MR Imaging near metallic implants using Selective Multi-Acquisition with Variable Resonances Image Combination

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Introduction

With a substantial part of the population having metal implants, there is a clear need for MR imaging which is resistant to metal artifacts. Recently, SEMAC and MAVRIC [1,2] were introduced and have been shown to significantly reduce susceptibility artifacts, at the cost of increased scan time. MAVRIC, especially, has been described as a spatially non-selective technique, which leads to clinically unacceptable long scan times depending on the size of the anatomy.

In this work, a new variation of MAVRIC is proposed, which is spatially selective. Selective MAVRIC (sMAVRIC) retains the well-defined spectral selectivity of the spectral bins and enables scan time reduction, without the risk of back-folding.

Theory

sMAVRIC extends MAVRIC (Fig. 1a) with spatial selectivity by applying a gradient during excitation (Fig. 1b). The gradient G_{EXC} during an excitation pulse with a bandwidth BW_{EXC} in combination with spatially non-selective refocusing pulses with a bandwidth BW_{REF} results in a selection of signal with volume thickness Δz:

$$\Delta z = \frac{BW_{EXC} + BW_{REF}}{\gamma |G_{EXC}|} \quad (1)$$

In this case, the width of a single spectral bin remains limited by BW_{REF}. Similar to MAVRIC, sMAVRIC does not require View Angle Tilting (VAT) [3], which may cause blurring in the readout direction.

Variations of sMAVRIC are possible, where a gradient is applied during refocusing pulses or even during both excitation and refocusing pulses. sMAVRIC differs from the earlier reported VS-3D-MSI [4] (Fig. 1c) by using a different strength and/or polarity for each of the selection gradients. This limits the spectral profile to the intended spectral bin and provides well-defined spatial selectivity. As a consequence, the number of slice encodes needed is completely determined by sequence parameters and independent of the total frequency range Δf0 induced by the implant.

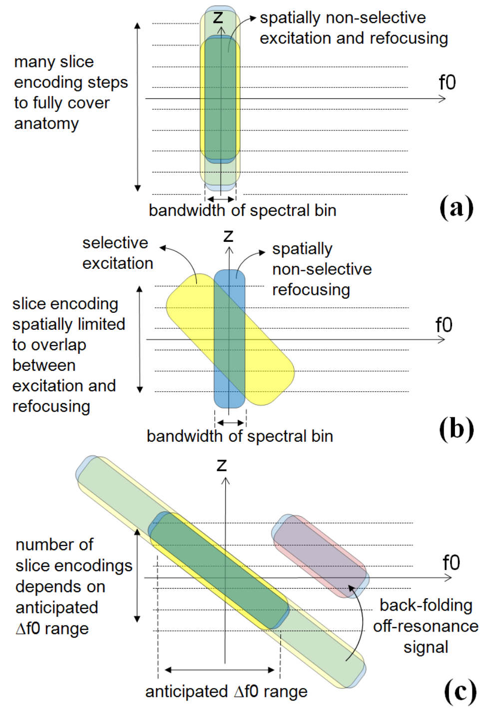

Figure 1: Spatial-spectral bin selection schemes of MAVRIC (a), sMAVRIC (b) and VS-3D-MSI (c). For clarity only single bins are displayed.

Methods

sMAVRIC was implemented on a 1.5T clinical MRI scanner. Phantom experiments were performed on a titanium hip implant. An 8-channel RF-coil was used to acquire T1w images (TR/TE 450ms/30ms) with 27 slice encodes, 2.8mm slice thickness, 160mm×160mm FOV. Using a SENSE factor of 2, a volume selective dataset was acquired in 3'01", with 13 spectral bins, each shifted by 830Hz. In-plane resolution was 1.2mm×1.2mm with a read-out bandwidth of 1063Hz/pixel. For comparison, a non-selective MAVRIC of the same geometry was acquired, as well as a non-selective MAVRIC of the entire object using 78 slice encodes in 8'23". Next, an otherwise healthy volunteer with fixation screws in the femoral neck was imaged using an sMAVRIC sequence with similar settings: an axial view with 27 slice encodes and 200mm×240mm FOV in 4'12" and a bilateral coronal view, 27 slice encodes, 240mm×420mm FOV, SENSE factor 2.5 in 5'39". For reference, a multi-slice TSE with 16 slices of 2.8mm was scanned with a read-out bandwidth of 624Hz/pixel.

