3T MRI of Arthroplasty Implants Using Highly Undersampled SEMAC: 3T versus 1.5T Intra-Subject Comparison

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Purpose

Because susceptibility artifacts increase with field strength, MRI of arthroplasty implants is most commonly performed at 1.5T. 3T MRI, however, has become popular due to the increased signal-to-noise ratio and may be the only available option in some institutions. Slice-encoding metal artifact correction (SEMAC) [1] has the potential to achieve substantial metal artifact reduction at 3T. The required higher number of SEMAC-encoding steps at 3T, however, results in long acquisition times, which is exacerbated by SAR limitations. The inherent sparsity of SEMAC can be exploited for acceleration of data acquisition through pseudo-randomized undersampling and iterative reconstruction [3]. We prospectively tested the hypothesis that highly accelerated SEMAC at 3T can facilitate MRI of arthroplasty implants with similar quality as 1.5T.

Methods

Ten volunteers with metal-on-metal hip arthroplasty implants underwent both, 1.5T MRI (MAGNETOM Aera, Siemens Healthcare) and 3T MRI (MAGNETOM Skyra, Siemens Healthcare) using 18-channel phased array body matrix a 20-channel spine matrix coils. Accelerated SEMAC imaging was performed with a prototype sequence implementing 8-fold incoherent undersampling of the 2D phase-encoding matrix and non-linear, SENSE-type reconstruction with L1-norm-based regularization [4]. At 1.5T, coronal, sagittal and axial intermediate-weighted (IW) and axial STIR accelerated SEMAC sequences were acquired (IW SEMAC: TR, 4510-6170 ms; TE, 28 ms; pixel size, 0.5 x 0.5 mm^2; SL, 3.5 mm; STIR SEMAC: TR, 7530 ms; TE, 20 ms; TI, 160 ms; pixel size, 0.6 x 0.6 mm^2; SL, 4 mm) with 15 SEMAC-encoding steps and acquisition times of 4:55 min, 4:43 min, 4:42, and 6:50 min, respectively (Figure). At 3T, the same sequences were acquired (IW SEMAC: TR, 4010-4520 ms; TE, 33 ms; pixel size, 0.4 x 0.4 mm^2; SL, 3.5 mm; STIR: TR, 6460 ms; TE, 33 ms; TI, 220 ms; pixel size, 0.5 x 0.5 mm^2; SL, 4 mm) utilizing the 3T signal gain for higher spatial resolution and 21 SEMAC-encoding steps, thereby keeping the acquisition times similar at 5:08 min, 4:58 min, 4:54, and 6:45 min, respectively. Three fellowship-trained, full-time musculoskeletal radiologists graded the overall diagnostic quality, artifact reduction, edge sharpness, noise, fat suppression, and visibility of arthroplasty-bone interface, pseudocapsule, tendons, muscles and, nerves using standardized 5-point Likert scales. Qualitative measurements were statistically analyzed using non-parametric tests. P values of less than 0.05 were considered significant.

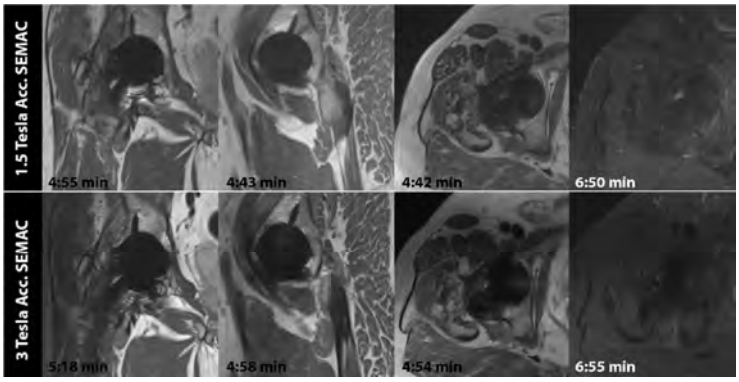

Figure: 61-year-old man with metal-on-metal total right hip replacement. Top row shows 1.5-Tesla coronal, sagittal and axial IW and STIR accelerated SEMAC images. Bottom row shows corresponding 3-Tesla coronal, sagittal and axial IW and STIR accelerated SEMAC images.

Results

The accelerated TSE SEMAC sequences achieved similar high overall diagnostic quality, artifact reduction, fat suppression, edge sharpness, as well as visibility of arthroplasty-bone interface and pseudocapsule with no statistically significant difference between 1.5 and 3T ($p = 0.115–0.877$). On the 3T images, there was significantly less noise and there was better visibility of the tendons, muscles and nerves ($p<0.05$). There was mildly reduced edge sharpness with no statistical difference between 1.5T and 3T ($p=0.519$).

Discussion

We demonstrate the clinical feasibility of 3T MRI of metal-on-metal hip arthroplasty implants using a highly undersampled TSE SEMAC sequence with iterative reconstruction. The intrinsically higher signal-to-noise ratio of 3T can be utilized to image with higher spatial resolution and to compensate for the higher number of SEMAC-encoding steps that are required to achieve similar metal artifact reduction as with 1.5T.

Conclusion

Incoherent k-space undersampling and iterative reconstruction enables 3T MRI of hip arthroplasty with similar metal artifact reduction and acquisition times as compared to 1.5 Tesla. Further, a comprehensive 3T hip arthroplasty SEMAC protocol can be performed with higher spatial resolution and similar imaging time.

References

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