MR imaging after spinal fusion using Slice Encoding for Metal Artifact Correction (SEMAC)

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INTRODUCTION: Failed Back Surgery Syndrome (FBSS) is a relatively common complication of lumbar spine surgery, occurring in between 5-10% of cases, and resulting in severe, chronic, and debilitating pain. MRI is often of limited value in these patients due to the significant metal artifact occurring around orthopedic hardware, particularly at higher field strengths (Fig. 1). Slice Encoding for Metal Artifact Correction (SEMAC) is an MRI technique that corrects for spatial distortions by performing extra slice encoding and using view-angle tilting [1,2]. Clinical use of SEMAC has previously been limited by the long acquisition time. Patients with significant back or leg pain in particular found it extremely difficult to remain still for the duration of the scan. However, the use of parallel imaging with auto-calibrating reconstruction (ARC), reduced FOV and partial Fourier acquisition, has allowed the acquisition of SEMAC in clinically feasible scan times [3]. The purpose of our study was to determine whether SEMAC could successfully be used in the investigation of patients with residual or recurrent back pain and radicular symptoms following instrumented spinal fusion.

METHODS: After IRB approval and informed consent, MRI was performed on the lumbar spine of 8 patients (45-79 years of age, mean 57.6 years) with previous spinal fusion surgery. Images were acquired on a 1.5T MRI scanner (Signa, GE Healthcare, Waukesha, WI) using a multi-channel receive-only lumbar coil. Sagittal and axial SEMAC images were acquired with conventional 2D FSE T2 sequences for comparison. Common parameters were: TE/TR 95-105/5500 ms; matrix 256×224 (sagittal), 384×256 (axial); FOV 28×28 cm^2 (sagittal), 24×24 cm^2 (axial); 20-40 slices; slice thickness 4 mm; receive bandwidth ±125 kHz. Additional parameters for SEMAC were: ZPE 10-16; partial Fourier; scan time 4-8 min. Additional parameters for 2D FSE were: NSA 2; no phase wrap; slice flow compensation, scan time 2-5 min. No parallel imaging was used due to the orientation of the coil and acquisition geometry. Paired sagittal and axial SEMAC and 2D FSE images were then evaluated by 2 experienced musculoskeletal radiologists. The sequences were compared for visualization of the spinal canal, neural foramina, and nerve roots at the level of the fusion, and nerve roots above and below the level of the fusion. The sequences were also assessed for visualization of structures immediately adjacent to the metal, through-plane and in-plane artifact, and overall image quality. For each structure, images (A versus B) were graded on a 5 point scale from -2 to +2: -2 = A much better than B, -1 = A somewhat better than B, 0 = no difference between images, +1 = B somewhat better than A, and +2 = B much better than A. The ratings of both readers were analyzed using a two-tailed, Wilcoxon signed rank test. Inter-observer agreement was assessed by linear-weighted kappa correlation. All statistical analyses were performed with Stata (release 9.2, Stata Corp., College Station, Texas).

RESULTS: Reduced metal artifact was seen on the SEMAC images compared to 2D FSE, allowing significantly improved visualization of the spinal canal ($p<0.0001$) (Fig. 1d), neural foramina ($p<0.0001$) and exiting nerve roots at the level of the fusion ($p<0.0001$) (Fig. 2b). There was significantly less in-plane ($p<0.0001$) and through-plane artifact ($p<0.0001$) on SEMAC images (Figs. 3-4), improving visualization of bone marrow and cortical bone adjacent to the screws ($p<0.0001$), as well as decreasing image distortion. These findings lead to a perceived higher overall image quality in SEMAC images ($p<0.0001$). Inter-observer agreement was high, with a kappa score of 0.96.