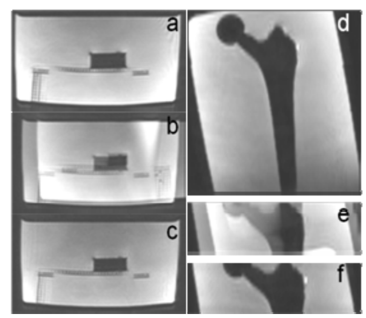

Figure 2: Axial scans (left) and coronal reformats (right) of hip implant. MAVRIC full coverage (a,d), MAVRIC limited coverage (b,e), sMAVRIC (c,f).

Results

The phantom images showed that sMAVRIC was similarly effective at reducing metal artifact as the standard MAVRIC sequence (Fig. 2) while reducing the coverage needed, and avoiding slice wrap (cf. Fig. 2b,e, and Fig. 2c,f). The in-vivo images of the hip show that the strong in-plane distortions and signal pile-up in standard TSE (Fig. 3a) are corrected by non-selective MAVRIC and sMAVRIC (Fig. 3b,c). However, the axial non-selective MAVRIC clearly showed back-folded signal (Fig. 3b) which was absent in the sMAVRIC images (Fig. 3c, Fig. 4).

Discussion and Conclusion

sMAVRIC is a volume selective multispectral method which reduces susceptibility artifacts near metal as compared to conventional TSE. In a recent paper by Hayter et al., non-selective MAVRIC of the hip was evaluated using 50-60 slice encodes [5], indicating that sMAVRIC indeed can reduce imaging time. Further acceleration is possible by interleaving the acquisitions of spectral bins. Scan time reductions can be traded for increased in-plane image resolution.

In conclusion, sMAVRIC is a metal artifact reduction technique that can be particularly useful for evaluating large anatomies such as hip and spine in clinically feasible imaging times.

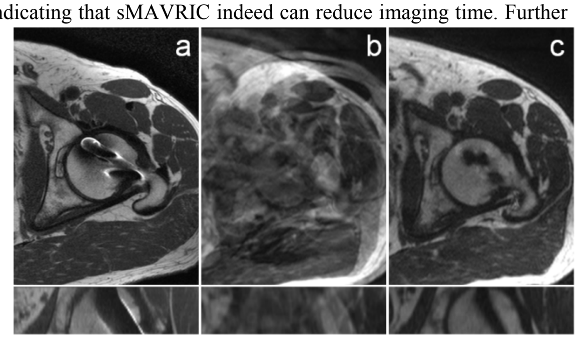

Figure 3: Axial scans and coronal oblique reformats of hip with fixation screws. TSE (a), MAVRIC (b), sMAVRIC (c).

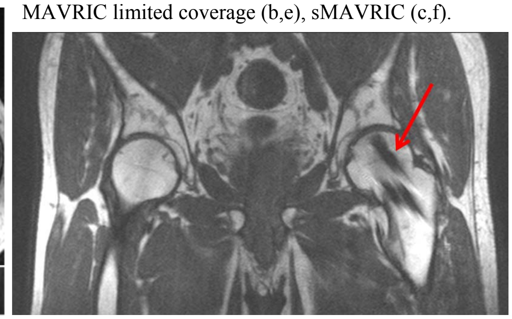

Figure 4: Coronal T1w sMAVRIC of bilateral hip.

References:

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