Fast Imaging of Metallic Implants by Data Subsampling

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PURPOSE: The ability to perform magnetic resonance imaging near metallic implants is highly desirable due to their prevalence and the high rate of complications[1]. However, these implants cause large field distortions that lead to severe imaging artifacts in conventional MRI scans[2]. Methods to correct for this include MAVRIC[3] and SEMAC[4]. SEMAC corrects for through-plane distortions by applying phase encoding in the slice direction, while resolving in-plane distortion with a View Angle Tilting (VAT) gradient. This technique is effective but requires long scan times, particularly at high field strengths. In this work, we demonstrate how SEMAC's imaging of a sparse 3D volume with a typical region of support allows for a reduction in scan time by subsampling k-space in a checkerboard pattern.

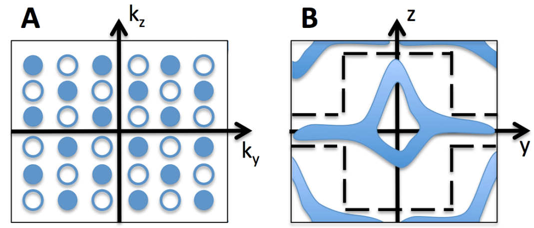

Figure 1: By subsampling in a checkerboard pattern (A), aliased replicas get packed into unused regions (B). The effective field of view contains no replicas (dashed line in B).

THEORY: SEMAC resolves slice distortion by applying phase encoding in the slice direction. For each desired slice, a phase encoded 3D volume is acquired. The 3D volumes for each excited slice are then combined during post-processing. Assuming the implant is small compared to the in-plane field of view, the slice distortion is small for most of the 3D field-of-view (FOV). Subsampling k-space in the ky-kz plane in a checkerboard pattern, (Fig. 1A) packs aliased replicas more closely, but such that they do not interfere (Fig. 1B)[5,6]. The effective field of view is then shown with dashed lines in Figure 1B, and aliased regions can be zeroed out before the volumes are combined. Overall, this scheme reduces scan time by up to 50%.

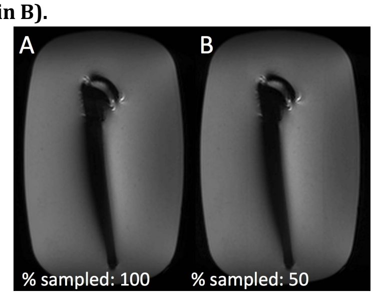

Figure 2: A titanium shoulder prosthesis scanned with fully sampled (A) and prospectively subsampled (B) SEMAC.

METHODS: Our first demonstration used prospectively fully-sampled and sub-sampled 3.0T scans of a titanium shoulder prosthesis immersed in agar gel. The aliased copies were removed from each volume by detecting the slice PE that had the largest total signal, keeping a central portion around it as shown in Figure 1B and zeroing out the rest of the volume. The effective scan time reduction is 50%

Next, we show compatibility with partial-ky scanning, using a scan of a subject with spinal fixation hardware, acquired on a 1.5 T MRI system. The scan used 55% partial-ky sampling with a 6:49 scan time. We applied the checkerboard subsampling outside the calibration region retrospectively. After homodyne reconstruction of each 3D volume, aliased images were removed in the same manner as for the prosthesis scan, and the 3D volumes recombined. The effective scan time reduction is 39% to 4:11.

Finally, we showed feasibility in a data set with a hip titanium implant, acquired with 55% partial ky and an 2x parallel imaging acceleration in ky. The effective scan time reduction is 35%, from 6:42 to 4:22.

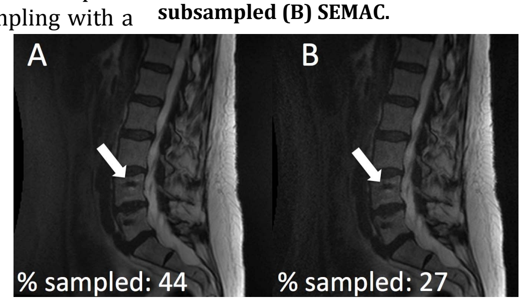

Figure 3: An in vivo spinal scan from a conventional (A) and retroactively subsampled (B) SEMAC data set. The arrows show spinal fixation hardware.

RESULTS: Figure 2 shows comparable images of the shoulder prosthesis with full and subsampled k-space (50% reduction). The *in vivo* scans also have similar image quality with and without the subsampling scheme retroactively applied. Artifacts are equally reduced in both images (Figs. 3-4). No aliasing effects can be seen in the subsampled image. SNR in the subsampled image is reduced since energy is spent on the aliased copies.

DISCUSSION: To date, most Multi-Spectral Imaging (MSI) makes few assumptions about the amount of distortion. This work shows that by assuming a limited, non-rectangular region of support in the 3D volume, significant reduction in scan time can be achieved. Further improvements are possible, including centering the effective FOV in y based on signal detection (as is currently done in z), detecting the distorted profile extent during a modified prescan, and using an even more sparse sampling pattern to obtain a more than twofold acceleration with an even more efficient packing scheme.

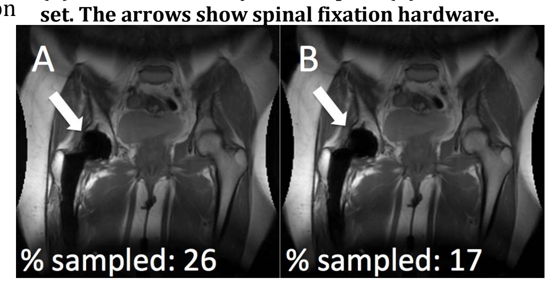

Figure 4: A hip scan acquired with NEX=0.5 and ARC 2x acceleration in ky but otherwise conventionally sampled (A) and retroactively subsampled outside of the calibration area (B). The arrow shows a titanium hip implant.

CONCLUSION: Subsampling ky-kz in a checkerboard pattern can improve the FOV/scan-time tradeoff in SEMAC imaging, saving close to 50% in scan time. We have demonstrated compatibility with both partial-ky and parallel imaging. This will allow the imaging of many patients with metallic implants with twice the FOV with minimal scan time increase, or allow a scan time reduction where SNR permits.

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