Comparison of Magnetic Resonance Electrical Impedance Tomography at 4T and 7T Field Strengths

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Purpose

Low level injected currents generate a magnetic field within a body that can be measured using MRI. Magnetic resonance-electrical impedance tomography (MREIT) utilizes these measurements due to injected currents to construct the conductivity distribution within an object. Electrical conductivities of tissues are different among normal, malignant, and benign tissues. In-vivo impedance imaging of suspicious lesions could aid in the diagnosis and specification of malignant tumors. Several studies using phantoms and small animal bearing tumors demonstrated the efficacy of the algorithm [1, 2]. The magnetic flux density is extracted from MRI phase images and one of the challenges in MREIT is acquiring phase information with sufficient SNR while maintaining the injected currents at safe levels. Sadleir et. al. carried out noise analysis in magnetic flux density measurements at 3T and 11T and they suggest that the noise level in magnetic flux density is reduced as field strength is increased by a factor approximately proportional to the increase in the field strength [3]. In this study, we carried out experiments at 4T and 7T field strengths to compare the effect of increased magnetic flux density SNR in the final reconstructed conductivity images.

Methods

For the test phantom, a hollow acrylic tube and agarose gels with different NaCl concentrations were used. 2gr/100mL agarose powder and 4mM $CuSO_4$ were kept the same for all regions. Amount of NaCl was set to 1gr/100mL and 4gr/100mL for background and objects (O1,O2), respectively. The conductivity values were measured in an independent system as 5.68Sm^{-1} and 1.61Sm^{-1} (3.3:1 contrast). The diameter of the both objects were 6mm and their centers were located 1cm apart giving 4mm gap between their boundaries. The thickness of the phantom was 1cm and in-slice dimensions of the phantom are defined in Fig 1. Four copper electrodes each 3mm wide were placed equidistantly along the inner acrylic wall and used to probe the interior region. Bipolar current injection scheme was used the resulting magnetic flux density distribution measured using a modified spin-echo pulse sequence as shown in Fig 2. [4]. Opposite electrode pairs were used to get two current injection profiles. Iterated sensitivity matrix method (SMM) with Tikhonov regularization was used for conductivity reconstruction [1].

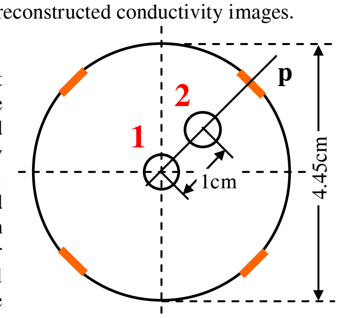

Fig 1. Phantom definitions

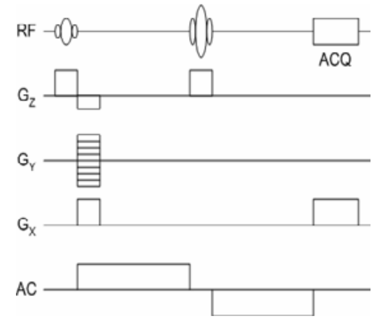

Fig 2. MREIT Pulse Sequence

Results

MREIT experiments were carried out using two phantoms with the same distribution in 4T and 7T systems. Since ion diffusion alters the initial conductivity distribution [5], we prepared the phantom immediately before each experiment to minimize these effects in the comparison. The pulse sequence parameters for both experiments were as: TR = 500ms, TE = 60ms FOV = 7cm, slice thickness = 2mm, field image matrix = 64x64, NEX = 4. The sampling bandwidth was set to 33.3KHz and 1.25MHz for 4T and 7T systems, respectively. The amplitude of the injected current was 1mA and the duration of the positive and negative cycles were 27.3ms and 27.7ms. Reconstructed conductivity images and profiles along p-line (as defined in Fig 1) at both field strengths are given in Fig 3. Although the phantom is slightly rotated between two cases, this does not affect the relative positions of the objects with respect to each other. We calculated full-width-at-half-maximum (FWHM) for both objects through x and y cross-sections and also we looked at peak contrast in the object. Note that the SMM reconstructs relative conductivity values if magnetic flux density measurements are used alone and the values presented here are normalized to the background conductivity. The peak reconstructed contrast and FWHM values are summarized in Table 1 for both field strengths and objects. The objects were not fully resolved in the p-line profile for 4T case but more separable in the 7T case. For all cases, the constructed contrasts are lower than the expected ones, especially for the object located at the center.

Table 1. Comparison of reconstructed peak contrast and FWHM

	peak contrast		FWHM-x (cm)		FWHM-y (cm)	
	O1	**O2**	**O1**	**O2**	**O1**	**O2**
True	3.3	3.3	0.6	0.6	0.6	0.6
4T	1.6	1.8	1.3	1.0	1.4	0.9
7T	1.8	2.2	1.0	0.8	1.1	0.8

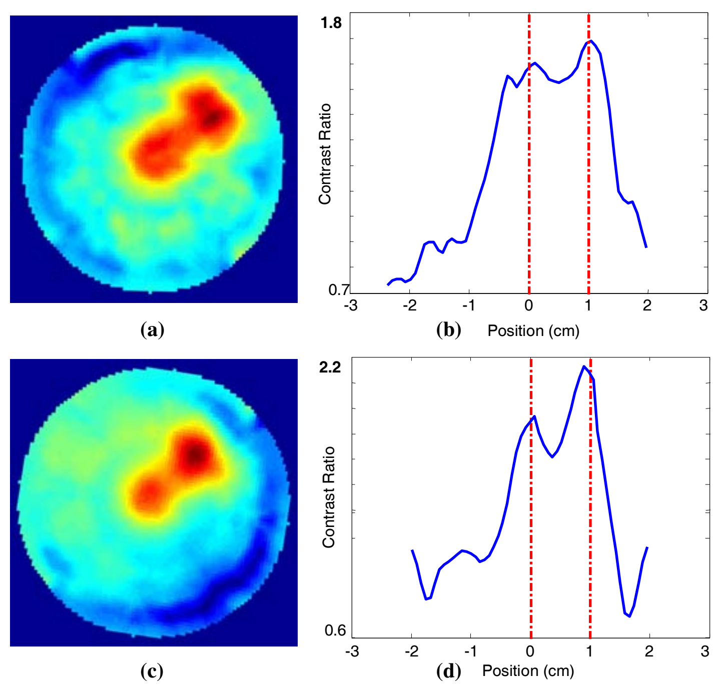

Fig 3.**(a)** image at 4T **(b)** 4T profile (along p-line) **(c)** image at 7T **(d)** 7T profile (along p-line)

Discussion

In this study, we carried out MREIT experiments at two different field strengths to understand how the improvement in magnetic flux density SNR affects the reconstructed conductivity values and target detection. When the reconstructed images are compared, it is seen that given the same amount of experimentation time, the accuracy and the spatial resolution of the conductivity images at 7T is better compared to 4T. Although the reconstructed contrast values are lower than the expected values due to ion diffusion in all cases, the comparison between different field strengths shows 13%-22% improvement at 7T compared to the 4T case. Major improvement is noticable in the resolution of the objects, especially for the one at the center, when higher field strength is used.

References

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Acknowledgments

This research is supported in part by Department of Defense Award W81XWH-04-1-0446 and NIH/NCI Award R01 CA114210.