Calculated Magnetic Field Produced by Low-Amplitude Electric Current Injection into a Hydrogel Using Magnetic Resonance Electrical Impedance Tomography (MREIT)

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Introduction

Magnetic resonance electrical impedance tomography (MREIT) can image current density distribution of current, injection into a conductive object, by mapping changes in the MRI signal phase resulting from the induced magnetic field in the direction of the static magnetic field. This technique can provide insight into the mechanisms of electrical stimulation in biological tissue *in vivo* (e.g. brain). Common injection current ratings, on the order of milliamps, translate to a field change in the order of nano-to-pico Tesla. Hence the sensitivity of this imaging method to these small fields is limited by the available signal-to-noise ratio. In this study, we characterized the magnetic field changes with injected current observable at 4.7 T using the injection current non-linear encoding (ICNE) pulse sequence (1) and compared the results to those obtained from a regular spin echo acquisition.

Experimental

The data was acquired in a 4.7T Agilent magnet system in the AMRIS Facility of the NHMFL using a volume transmit-receive coil and both a standard spin echo sequence and ICNE sequence with bipolar current pulses. Figure1 shows the combined pulse sequence diagram for the standard spin echo acquisition technique (bipolar pulses in the 5th line) and the ICNE sequence (bipolar pulses in the 6th line). Two insulated copper wires with exposed tips were inserted on opposite sides of 50 ml tube filled with hydrogel. Five 2 mm thick image slices were acquired with an in-plane resolution of 240 μm using a TR = 2000 ms, TE = 50 ms, T_s (sampling time) = 8 ms. Two image data sets with bipolar current pulse of 100 μA but opposite polarities were acquired and the resulting two image datasets were complex divided to obtain greater sensitivity to phase changes. In the standard acquisition, magnetic field maps were computed from the linear relationship to induced phase change. For the ICNE acquisition, an extra dataset without any current injection was acquired to facilitate the field map computation (1). The total current injection for the standard acquisition time was 40 ms, while the ICNE utilized an increased current injection time of 48 ms.

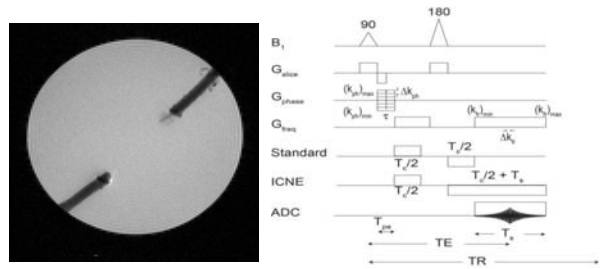

Figure 1. Left: Magnitude mode image of the phantom. Right: Combined pulse sequence diagram of the standard spin echo and ICNE acquisitions.

Results and Discussion

The top row of images in Figure 2 shows the computed magnetic fields from the standard spin echo acquisition and the bottom row from the ICNE sequence. The intensities in the images were scaled from -30 nT to 30 nT. Because of the longer current injection time, the ICNE sequence provides better sensitivity. The red areas at the electrode tips, in the field top row maps, result from gel tear susceptibility artifacts.

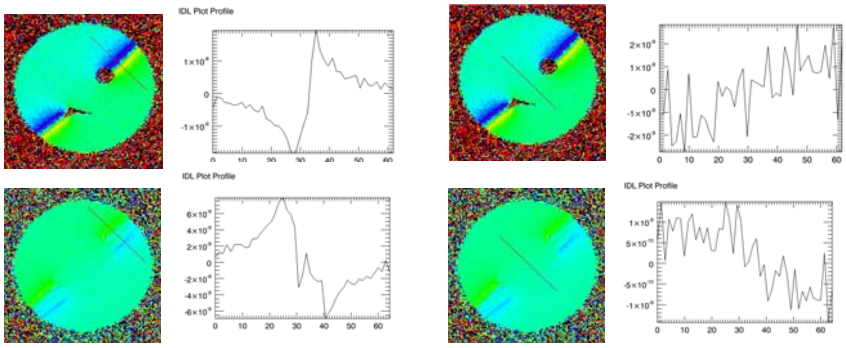

Figure 2. Magnetic field images and line plots acquired (top row) using a spin echo sequence and ICNE sequence (bottow row).

Conclusions

ICNE acquisition provides greater sensitivity for detecting the very weak magnetic fields produced by the injected current. Future work will combine this acquisition method with faster readout sequences utilizing multiple echo readout, like the EPI and RARE, for the estimation of the current distribution producing the magnetic fields.

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References

[1] Kwon et al., Physiol Meas 2007;28(11):1391-1404.