Multi-Spectral Imaging Near Metal: Understanding Performance Differences Between 1.5T and 3.0T

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Introduction: 3D Multi-Spectral Imaging (MSI) techniques (MAVRIC, SEMAC, MAVRIC SL) are optimized to perform MR imaging in the presence of metal hardware [1-3]. Clinical investigations have shown the utility of MSI in assessing soft tissue complications near metal at 1.5T [4,5]. Here we investigate the observed and expected differences in MSI performance at 1.5T vs 3T.

Theory: Theoretically, susceptibility artifacts are expected to double when moving from 1.5T to 3T. This expected trend is slightly oversimplified for application to MSI imaging. This is because bulk residual image distortions in MSI techniques are limited to the applied RF bandwidth – independent of field strength [1]. However, it has previously been shown that regions of very rapid local field variation in the frequency-encoding direction introduce additional intensity artifacts in MSI (or any technique applying frequency encoding) [6]. Since local field gradients near metal will double from 1.5T to 3T, we expect slightly more signal loss from this dephasing process at 3T.

Measurements: MSI images were acquired using the MAVRIC SL technique (3), which applies 2.25 kHz overlapping Gaussian spectral profiles separated by 1kHz in conjunction with a slab-selective excitation gradient. A conventional 1.5T protocol was applied at both field strengths, whereby 22 spectral bins are acquired, spanning 23 kHz. MAVRIC SL and 2D-FSE phantom images were acquired with 250kHz readout bandwidth. Images were acquired on a total hip replacement phantom (cobalt-chromium and titanium) placed in an aqueous solution and fitted with a plastic 3D grid. Extra off-resonance MSI images (+/- additional 10 kHz) were manually acquired as separate acquisitions on the phantom data to investigate the value of further off-resonance spectral bins at 3T. Based on preliminary analysis of this data, an extended spectral coverage MAVRIC SL sequence was then developed to acquire 30 spectral bins covering 31 kHz. In addition, clinical 2D-FSE and MAVRIC SL images were acquired on the same total hip replacement patient at both field strengths. 2D-FSE images were acquired with a readout bandwidth of 200kHz. Conventional clinical MAVRIC SL (22 bin) images were acquired at both field strengths.

Results: Figure 1 clearly indicates the distortion reduction of MAVRIC SL compared to 2D-FSE at both field strengths. Comparison of the MAVRIC SL images shows greater signal loss around the metal interface in the 3T images, as well as B1 shading along the shaft of the implant [7]. Figure 2 offers similar results, observed in a clinical setting, and quantifies the additional signal loss, indicating nearly 0.5cm of signal missing near the implant interface in the 3T MAVRIC SL image. Figure 3 demonstrates the source of this signal loss. A spectral bin trace shows signal degradation as the implant interface is approached (green arrow). This dephasing-based signal loss is a previously studied phenomenon that is expected to be more severe at 3T [6]. The green arrow indicates where this effect is most pronounced. The zoomed trace indicates the remaining signal (4.5 mm) attainable through the use of additional bins compared to the bins used in a conventional 1.5T protocol. This additional signal correlates to the addition of about 5 extra spectral bins (expanding coverage to +16kHz off resonance). The bottom row of Figure 3 shows the imaging impact of this analysis. When 10 more bins are added to the MAVRIC SL sequence (taking the acquisition time from 4:30 to 5:30 in this case), an extra 1cm of signal is gained on the phantom implant case. Note that this still results in roughly 7mm of signal loss relative to the 1.5T image.

Conclusion: MSI imaging approaches for imaging near metal will always perform better at 1.5T compared to 3T. However, it is clear that MSI remains effective at substantially reducing distortions compared to 2D-FSE at 3T. Thus, MSI is recommended at 1.5T whenever possible, but can be applied successfully at 3T when properly equipped 1.5T systems are not available. The analysis presented here suggests that a modified protocol with additional spectral bins may allow incremental improvements signal recovery near some metal interfaces at 3T – at the expense of moderate increases in acquisition time.

