Accelerated Slice-Encoding for Metal Artifact Correction

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Introduction: With over one million surgeries for hip or knee replacements or spinal fusion performed in the United States alone each year, there is a clear need for non-invasive methods for post-surgical and ongoing evaluation in their recipients. MRI provides excellent soft-tissue contrast for orthopaedic imaging, but the large metal-induced B_0 field inhomogeneities cause signal loss, through-slice distortion and in-plane distortion. Two recent techniques correct metal-induced artifacts by additional encoding of either the frequencies causing distortion [1] or the undistorted position [2], both with a significant scan time increase. Here we demonstrate that with a simple linear reconstruction, the latter technique, slice-encoding for metal artifact correction (SEMAC), can include a combination of echo train imaging, parallel imaging and partial Fourier acquisition, to provide useful contrast and reasonable scan times.

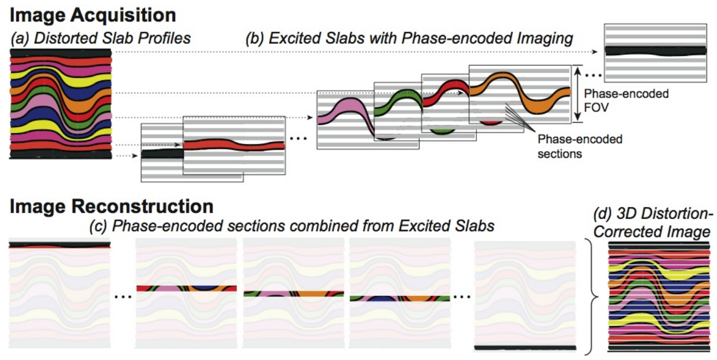

Figure 1: SEMAC uses additional through-slice phase encoding to resolve the shape of each slice (a,b). At reconstruction, data are from different slices are resampled to correct through-plane distortion (c,d).

Methods and Results: Slice-encoding for metal artifact correction (SEMAC) uses a simple strategy to correct through-plane distortions (Fig 1). 2D slices are excited, and imaged using a spin echo (or echo train) and view-angle tilting to correct in-plane distortion during acquisition [3]. Each slice is imaged in 3D, using additional through-plane SEMAC phase encoding (Fig 2) and careful consideration to ensure similar phase on each excited slice. During reconstruction, the slice profiles are resolved (Fig 1b), and signals at a resolved position from different slices (Fig 1c) are simply added to create a through-slice corrected data set (Fig 1d). Because these steps are *linear*, the through-plane correction can be applied before the in-plane Fourier transform to allow inclusion of standard parallel imaging and partial Fourier reconstruction. Our SEMAC sequence used an RF bandwidth of 1.6 kHz, readout bandwidth of 1 kHz/pixel, and 16 SEMAC phase encodes per slice.

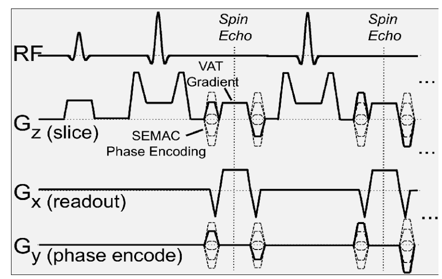

Figure 2: SEMAC corrects through-plane and in-plane distortions using additional SEMAC phase-encoding and view-angle tilting (VAT), and a multiple spin echo train.

We scanned a gel phantom containing a shoulder implant using an 8-channel head coil at 1.5T with a PD-weighted SEMAC sequence with TR/TE = 3400/12 ms, ETL=8, 24 slices (2.5 mm thick), 256x144 matrix, and 20 x15 cm FOV for a 16:26 scan time. SEMAC was repeated with 2x acceleration using autocalibrating reconstruction for Cartesian imaging (ARC) [4,5], and the combination of 2x ARC with partial Fourier resulting in scan times of 10:05 and 7:22. Finally, a spin echo sequence with the same bandwidth and no VAT was included for comparison. Results in Fig. 3 show that all SEMAC images clearly depict the detail of the shaft/head of the implant which is obscured by distortion in the spin echo image.

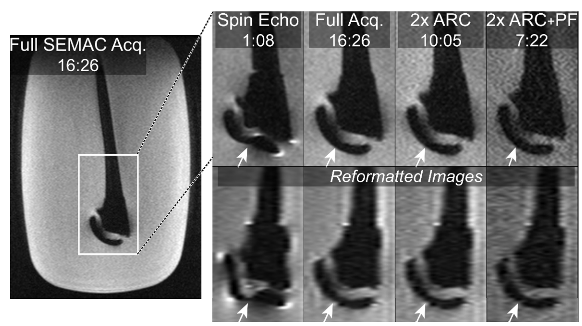

Figure 3: Images of a titanium / cobalt-chromium shoulder implant with Spin Echo and SEMAC (Full, 2x ARC, and 2x ARC with partial Fourier). Inset images and reformatted images clearly depict the rounded implant shape in all SEMAC methods (arrows), and show some SNR loss.

Using a similar protocol, with 32 slices (3mm thick), TR/TE = 540/11ms ETL=1, and 256x128 matrix over a 16cm FOV, we scanned the knees of several volunteers with an 8-channel knee coil at 1.5T. We used T_1-weighted SEMAC with 1x, 2x and 3x ARC, for scan times of 18:48, 11:06 and 8:29. Examples (Fig 4) show that SEMAC dramatically improves the distortion compared to spin echo (with a 256x256 matrix), clearly depicting the tissue around stainless steel screws. Again, acceleration does not affect the artifact correction, but reduces SNR as expected.

Discussion: We have shown that SEMAC imaging can include echo-trains, parallel imaging and partial Fourier reconstruction to substantially accelerate imaging to compensate for the increased SEMAC encoding time. The current challenges are to address the SNR of the technique, which also suffers from addition of sparse signals, and to correct the minor residual artifact seen near the screws (Fig 4), which results from discontinuities between slices. Nonetheless, as Fig 4 shows, accelerated SEMAC allows clear visualization of tissue near metallic implants with dramatically reduced artifact levels in reasonable scan times.

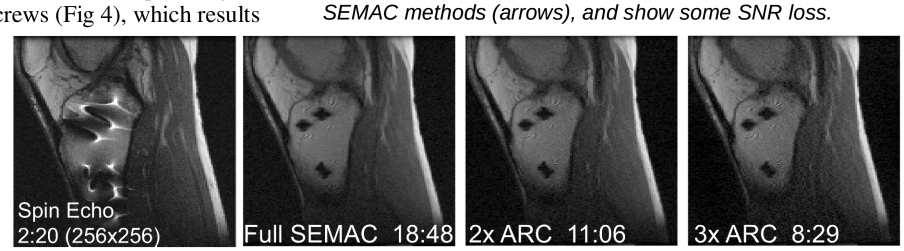

Figure 4: Standard Spin Echo (left), and SEMAC images with 1x, 2x and 3x ARC acceleration in the knee of a subject with stainless steel screws. Artifact reduction is comparable for all acceleration factors, while SNR decreases as expected.

References:

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