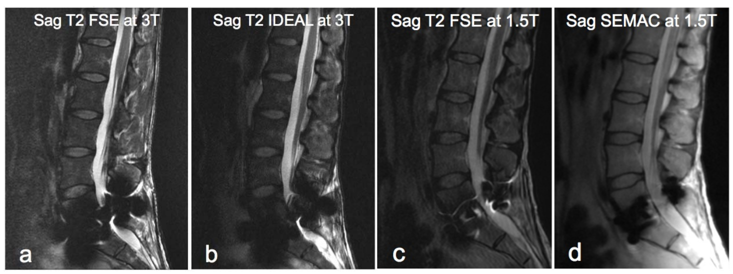

Figure 1. (a) Sagittal T2 FSE and (b) T2 IDEAL images through the spine of a 45 yr old patient obtained on a 3T scanner. Extensive metal artifact causes obscuration of the spinal canal on both images. (c) Sagittal T2 FSE and (d) SEMAC images of the same patient obtained on a 1.5T scanner. Again metal artifact causes obscuration of the spinal canal on T2 FSE. However, the spinal canal can be clearly visualized on the corresponding SEMAC image.

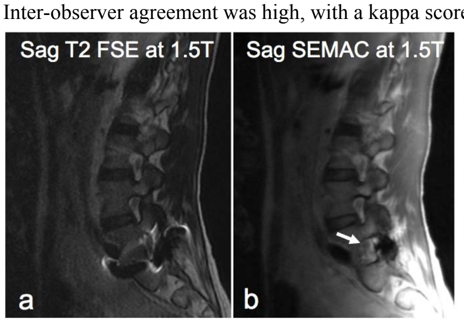

Figure 2. (a) Sagittal FSE and (b) SEMAC images through the spine of a 45 yr old patient. In-plane artifact is seen around the metal on the FSE, obscuring the L5-S1 neural foramen. On the corresponding SEMAC image the neural foramen and exiting L5 nerve root is clearly visualized (arrow).

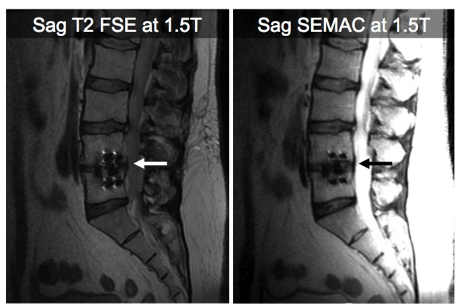

Figure 3. Sagittal images of the lumbar spine of a 50 yr old male. Significantly less in-plane (pile up) artifact is seen on SEMAC images, allowing improved visualization of the bone marrow adjacent to the screws. There is also no distortion of the posterior vertebral margin on SEMAC (arrow).

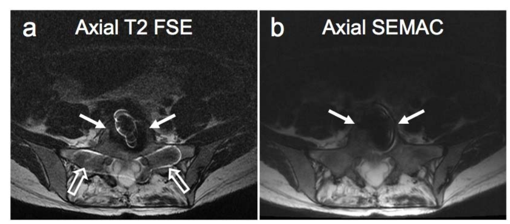

Figure 4. (a) Axial 2D FSE and (b) SEMAC images through the lumbosacral junction of a female patient. Increased in-plane artifact (white arrows) is seen around the screws within the vertebral body on 2D FSE. In addition there is extensive through plane artifact (open arrows) projecting over the sacral ali in the 2D FSE image.

DISCUSSION: Failed back surgery syndrome is a common complication of spinal fusion. MRI of these patients with spinal hardware is currently limited by local inhomogeneities in the main magnetic field induced by the metal. This produces both in-plane and through plane artifact in the images, as well as inhomogeneous fat saturation, thereby limiting assessment of adjacent structures which may be responsible for symptoms. Several techniques have been developed to minimize metal artifact on MRI, including SEMAC and Multi-Acquisition with Variable Resonance Image Combination (MAVRIC). Both sequences have previously been used to evaluate patients with total knee arthroplasties [4]. However, to our knowledge, these metal suppression techniques have not been used to evaluate patients with spinal implants. Our preliminary results demonstrate significantly less in-plane and through-plane metal artifact with SEMAC, leading to better visualization of anatomic structures adjacent to the metal, which will hopefully translate into improved diagnostic capabilities. Efficient k-space sampling strategies with partial Fourier acquisition have also dramatically reduced the scan times, which will allow SEMAC to be incorporated into regular imaging protocols, without significantly prolonging total scan time.

CONCLUSION: SEMAC is a promising metal-suppression MRI technique for evaluating the spine in patients with residual or recurrent symptoms following instrumented spinal fusion.

ACKNOWLEDGEMENTS: Funding by GE Healthcare, and NIH R21-EB0008190, P41-RR009784.

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