References: [1] Koch et al, MRM 61:381-90 2009 [2] Lu et al, MRM 62:66-76, 2009 [3] Koch et al, MRM 65:71-82 2011 [4] Hayter et al, Am Journ. Roent. 197 :W405-11 2011 [5] Chen et al, JMRI 3(5):1121-7 2011 [6] Koch et al, Proc ISMRM 2011, 293 [7] Koch et al, Proc ISMRM 2010, 3082

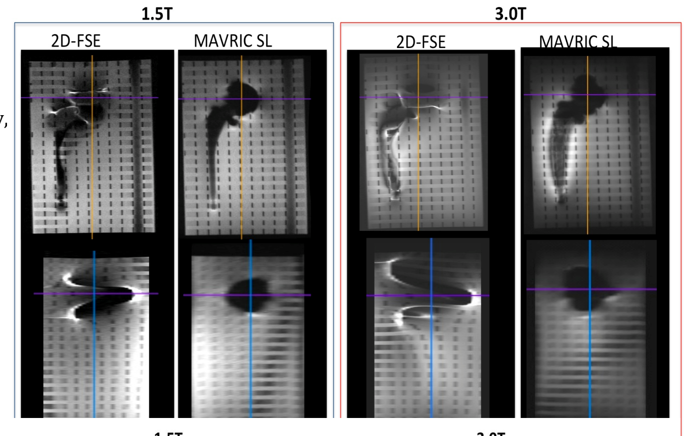

Figure 1: Top row, Coronal 2D-FSE and MAVRIC SL images at 1.5T at 3T. Bottom row, sagittal reformats of images. Scan time for all techniques: 4.5 min

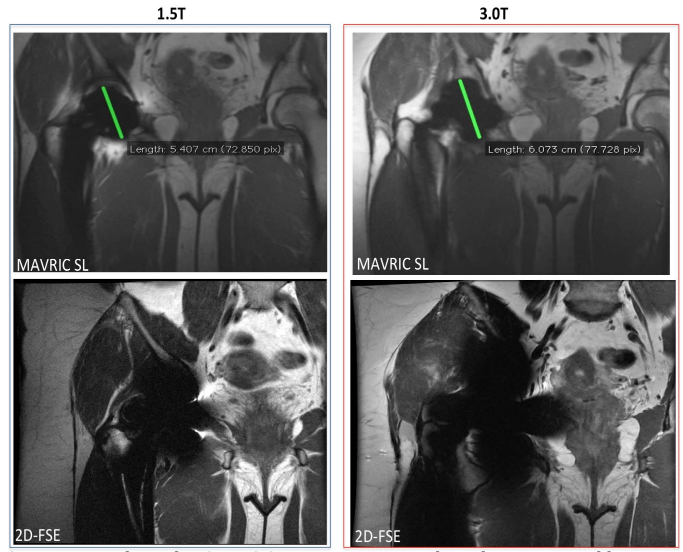

Figure 2: Top row, clinical MAVRIC SL images acquired on the same total hip arthroplasty patient at 1.5T and 3T . Bottom row, 2D-FSE images acquired on the same patient at both field strengths. Scan time for all images: 6.5 min

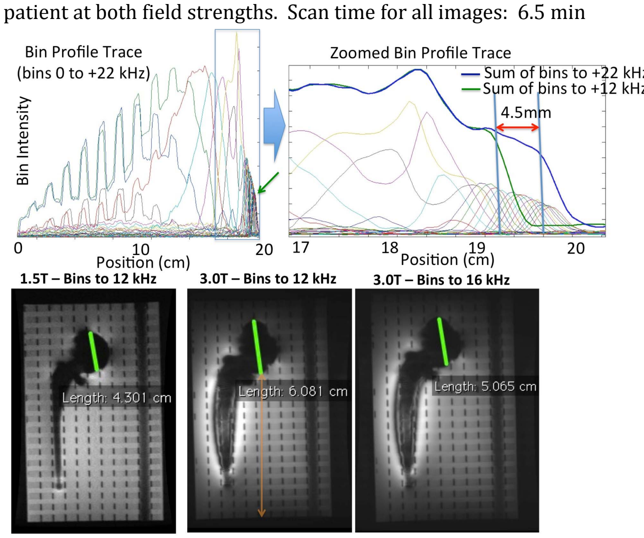

Figure 3: Top row: spectral bin traces in 3T image as indicated by orange line in center image in bottom row. Outlined region in left plot is zoomed for right-hand plot. Green arrow indicates region of gradient-induced signal loss in bin acquisitions. Bottom row: Comparison of phantom images at 1.5T, 3.0T (22 bin), and 3.0T (30 bin) MAVRIC SL images.