Metal Implant-Induced Spectral Range Optimization using Rapid 3D-MSI Calibration Scans

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Target Audience: Clinicians and researchers utilizing 3D-MSI metal artifact reduction technology.

Purpose: 3D Multi-Spectral Imaging (3D-MSI) techniques, such as MAVRIC (1), SEMAC (2), and MAVRIC SL (3) collect multiple independently spatial-encoded images at discrete Larmor frequency offsets. Prospective knowledge of the range and location of off-resonant spins can aid in optimizing the efficiency of these sequences. Here we present a clinically viable 3D-MSI calibration scan that can provide such information. In addition, we demonstrate a practical method to automatically determine off-resonance frequency ranges using such calibration data.

Methods: The MAVRIC technique was utilized to collect 3D-MSI calibration data. As previously shown, MAVRIC raw data can be utilized to generate off-resonance maps around metal implants (3).

Figure 1 presents a MAVRIC calibration scan (a) and resulting off-resonance map. The presented calibration required just over one minute to acquire.

Figure 2 presents (a) a MAVRIC off resonance map and (b) histogram. Using such histograms, an off-resonance range can be computed so as to capture all available signal to within a predefined "acceptable" level of missing volumetric tolerance around the implant interface. This can be accomplished through the following algorithm. First an acceptable signal loss threshold around the implant interface is chosen. A symmetric number of voxels on either side of the histogram distribution summating to this volumetric tolerance is then determined. The range of frequencies between the frequency bin values for these two histogram bins is then computed and used to determine the MAVRIC or MAVRIC SL spectral range required for a given implant.

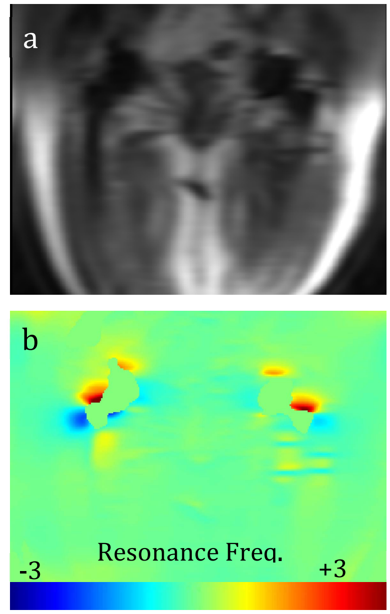

Figure 1: MAVRIC 3D-MSI calibration image (a) acquired in 1min 5sec covering entire pelvic region using 128x32x32 imaging matrix and collection 24 spectral bins. (b) Associated MAVRIC off-resonance map computed from calibration spectral data

Discussion: 3D-resolved MSI calibration images have a number of potential uses. Here, we have shown a relatively simple utility of such calibrations, where, through adaptive modulation of acquired spectral bins, substantial acquisition efficiency can be gained in MAVRIC or MAVRIC SL scans where fewer bins are needed. This savings can be substantial for smaller implants or implants made of lower susceptibility metals such as titanium screws or oxidized zirconium joint replacements. The accuracy of the off-resonance range distribution determination is limited by the resolution of the calibration maps. However, it is unlikely that this spatial inaccuracy will have substantial impact on computing numbers of spectral bins that contain clinically relevant amounts of signal.

The presented calibration principle also has potential applications with the SEMAC 3D-MSI technique. For example, the calibrated spatial off-resonance distribution could be utilized to optimize the number of slice-encodes applied to each slice, which is a 3D resolved implementation of a previously published SEMAC scout concept (4). In addition, the off-resonance distribution can be used to inform hexagonal sampling SEMAC methods (5).

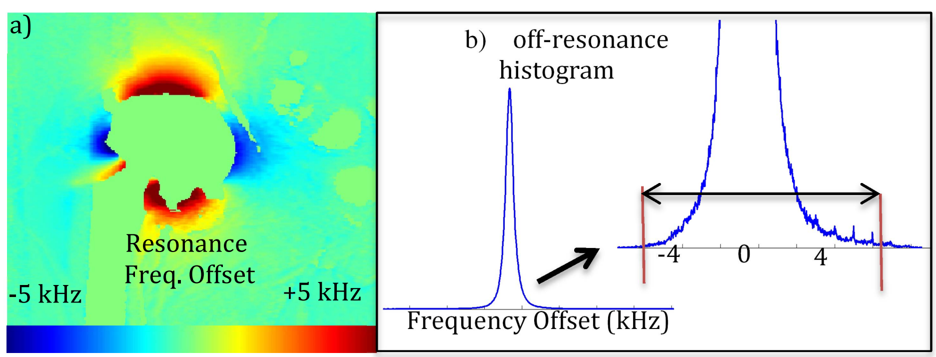

Figure 2: a) MAVRIC off-resonance map for a total hip replacement. b) off resonance histogram for the implant shown in (a). A zoom of the histogram shows computed low and high threshold ranges which hold all but 0.5 cm³ of the signal around the implant. The computed off-resonance range to be acquired is the difference between these thresholds

Conclusion: We have introduced the concept of a 3D-MSI calibration scan based on MAVRIC methods and field map construction methods. This calibration approach has a variety of potential uses across differing 3D-MSI implementations.

[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] Hargreaves et al, Proc ISMR, 2010, 3083. [5] Sveinsson et al. MRM, Early View, DOI 10.1002/mrm.25132