Fat-Suppressed and Distortion-Corrected MRI Near Metallic Implants

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Introduction: The use of orthopedic implants including joint replacements and fixation devices is increasingly common, necessitating follow-up evaluation to assess possible complications such as loosening or infection. Due to metal-induced distortion and other artifacts on conventional MRI, follow-up is often limited to X-ray images. With additional encoding and parallel imaging, MR images with minimal distortion can be acquired in subjects with metallic implants in reasonable scan times [1,2]. Here we achieve distortion-corrected imaging with fat suppression by integrating short TI inversion recovery (STIR) [3] with slice-encoding for metal artifact reduction (SEMAC) [2]. STIR offers fat suppression that is insensitive to susceptibility variations, so it is a robust choice for fat suppression near metal.

Methods: The SEMAC pulse sequence (Fig. 1) excites 2D slices, but uses a 3D readout to resolve through-slice distortion near metal, and view-angle tilting (VAT) to correct in-plane distortion [2,4]. The 90° and 180° pulses are 2 kHz sinc pulses. A spatially-selective 2kHz Silver-Hoult adiabatic inversion pulse is used for fat suppression. The key point is to match the gradient amplitude during the inversion, 90° excitation, 180° refocusing pulses and readout (for VAT), to ensure identical slice distortion at all stages.

Following informed consent, we compared SEMAC (with and without STIR) with standard sequences on 1.5T GE Excite scanners in one healthy volunteer and 5 patients with metallic implants (knee replacement, hip replacements and tibia fixation hardware). Appropriate 8-channel coils were used in all subjects. Table 1 shows typical scan parameters, and SEMAC sequences used 2x parallel imaging and half-Fourier acquisition [5]. We reconstructed images using a sum-of-squares combination of resolved slices, which helps to suppress noise from low-signal regions [1].

Table 1: Typical Scan Parameters (Coronal Hip Scans).

Sequence	TR (ms)	TE (ms)	TI (ms)	Matrix	Sl.Thk (mm)	BW/ pix	FOV (cm)	Scan Time
T1 Spin Echo	500	7	-	512x192	5	488	34	3:16
Standard STIR	4700	54	150	512x192	5	244	34	5:40
PD SEMAC	2100	10	-	256x192	5	976	40	5:06
STIR SEMAC	3000	10	150	256x192	5	976	40	6:18

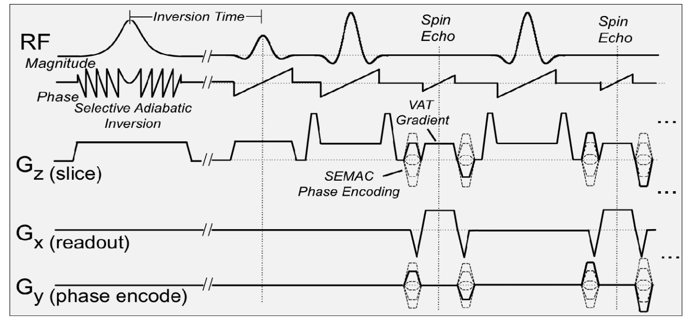

Figure 1: The STIR SEMAC pulse sequence uses a slice-selective adiabatic inversion followed by a CPMG sequence. 2D slices are excited, with a 3D readout using VAT to correct through-slice and in-plane distortions respectively.

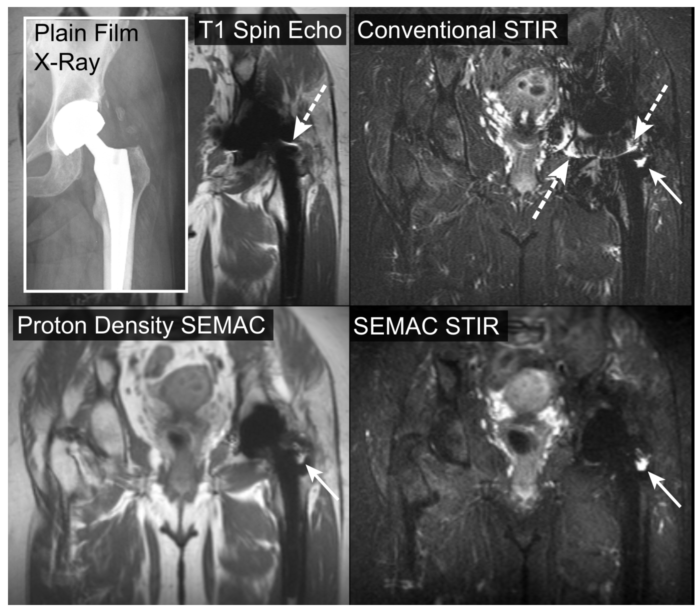

Figure 2. Conventional (top) and SEMAC (bottom) images of a patient with a total hip replacment. Susceptibility artifacts cause "pile-up" artifacts (dashed arrows) and inaccurate depiction of the implant on conventional MR images. SEMAC images dramatically reduce the distortion, and SEMAC STIR allows fluid near the implant to be unambiguously identified.

Results and Discussion: The straightforward combination of STIR and SEMAC reliably produces fat suppressed images with significantly reduced distortion near metal, albeit at a cost of resolution and scan time. Sample images are shown in Fig. 2 for a subject with a cobalt-chromium hip replacement using an 8-channel cardiac coil. In conventional STIR, the bright signal from susceptibility artifacts could be confused with the fluid, which is unambiguously shown in SEMAC images. Although both SEMAC images dramatically reduce metal-induced distortions, the SEMAC STIR contrast is particularly important for identification of fluid regions and marrow signal changes near the implant. The sum-of-squares combination [1] provides some effective averaging so that the increased scan time does also improve SNR, which is particularly useful in STIR imaging.

Conclusion: Using STIR preparation and SEMAC, fat-suppressed imaging with minimal distortion can be achieved near metallic implants. In our initial experience, the resulting contrast is particularly important for detection of fluid near metallic implants fixated to bone, which may indicate loosening or infection.

References: [1] Koch KM, et al. MRM 2009; 61:381–390 [2] Lu W, et al. MRM 2009; 62:66–76. [3] Bydder GM, et al. MRI 1985; 3:251-254. [4] Cho ZH, et al. 6th SMRM 1987, p.912. [5] Hargreaves BA, et al. ISMRM 2009 p.258. **Acknowledgements:** Funding from NIH – R21EB008190, GE Healthcare.