat acts as an insulator and blocks current. Current flows in the high conductivity muscle tissue and is locally intense closer to the electrode. However, slice C has some artifact because the RF fields are too intense, causing signal loss due to extreme phase variation.

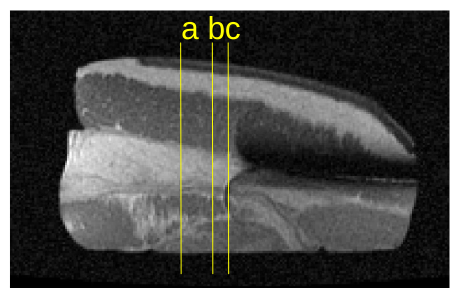

Figure 3: Spin echo MR image shows approximate slice locations for ablation electrode current density reconstruction.

Discussion & Conclusions: Conductivity contrast is clearly present in the tissue tests. In more heterogeneous tissue such as the breast, RF ablation current pathways will be quite irregular. The basic technique can map only the RF current component flowing parallel to the magnet Bo field. Thus, scanners that have the flexibility for axial or sideways entry such as the Signa SP, can allow patient orientation so that the RF ablation currents are predominantly directed along Bo. Future work will entail the combination of the technique with PRF thermal mapping so that time course studies of tissue ablation and pathway changes can be investigated.

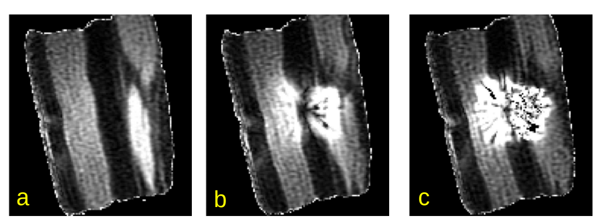

Figure 4: Current density magnitudes below the ablation electrode. Fat acts as an insulator and appears dark. Muscle tissue is conductive and appears bright. Local anatomy differences cause more current to be shunted in the lower right of slice (a). FOV 16cm, 256x256 cropped, TR 300ms, TE 16ms, slice:5mm.

References:

[1] K. Vigen et al, Proc 11th ISMRM, p685, 2003
[2] G. Scott et al, Magn. Reson. Med. 33:355, 1995
[3] G. Scott et al, Proc 12th ISMRM, p989, 2004.

The authors would like to acknowledge the support of the Whitaker Foundation.