Magnetic resonance electrical impedance tomography (MREIT) with a 3.0 Tesla MRI system

S. H. Oh[1], B. I. Lee[2], S. Y. Lee[1], E. J. Woo[2], T. S. Park[1], M. H. Cho[1]

[1]Graduate School of East-West Medical Science, Kyung Hee University, Yongin, Kyungki, Korea, Republic of, [2]School of Electronics and Information, Kyung Hee University, Yongin, Kyungki, Korea, Republic of

Synopsis

We present experimental results of Magnetic Resonance Electrical Impedance Tomography (MREIT) performed without any subject rotations on a 3.0 Tesla MRI system. MREIT is a newly introduced conductivity imaging modality which combines MRI and electrical impedance tomography (EIT). With a specially designed conductivity phantom, we have evaluated the performances of MREIT including noise characteristics and spatial resolution. We have found that the spatial resolution reaches 2mm and the L^2 error in the reconstructed conductivity image ranges in 18-38% when the injection current is 12mA. In vivo animal imaging with smaller currents will be done in future studies.

Introduction

Electrical conductivity has rich information about physiological status of biological tissues. MREIT was recently introduced to image conductivity distribution with a MRI system. In MREIT, we use the information about the magnetic field produced by externally injected currents. Previous MREIT studies were performed with subject rotations inside the MRI magnet[1], which are practically impossible in animal or human studies. In this work, we used the harmonic B_z algorithm to reconstruct the MREIT images. Since the algorithm uses B_z data only, we need not to rotate the subject to get other components of the magnetic field. With a specially designed conductivity phantom and a 3.0 Tesla MRI system, we have evaluated the performances of MREIT including noise characteristics and spatial resolution.

Methods

We have made a conductivity phantom as shown in Fig. 1. The conductivity phantom consists of two wedge-shaped sponges (σ_2 and σ_3) and six cotton threads immersed in electrolytic solution (σ_1). The sponges have different physical densities, hence, different electrical conductivities. The cotton threads are for the spatial resolution measurement. During the MREIT experiments, we injected currents I_1 and I_2, and measured the magnetic field components, B^1_z, B^2_z, that were produced by I_1 and I_2, respectively. We applied the harmonic B_z algorithm to the measured magnetic field data to reconstruct the conductivity images[2]. In the harmonic B_z algorithm, we use the following relation,

$$\frac{1}{\mu_0}\nabla^2 B_z^i = \left(\frac{\partial\sigma}{\partial x},\frac{\partial\sigma}{\partial y}\right)\cdot\left(\frac{\partial V_i}{\partial x},-\frac{\partial V_i}{\partial y}\right) \quad \text{for } i = 1 \text{ and } 2. \qquad [1]$$

It is an iterative algorithm starting with an arbitrary initial conductivity distribution σ_m with $m = 0$. In the m-th iteration with m>1, we numerically solve [1] by replacing σ with σ_{m-1} to compute the internal potential distribution V_i for $i = 1$ and 2. Plugging the measured data B^i_z and the computed V_i into [1], we can calculate the conductivity distribution σ_m.

Results

We measured the magnetic field data with a 3.0T MRI system for the injection currents of 6 mA, 12 mA, and 24 mA. We used the spin echo MRCDI sequence with TR/TE of 1400/60 ms. The current pulse width was 48 ms. The FOV and slice thickness were 200×200mm^2 and 5mm, respectively. Figure 2 shows the reconstructed conductivity images obtained with the injection current of 24 mA. In the images, we can notice that the cotton threads the diameter of 2, 3, and 4mm, are well resolved. The two sponges (σ_2= 0.16 S/m and σ_3=0.25 S/m) and the electrolytic solution (σ_1= 0.63 S/m) contrast well with each other. It has been found that the L^2-error in the reconstructed conductivity images ranges in 18-38% when the injection current was 12 mA.

Conclusions

We have reconstructed conductivity images without any subject rotations using the harmonic B_z algorithm. When the injection current was as big as 24 mA, the spatial resolution reaches 2mm. However, the conductivity images have some artifacts due to the noise effects. If we sacrifice the spatial resolution in MREIT studies, it seems possible to apply MREIT to animal studies.

References

[1] Oh SH, et al., Mag Reson Med 2003;50:875-878.
[2] Oh SH, et al., Phys Med Biol 2003;48:3101-3116

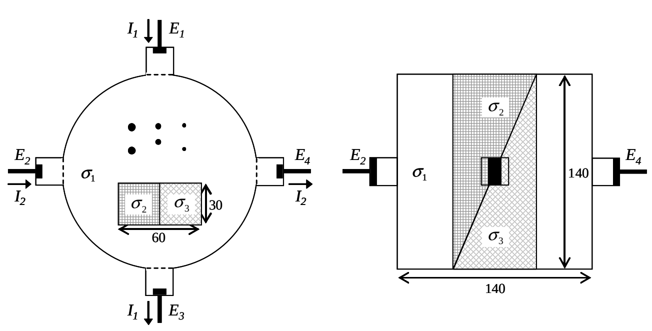

Fig.1 The conductivity phantom composed of sponges (σ_2 and σ_3) and cotton threads immersed in electrolytic solution (σ_1).

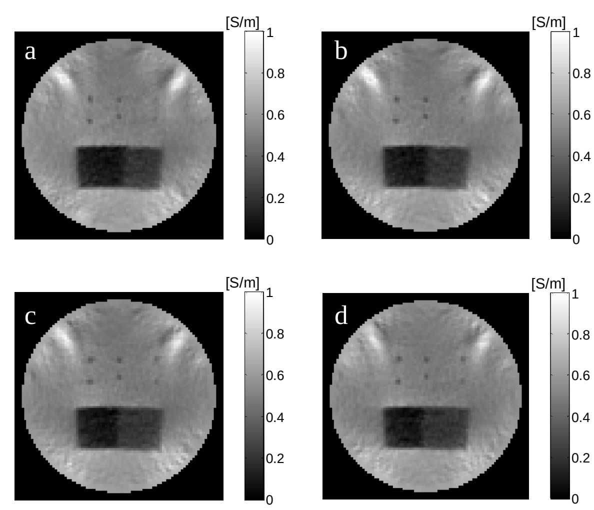

Fig. 2 The reconstructed conductivity images at different slices.