Magnetic Resonance Current Density Imaging of a Small Animal with Chemical Shift Artifact Correction

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Synopsis

Magnetic resonance current density imaging (MRCDI) is a useful tool to measure electrical current density inside a subject. Due to the chemical shift effect, MRCDI is often seriously distorted when it is applied to biological tissue imaging. In this work, we propose a chemical shift artifact correction method for MRCDI. With the chemical-shift-artifact corrected MRCDI technique, we obtained current density images of biological tissue phantoms and a post mortem rat using a 3.0 Tesla MRI system. The MRCDI results suggest that MRCDI of live animals is very feasible in the near future.

Introduction

Magnetic resonance current density imaging (MRCDI) is a useful tool to measure electrical current density inside a subject [1]. Recently, Oh *et al* have proposed a new MRCDI technique for a single current density component imaging in which the object rotations are no longer necessary [2]. However, the MRCDI technique suffers from chemical shift artifact when it is applied to biological tissue imaging. We propose a chemical shift artifact correction method for the MRCDI and we present experimental results of biological tissue imaging performed with a 3.0 Tesla MRI system.

Methods

Since chemical shift artifacts appear as pixel shifts in the read-out direction and phase anomalies in MRCDI, chemical shift artifacts have serious effects on MRCDI in which extra phase caused by the injection current is measured for the reconstruction of current density images. In the gradient-echo MRCDI, the reconstructed MR image, ρ, is given by,

$$\rho = \left(\rho_w + \rho_f e^{-i\Delta\omega_{fw}TE}\right) e^{-i\gamma\Delta B\ TE} e^{-i\phi_0} e^{-i\phi_C} \qquad (1)$$

where ρ_w and ρ_f are the water and fat component images, $\Delta\omega_{fw}$ is the resonant frequency difference between the water and fat protons, ϕ_o is the phase error of the MRI system, and ϕ_c is the extra phase caused by the injection current. With ΔB, ϕ_o, ρ_w and ρ_f unknown, we are to measure ϕ_c for the current density calculation in MRCDI. We applied positive and negative current pulses in an interleaved scheme to cancel out the effects of ΔB and ϕ_o on the phase measurements [2]. To reconstruct water and fat component images, we used the three point chemical shift artifact correction method [3]. That is, we acquired two in-phase MRI data (water and fat signals have the same phase) with two different echo times TE_1 and TE_2, and one opposed-phase MRI data (water and fat signals have the opposite phase) with the echo time TE_3. Once the water and fat component images have been obtained, the two images were combined with the fat component images shifted back in the read-out direction. The extra phase ϕ_c was, then, extracted from the combined images with the chemical shift artifact corrected, and it was used for the current density image reconstruction.

Results

For MRCDI of biological tissues, we made a phantom using porcine fat tissues, chicken muscle, chicken bone and agar gelatin. In Fig. 1(a), we have shown an MRI image of the phantom. We can clearly notice the chemical shift artifact in the image. For MRCDI with chemical shift artifact correction, we used the repetition time of 120ms, TE_1 and TE_2 of 14.02ms and 16.36ms, respectively, and TE_3 of 15.19ms, and the slice thickness of 5mm. The current pulse amplitude was 48mA and the current pulse width was 10ms. In Fig. 1(b) and (c), we have shown the reconstructed current density images obtained without and with the chemical shift artifact correction, respectively. We can notice the big current density anomalies in Fig. 1(b) due to the chemical shift artifact. In Fig. 1(c), we observe smaller current densities at the porcine fat and chicken bone regions due to smaller conductivities at the regions. The average current densities are 3.23mA/cm^2 and 0.35mA/cm^2 at the chicken muscle and the porcine fat regions, respectively. Figure 2(a) and (b) show an MR magnitude image and the corresponding current density image, respectively, at the chest region of a post mortem rat. The current was injected from the hind legs to the fore legs. We can clearly notice lower current densities at the lung region due to its low electrical conductivity.

Conclusions

MRCDI has been successfully applied to current density imaging of biological tissues with chemical shift artifact correction. For the MRCDI to be applied to *in-vivo* studies, we have to reduce the injection current down to 1mA and improve the sensitivity of MRCDI.

References

[1] Scott GC, et al., IEEE Trans Med Imag 1989; 10:2: 362-374.

[2] Oh SH, et al., Magn Reson Img 2003;21:1023-1028.

[3] Haacke EM, et al., *Magnetic resonance imaging: Physical principles and sequence design*, Wiley-Liss, New York, 1999

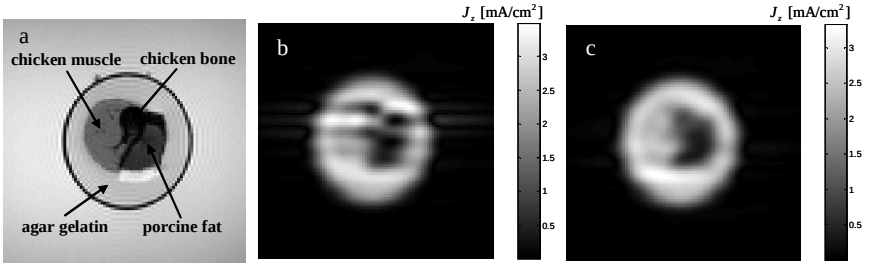

Fig. 1. (a) An MRI image of the biological tissue phantom corrupted by the chemical shift artifact. (b) (c) The current density images obtained without and with the chemical shift artifact correction, respectively.

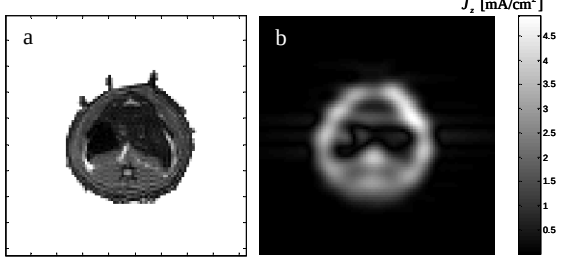

Fig. 2. (a) An MRI image of the post mortem rat. (b) The corresponding current density image.