Electrical impedance tomography using magnetic resonance as the voltage source

M. Negishi[1], T. Tong[1], P. Brown[1], T. Nixon[1], and R. T. Constable[1,2]
[1]Diagnostic Radiology, Yale University, New Haven, CT, United States, [2]Neurosurgery, Yale University, New Haven, CT, United States

Introduction

Electrical Impedance Tomography (EIT) is a method for reconstructing the complex permittivity distribution in a target volume. EIT uses surface electrodes for both the current (voltage) application and the voltage (current) measurement. To improve the spatial resolution of impedance imaging, Magnetic Resonance Electrical Impedance Tomography (MREIT) has been recently developed, which uses surface electrodes for current injection and receiver coils for magnetic field measurements. A major problem with MREIT is its relatively low sensitivity, caused by the safety limit on the injected current. We recently proposed a method called Magnetic Resonance Driven Electrical Impedance Tomography (MRDEIT), wherein the magnetic resonance phenomena is used to apply voltages and the signals from surface electrodes or surface RF detectors are analyzed to yield complex permittivity distribution in the target volume. In the current study, we test whether the RF voltages measured by surface electrodes change as the theory predicts when the conductance of the phantom is altered and thereby seek to confirm that the MR phenomena can be used as the current source. Note that resultant images below are not permittivity images, computation of which require inverse solutions (Negishi et al. 2011).

Methods

A cubic phantom with a pair of copper electrodes immersed in 25x25x25 cubic centimeters saline solution was constructed (Fig. 1 (c)). The outputs from the electrodes were routed to an impedance matching circuit, whose output was connected to a pre-amplifier and then to a head coil connector at the scanner (Siemens TIM Trio, Erlangen, Germany). Since our goal was to observe the electric field change rather than the magnetic field change, the cable was routed in such a way that it was not sensitive to the transverse magnetic field change. A standard T1 flash sequence was used for the excitation (T1=4s, TE=5 ms, flip angle=90 degrees, bandwidth = 100Hz, 2 averages, base resolution = 128x128, 25 5mm slices, no skip). The images were collected from the phantom with three different saline concentrations (1%, 2%, and 4%, corresponding to conductivities at 17, 33, and 64 mS/cm). To correct for the intensity changes due to factors other than the conductance changes such as proton density and T1 / T2 relaxation times, the images were normalized by a voxel-wise division with the corresponding image acquired using a body coil. The resultant images were compared with simulation results from the Finite Element Method (Negishi et al. 2011).

Results

Fig. 1(a) shows the average intensities (from the experiments) on the lines of voxels in the middle slice (slice 13) that are parallel to the line that connects the two electrodes, showing the intensity profile at various positions as one moves along the B0 direction. Fig. 1(b) shows the average intensities (from the experiments) on lines of voxels in the middle slice that are parallel to the B0, showing the intensity profile at various positions as one moves along the line that connects two electrodes. Both Fig. 1(a) and (b) show that the overall intensities increase as the conductivity increases, although there is a slight reversal in the middle of two electrodes. The same tendency can be seen in Fig. 2 (b) and Fig. 2 (c). Fig. 1 (b) fits the simulation result Fig. 1 (d), although higher intensities on the left in Fig. 1 (b) is probably caused by the asymmetry in the phantom and cable constructions. Likewise, higher intensities at the side left of Fig. (a) are likely due to the asymmetry in the phantom construction. In Fig. 1 (a), it can be seen that there is an abrupt dip in the middle of the two electrodes. The same line can be seen as dark horizontal lines in Fig. 2 (a). The existence of such dark lines is predicted from the fact that currents generated by the excitation of any voxel on such lines form loops that do not have components parallel to the line that connects the two electrodes.

Conclusions

This work confirms that a higher conductivity results in a higher average electrode voltage and that the spatial voltage profile matched the simulation result confirming the theory that it is possible to use the resonance phenomena itself as the current source for electrical impedance tomography. To prove the feasibility of MRDEIT, further experiments are underway using phantoms with multiple compartments containing different conductivities.

Reference

M. Negishi, T. Tong and R. T. Constable (2011) Magnetic Resonance Driven Electrical Impedance Tomography: A Simulation Study under review.

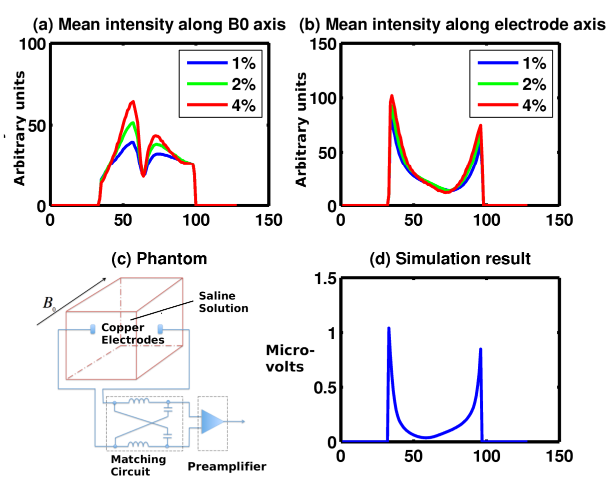

Fig. 1. (a), (b): Intensity profile along z (B0) and x directions in the middle slice from the experiments (see text). (c): A schematic diagram of the phantom. (d) A simulation result corresponding to

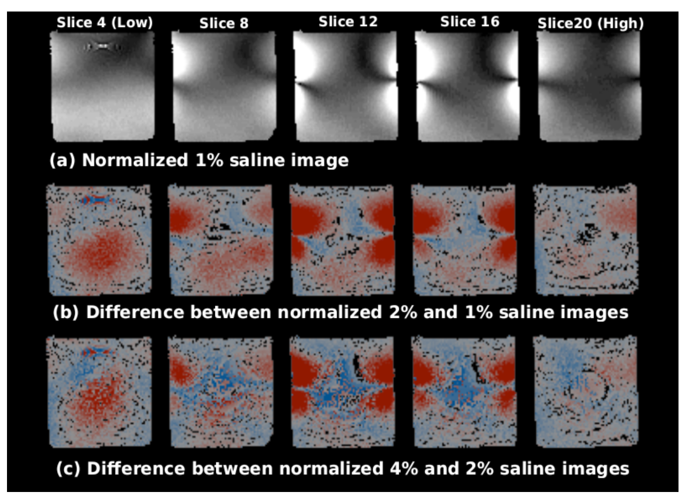

Fig. 2. (a) Multiple slice images from 1% saline image acquired with the electrodes, normalized by the corresponding mage acquired with a body coil. (b) Normalized 2% saline image minus normalized 1% image. The blue color indicates positive and the blue color indicates negative. (b) Normalized 4% saline image minus normalized 2% image.