Multiband Imaging Method for Metal Artifact Correction with 3D Multi-Spectral Imaging

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Introduction

The number of patients who have metallic implants has been increasing. MR imaging of these patients becomes more important for diagnosing complications near metallic implants[1]. However, in conventional MRI, the metallic implants generate severe geometric artifacts so that images could not be used in diagnosis. In recent years, 3D multi-spectral imaging (MSI) methods[2] such as slice encoding for metal artifact correction (SEMAC) and multi-acquisition variable-resonance image combination (MAVRIC) have significantly improved image quality near metallic implants. These techniques acquire the spectral data, which reduces signal loss and other off-resonance artifacts. However, 3D MSI needs very long imaging time to acquire several spectral bins for covering whole distorted magnetic field. Although many fast imaging techniques such as parallel imaging and partial Fourier imaging would help to reduce imaging time, it still takes too much time for patients. Multiband imaging technique could be one of the solutions for shortening the imaging time of 3D MSI. Multiband imaging acquires the signal of multiple spectral bins simultaneously so that the number of excitations decreases. In this paper, multiband 3D MSI method will be proposed for accelerating the imaging speed.

Method

Most of 3D MSI methods use VAT (View Angle Tilting) [3] gradient for correcting in-plane metal artifact. However, VAT gradient generates offset of spectral bin in frequency-encoding direction when multiband RF is used [Fig 1(a)]. Moreover, signal loss occurs on the region overlapped by simultaneously excited spectral bins. Therefore, each spectral bin data should be decomposed from multiband data for applying to 3D MSI. Because spectral bins share the same FOV, it is impossible to separate each bin using sensitivity difference of multi-channel coils. To solve this problem, CAIPIRINHA[4] is modified for 3D MSI. Each spectral bin contains variable phase information depending on phase-encoding line, which gives the opportunity to use coil sensitivity from acquired signal [Fig 1(b)]. Now, each spectral bin could be decomposed by parallel imaging techniques. In this experiment, slice-GRAPPA[5] is implemented for separating each spectral bin.

Each spectral bin needs to be further apart from neighboring bins for avoiding signal loss by intra voxel dephasing. In this experiment, multiband RF pulse excites two spectral bins simultaneously and the distance between bins is 8 times of bandwidth of each bin. Multiband RF pulse generates 180 degree offset along two phase-encoding directions each, so that the sensitivity difference of two phase-encoding directions could be used [Fig 2].

Experiments were conducted on a 3.0 T MRI scanner (Siemens Verio, Germany) and 12-channel head coil. MAVRIC-SEMAC hybrid sequence was implemented with the imaging parameters of 4000_{ms} / 25_{ms} / $500_{\mathrm{Hz/pixel}}$ (TR/TE/$\mathrm{BW}_{\mathrm{readout}}$) with hip-joint replacement. Image size is $101 \times 256 \times 12$ and voxel size is $1.7 \times 1.0 \times 5.0\ \mathrm{mm}^3$. Each spectral bin has Gaussian shape with 1.5 kHz bandwidth and the distance between neighboring bins in multiband RF pulse is 12 kHz. Spectral resolution is 750 Hz with 32 samples so that total spectral coverage is 24 kHz. In addition, image-interleaving technique is applied to reduce the imaging time.

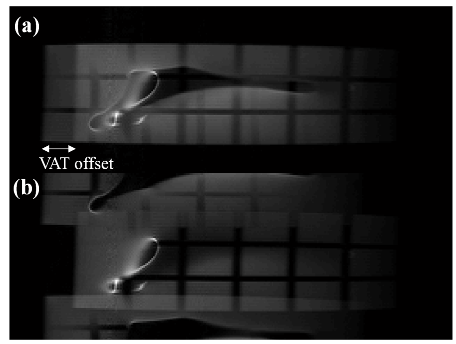

Fig 1. (a) Multiband VAT image, and (b) Multiband VAT image with RF phase alternating.

Results and Discussion

Fig 3 shows (a) 3D MSI image, (b) multiband image before reconstruction, (c) multiband 3D MSI image reconstructed by slice-GRAPPA, and (d) 10 times amplified difference image between (a) and (c). The results show that multiband 3D MSI method corrects metal artifact well in a reduced imaging time. Multiband 3D MSI is also useful to improve the spectral resolution and to reduce the crosstalk of image interleaving technique. Moreover, the proposed method can minimize the SNR loss of adaptive phase-encoding method. One of possible problems of multiband 3D MSI is the intensity changes of spectral bins. This problems could be suppressed by adjusting image-interleaving order and the sequence of ACS lines. In further works, it will be studied in details.

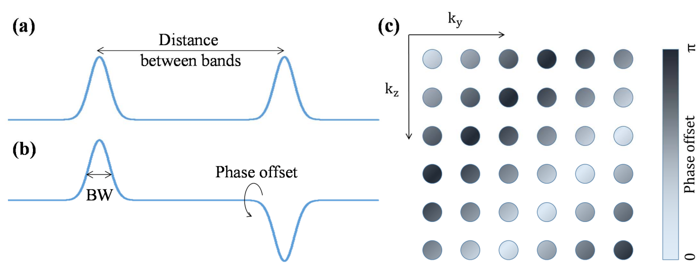

Fig 2. Mutiband RF profile of (a) 0-0 degree, (b) 0-θ degree, and (c) phase offset of multiband RF pulse.

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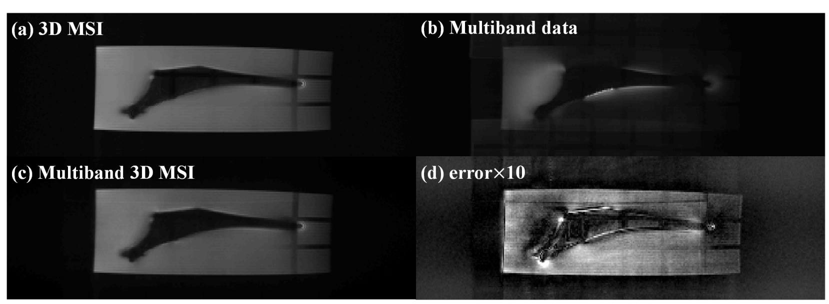

Fig 3. (a) 3D MSI image, (b) multiband data before reconstruction, (c) multiband 3D MSI image reconstructed using slice-GRAPPA, and (d) 10-times amplified difference image between (a) and (c).

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