# A Mechanism for Quantifiable MRI-Based Detection of Cobalt-Chromium Particulate Deposits Near Total Hip Replacements

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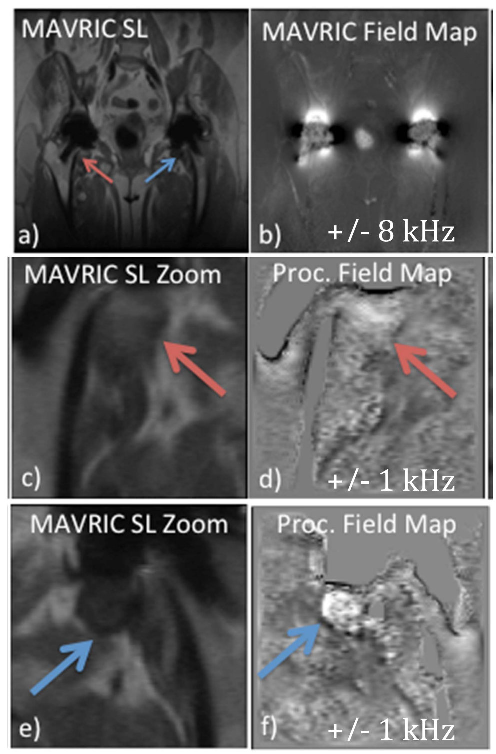
**Target Audience:** Clinicians and researchers interested in non-invasive quantitative assessment of wear-induced metallic particle deposition near orthopedic implants.

**Purpose:** Recent years have seen an increasing trend of adverse local tissue reactions near total hip replacements, particularly those with metal on metal bearing surfaces [1]. The presence of soft-tissue masses near hip replacements is not necessarily correlated with metallic deposition or clinical presentation of symptoms [2]. However, findings of substantial metallic debris could potentially highlight wear related to edge loading on the bearing surfaces [3] and subsequently aid in patient management decisions.

**Methods:** Metallic debris generates a local Larmor resonance frequency shift that can be detected using MRI methods. Such resonance shifts are the physical basis of susceptibility-weighted imaging (SWI) and quantitative susceptibility mapping (QSM). Unfortunately, no conventional SWI or QSM methods are feasible near metal implants, due to the substantial artifact-producing magnetic field perturbations induced by the implants when using the requisite gradient-echo image acquisition methods.

Here, we show that magnetic field maps generated with the MAVRIC susceptibility-artifact reduction mechanism [4,5] can be used in conjunction with tools developed for conventional QSM processing to develop quantifiable image contrast of metallic particulate deposits directly adjacent to total joint replacements. The presented methods are demonstrated on a clinical subject with surgically confirmed soft-tissue masses of varying degrees of metal particle content. The subject was imaged under informed written consent guided by the local IRB.

**Results:** Panel (a) shows a MAVRIC SL image (intermediate proton-density contrast) of bilateral total joint replacements. Both hips showed adverse local tissue reactions (arrows) in the inferomedial recess and the patient underwent bilateral staged revision surgery. