

Quantified Estimates of Artifact Regions near Metal-on-Poly and Metal-on-Metal Hip Replacements at 1.5T and 3T

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Target Audience: This work is targeted towards clinicians attempting to visualize tissue and bone in the presence of total hip replacements at both 1.5T and 3T and physicists seeking solutions to reduce artifacts near such implants.

Purpose: In recent years, there has been increasing urgency in applying MR imaging methods to assessing complications from total hip replacements. The imaging artifacts associated with different implants can vary substantially, depending on implant construction, imaging field strength, and utilized artifact reduction methods.

Methods: A computational approach was developed using a 3D total hip implant model. The implant model was scaled, rotated, and translated and then embedded in a imaging volume from a proton-density MR hip scan for a volunteer that did not have a hip replacement. The transformed implant model was then assigned magnetic susceptibility values for the desired implant construction components and then input into a forward B_0 prediction model [1]. Artifacts were then predicted for metal-on-poly and metal-on-metal constructions at 1.5T and 3T.

Artifact regions were estimated for 2D-FSE with 1mm 500 Hz/px frequency encoding and 4mm 1kHz slice-selective excitations. Artifact regions in 2D-FSE were defined as anywhere outside the implant volume that resonates beyond 3kHz off-resonance, which correlates to over 1.5 cm of net spatial displacement (slice and read). 3D-MSI [2-4] images were also estimated using infinite spectral sampling as well as ± 12 kHz finite sampling. Since 3D-MSI images do not experience bulk image-distortions, artifact regions were correlated with the local gradient in the frequency-encoded direction [5]. Following the paradigm established in [5], regions beyond the amplitude of the applied frequency-encoding gradient were labeled as artifact.

Results: Simulated images are shown for each construction for both 3D-MSI and 2D-FSE -- where artifact regions are removed from the image. Displayed 3D-MSI images are those simulated under the assumption of infinite spectral sampling. A quantitative assessment of these artifact regions is also presented by plotting artifact volume for each scenario.

Discussion: It is clear that metal-on-metal designs show a great deal more artifact from metal-on-poly cases. However, there is some substantial impact on the field strength on the residual artifact. This is expected from established observations in a clinical setting. A few points of this study are notable. First, field-strength and implant construction have similar impacts on artifact increase. For example, note that the metal-on-poly implant at 3T looks very similar to the metal-on-metal implant at 1.5T. Second, it is plainly evident in Figure 3 that there is very limited benefit to increase spectral sampling from the finite approaches currently utilized in existing 3D-MSI sequences. This is because the severe local gradients destroy most of the further off-resonant signal that is missing from the finite sampled acquisition [5].

As a practical qualitative metric, visualization of the abductor tendon (blue arrow in Figure 1) was also considered in the computed model. Using 2D-FSE, all but the 1.5T metal-on-poly case show compromised assessment of the tendon. 3D-MSI shows clear visibility of the tendon for all but the metal-on-metal case at 3T, where we start to see some limited encroachment of the artifact region on the tendon.

Conclusion: A model-based computational study of various hip implant constructions has been presented at 1.5T and 3T and used to estimate the expected residual artifacts of both high-bandwidth 2D-FSE and 3D-MSI sequences.

[1] Koch et al, Proc ISMRM, 2008, p.1180, [2] Koch et al, MRM 61:381-90 2009 [3] Lu et al, MRM 62:66-76, 2009 [4] Koch et al, MRM 65:71-82 2011 [5] Koch et al, MRM, 2013, doi: 10.1002/mrm.24862

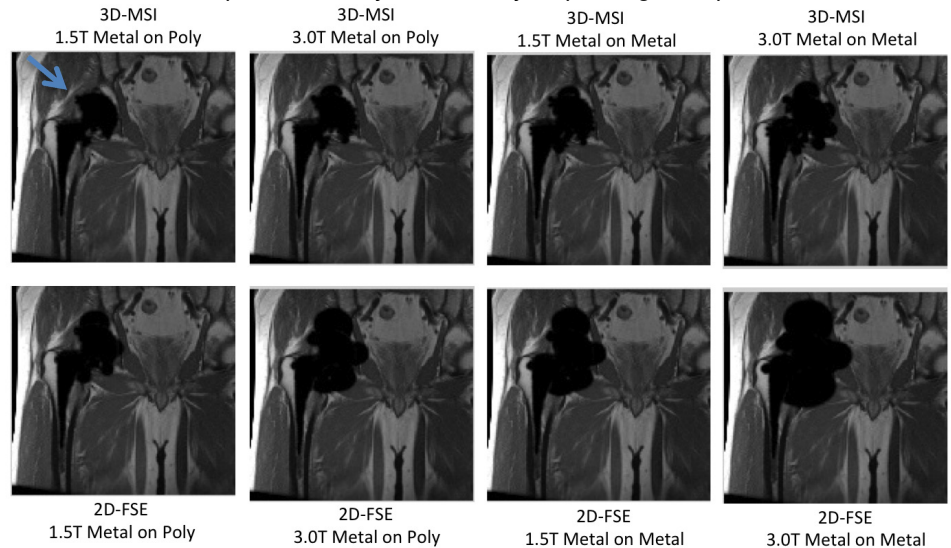


Figure 1

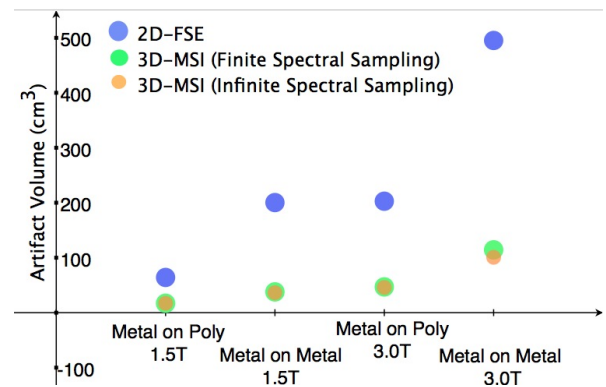


Figure 2