Fluid-Sensitive Metal Artifact Reduction using a 3D-Composite Fast Steady State Free Precession (COFIsp) sequence

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TARGET AUDIENCE: Physicists working on metal artifact reduction sequences and clinicians dealing with metal prostheses.

INTRODUCTION: Magnetic resonance imaging (MRI) in the vicinity of metal hardware is challenging mainly because of severe susceptibility-induced perturbations [1]. Nevertheless, MRI in the presence of metal has improved a lot with recent methodological advances, such as multiple-acquisition with variable resonances image combination (MAVRIC) [2], slice encoding for metal artifact correction (SEMAC) technique [3], and single point imaging techniques [4]. The major drawback of these methods, however, is their considerable prolongation of scan times for the acquisition of composite images and the low fluid sensitivity. Here, we propose an optimized composite steady state free precession sequence (COFIsp) as a fast, feasible alternative for acquisition of fluid-sensitive and distortion-free images in the presence of metal. Two techniques for distortion correction were investigated: a) additional prephasing gradients, 2) optimized phase encoding orientation.

METHODS: Imaging Sequence: A three dimensional (3D) FISP sequence was modified to include additional prephasing gradients (G_{PE}) in all three gradient axes (x, y, z). A set of three image (Fig. 1a-c) was acquired: one without additional prephasing (bin_0) and two with additional prephasing gradients, i.e., bin_m ($+G_{PEY}$, $+G_{PEZ}$, $+G_{PEX}$), and bin_p ($-G_{PEY}$,$+G_{PEZ}$,$+G_{PEX}$). A second dataset (Fig. 1d-f) was also acquired with the phase encoding direction parallel to the neck of the stem (i.e., rigid registration was performed in this case). Finally, a composite FISP (COFIsp) image was calculated using maximum intensity projection. Image protocol: The protocol was adapted to use non-selective short (40 µs) RF pulses for excitation. 35 slices with resolution 1.4 x 1.4 x 1 mm^3 were acquired in 50-60 sec per image (TR/ TE = (2.7-3.07) / (1.35-1.54) ms, FOV = 350 mm, Flip angle = 10°, Bandwidth (BW) = 1028 Hz/Px). Experiments were performed at a 1.5T MR clinical scanner. Images were acquired in the presence of a titanium total hip prosthesis (THP_1), a CoNiCrMo (THP_2) and a stainless steel (THP_3) prosthesis emerged in agar gel and doped with Gadolinium.

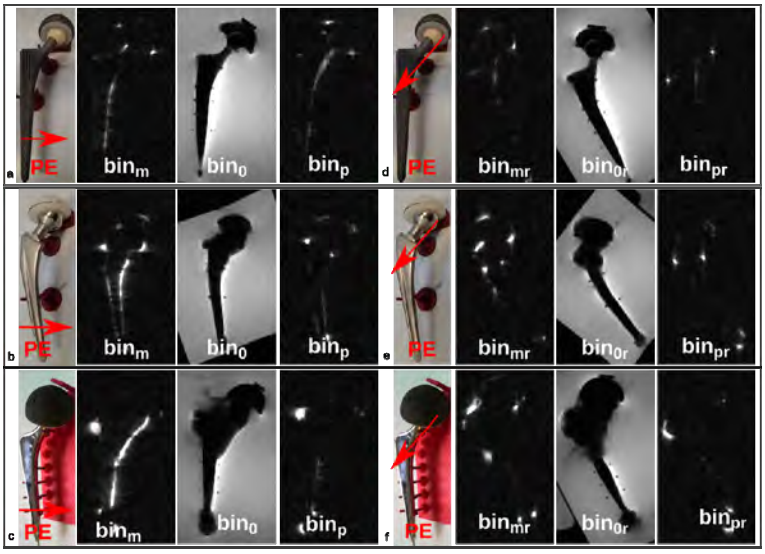

Figure 1: a) Single FISP images from THP_1, b) THP_2 and THP_3 c) with two different phase encoding orientations.

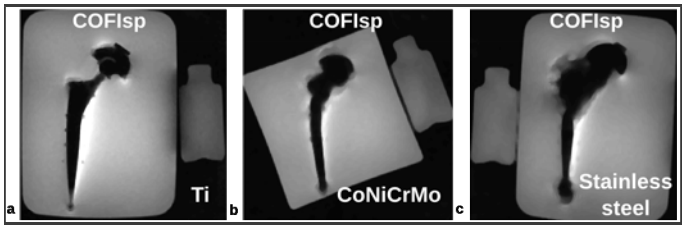

Figure 2: Composite FISP (COFIsp) images from a THP_{1-3}.

RESULTS: The COFIsp images (Fig. 2a-c) allowed visualization of the signal very close to the titanium implant, with very good image quality and fluid contrast. For the THP_2 an alternating orientation is needed to correct for strong gradients in the vicinity of the neck of the stem. For materials of high susceptibility (THP_3) it was observed that a second acquisition with phase encoding parallel to the axis of the neck allowed significant improvement of the distortion in the vicinity of the neck.

DISCUSSION & CONCLUSION: Optimized FISP imaging in the presence of metal hardware allowed acquisition of 35 slices in 3-6 min without noticeable artifacts for THP_1 and marginal artifacts for THP_2 and THP_3. In addition, COFIsp maintains its high fluid-tissue contrast which is very important for the visualization of inflammation frequently occurring in patients with orthopedic implants.

REFERENCES: 1. Koch et al. J. Magn. Reson. Imaging 2010; 32:773–787, 2. Lu et al. Magn Reson Med 2009;62(1):66-76, 3. Koch KM, Lorbiecki JL, Hinks RS, King KF. A multispectral threedimensional technique for imaging near metal implants. MRM 2009;61:381–390. 4. N.S. Artz, Magn. Reson. Med. DOI: 10.1002/mrm.24704 (2013).