Eliminating Metal Artifact Distortion using 3D-PLACE

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Introduction The clinical viability of MRI near metallic substances is hindered by consequential image artifacts. There are two main categories of artifact: (i) signal loss/pile-up, occurring in regions with large magnetic field perturbations, and (ii) geometric distortion, occurring in regions with moderate magnetic field perturbations. In standard 2DFT MR imaging, the phase encoding (PE) direction is relatively immune to distortion. Distortion artifacts are propagated along the frequency encoding (FE) and slice selection directions, known as in-plane and through-plane distortion respectively. Current methods of metal artifact reduction include variations on Cho *et. al.*'s view angle tilting [1-4], and the use of discretely stepped bandwidth radiofrequency pulses [5]. In this work we propose 3D-PLACE, a method incorporating the acquisition of 3DFT MR images to limit through-plane distortion. In-plane distortion is eliminated with Phase Labeling for Additional Coordinate Encoding (PLACE) [6], a technique previously developed for correcting distortion/ghosting in echo-planar imaging. Here two spin-echo images are acquired which differ by a relative phase ramp applied along the FE direction, so that distortions may be encoded into the phase difference of the images.

Methods A Lego™ (Billund, Denmark) structure was constructed around a Zimmer™ (Warsaw, IN) ASTM F75 Cobalt-Chromium-Molybdenum alloy hip prosthesis (Fig. 1). The entire structure was placed in a bottle of water with sponges positioned to ensure immobility. This phantom was imaged using a body coil in a 1.5T Siemens Avanto scanner. The scanning parameters for sagittal orientation data were as follows: 12x5mm slices, 30cm x 30cm FOV, 256x256 matrix size, 300 kHz readout bandwidth, 300ms TR, and 11ms TE. Axial images were identical except that the PE FOV/size was 17.8cm/152 pixels. Two complex images I_1 and I_2 were acquired using a 3D turbo spin-echo (TSE) sequence. The sequences of the two images differed slightly: before and after the data acquisition window of one image sequence, additional gradient areas were applied along the FE direction with opposite polarities. A phase ramp was thus generated in the FE direction across the FOV of the image with the added gradients. While this additional phase appears distorted by the magnetic field perturbation, the phase difference of I_1 and I_2 for each pixel is directly proportional to the true position of the associated spins.

The distortion correction was performed in a manner similar to ref. [6]. A complex image C was first calculated from the product of I_1 and I_2*. The phase ramp in C was then removed by applying a perfectly linear phase ramp in the opposite direction. This resulted in a new complex image C', with flattened phase representing a displacement field. Using this displacement field, each pixel was mapped to its undistorted location. In order to handle fractional pixel shift and reduce noise in the phase, the complex image C' and the distorted image were both expanded by a factor of 100. The expanded C' was smoothed, whereupon its phase was extracted and used to map the expanded and distorted image. Finally, after the mapping was completed, the expanded and corrected image was rebinned to its original size.

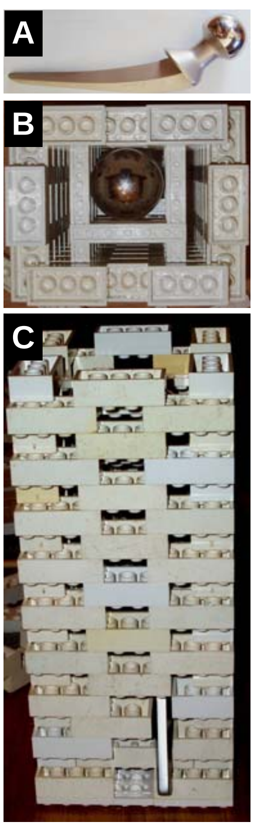

Figure 1: A) Zimmer hip prosthesis, B) top view of Lego structure, and C) side view of Lego structure

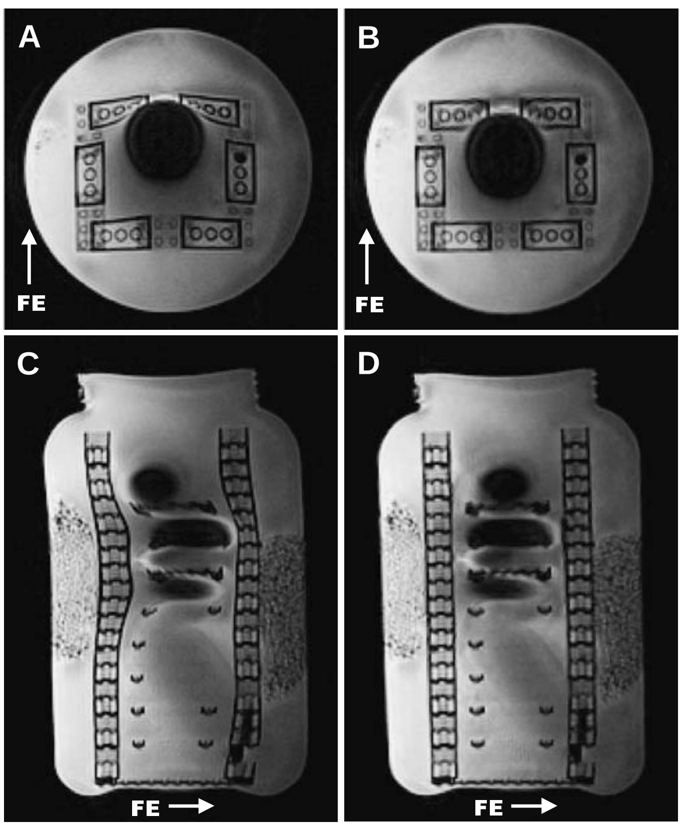

Figure 2: A) 3D Axial distorted TSE image, B) 3D PLACE-corrected Axial TSE image, C) 3D Sagittal distorted TSE image, and D) 3D PLACE-corrected Sagittal TSE Image. All images show the head of the prosthesis; C) and D) show parts of the neck and stem.

Results Fig. 2 portrays some of the results of applying PLACE along the FE direction to correct for in-plane distortion caused by a hip prosthesis. The distorted Lego features in the A) axial 3D-TSE image and C) sagittal 3D-TSE image are rectified in their respective PLACE-corrected counterparts B) and D). While the hip prosthesis still exhibits significant signal loss/pile-up artifacts, its alignment in D) now conforms to its true structure shown in Fig. 1A). No through-plane distortion was evident in these or any of the other reconstructed 3D-TSE images.

Discussion Scan times were 5.3 minutes for the two axial datasets, and 8.7 minutes for the two sagittal datasets. 3D-PLACE is time efficient; the acquisition of two images merely doubles the scan time of the original TSE sequence. The implementation of this technique is also relatively simple, since no sequence modifications are required other than the added FE gradient areas. Additionally, phase unwrapping is unnecessary in the pixel mapping process. Future directions include developing a correction scheme for the signal loss/pile-up artifacts, and removing slab-selection aliasing typical of 3D MR imaging of metals.

References*:*

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