Metal artifact correction using sensitivity information

Dongchan Kim[1], JaeJin Cho[1], Kinam Kwon[1], and HyunWook Park[1]
[1]*Electrical engineering, KAIST, Daejeon, Yuseong-Gu, Korea*

Target Audience

MR engineers who are interested in metal artifact correction.

Introduction

MRI is one of the most powerful imaging modalities for clinical diagnosis. However, the use of MRI is limited for the patients who have metallic implants, because metallic implants causes severe field inhomogeneity[1], which causes the geometrical distortion in image and the slice profile. To resolve these problems, slice encoding for metal artifact correction (SEMAC) technique was proposed. In SEMAC, additional z-phase encoding is applied in order to eliminate the distortion of slice profile. Also, SEMAC uses view angle tilting (VAT)[2] technique to correct the geometric distortion in readout direction. SEMAC technique could well correct the artifact caused by metallic objects, but it requires the long imaging time caused by additional z-phase encoding. In standard MR imaging scheme, multiple MR images with different contrast such as T1, T2 and FLAIR are usually acquired for clinical diagnosis, or time-series images are acquired to analyze brain function in functional MRI. In these cases, SEMAC is not practical technique due to the long imaging time. In this work, we propose a sensitivity information based metal artifact correction (MAC) technique to reduce the imaging time for multi-contrast and time-series imaging. The proposed method acquires a single metal artifact corrected image and estimates MAC coefficients by using the sensitivity information of each channel of RF coil. The MAC coefficients are used to correct metal artifacts of other images of multi-contrast and time-series images to reduce the imaging time.

Methods

Metal artifact can generate geometric artifacts in MR image as follows[1]:

$$\rho(x,y,z)\xrightarrow{\Delta\nu(x,y,z)}\hat{\rho}\left(x-\frac{2\pi\Delta\nu(x,y,z)}{\gamma G_x},\, y,\, z-\delta z\frac{\Delta\nu(x,y,z)}{\delta\nu_{RF}}\right), \tag{1}$$

where ρ is the distortion-free image, $\Delta\nu(x,y,z)$ is the off-resonance frequency distribution, $\delta\nu_{RF}$ is the spectral bandwidth of the applied RF pulse and δz is the slice thickness. As the shift in read-out direction (x-axis) can be neglected by applying view angle tilting (VAT)[2] technique, eq. (1) can be re-written as follows:

$$\rho(x,y,z)\xrightarrow{\Delta\nu(x,y,z)}\hat{\rho}\left(x,\, y,\, z-\delta z\frac{\Delta\nu(x,y,z)}{\delta\nu_{RF}}\right). \tag{2}$$

As shown in eq. (2), the acquired MR image contains unwanted signals from other slices due to the distortion of slice profile. Therefore, the acquired MR image of each multi-channel coil can be written in a matrix from as follows:

$$\begin{pmatrix} c_{11}(x,y) & \cdots & c_{1N}(x,y) \\ \vdots & \ddots & \vdots \\ c_{N1}(x,y) & \cdots & c_{NN}(x,y) \end{pmatrix}\begin{pmatrix} \rho_1(x,y,z_1) & \cdots & \rho_K(x,y,z_1) \\ \vdots & \ddots & \vdots \\ \rho_1(x,y,z_n) & \cdots & \rho_K(x,y,z_n) \end{pmatrix}=\begin{pmatrix} \hat{\rho}_1(x,y,z_1) & \cdots & \hat{\rho}_K(x,y,z_1) \\ \vdots & \ddots & \vdots \\ \hat{\rho}_1(x,y,z_n) & \cdots & \hat{\rho}_K(x,y,z_n) \end{pmatrix}, \tag{3}$$

where c is the MAC coefficients, N is the number of slices, and K is the number of RF coil channels. Then, the MAC coefficients can be estimated as follows:

$$\begin{pmatrix} c_{11}(x,y) & \cdots & c_{1N}(x,y) \\ \vdots & \ddots & \vdots \\ c_{N1}(x,y) & \cdots & c_{NN}(x,y) \end{pmatrix}=\begin{pmatrix} \hat{\rho}_1(x,y,z_1) & \cdots & \hat{\rho}_K(x,y,z_1) \\ \vdots & \ddots & \vdots \\ \hat{\rho}_1(x,y,z_n) & \cdots & \hat{\rho}_K(x,y,z_n) \end{pmatrix}\begin{pmatrix} \rho_1(x,y,z_1) & \cdots & \rho_K(x,y,z_1) \\ \vdots & \ddots & \vdots \\ \rho_1(x,y,z_n) & \cdots & \rho_K(x,y,z_n) \end{pmatrix}^{-1}, \tag{4}$$

As the MAC coefficients are independent from TR and TE, we can estimate the MAC coefficients from a single SEMAC acquisition and apply the estimated coefficients to reconstruct other images with different TR and TE.

Results

In-vivo experiments were performed at a 3.0T MRI system (Siemens Magnetom Verio, Erlagen, Germany) with a 12-channel head coil to verify the proposed MAC technique. The spin echo sequence with VAT gradient was applied to acquire data using the following parameters: field-of-view (FOV) = 256 × 256 mm^2, slice thickness = 5 mm and 25 slices. To show performance of the proposed technique, MR images were acquired with following TR/TE sets; TR/TE = 100/20, 200/20 and 200/40 ms.

The MAC coefficients were estimated by using the SEMAC images with TR/TE of 100/20 ms in Fig. 1. The estimated MAC coefficients were applied to other spin echo images. As shown in Fig. 2, metal artifacts were well corrected for all images regardless of TR and TE.

Conclusions

In this paper, a new MAC technique is proposed which could correct metal artifact by using the estimated MAC coefficients. As shown in our results, the images acquired by using the spin-echo sequence with VAT gradients were well corrected by the proposed method.

Reference

1.W. Lu et al., 2009 MRM 62:66-76, 2. Cho et al., 1988, Med. Phys. 15:7

Acknowledgement

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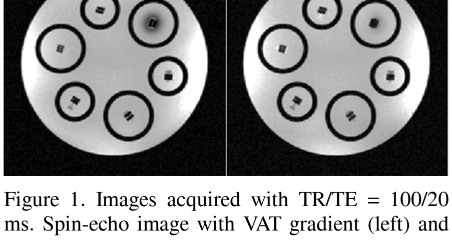

Figure 1. Images acquired with TR/TE = 100/20 ms. Spin-echo image with VAT gradient (left) and SEMAC image (right).

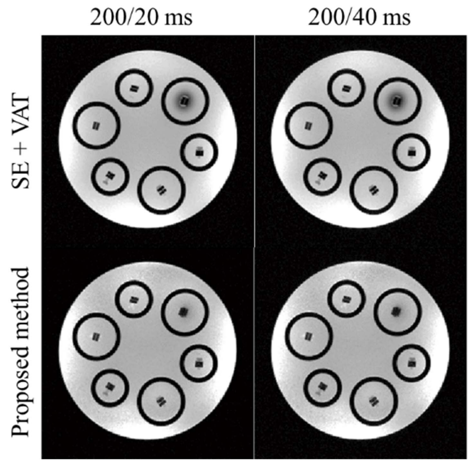

Figure 2. Spin-echo image with VAT gradient with different TR/TE sets (Top) and metal artifact corrected images using the proposed method (bottom).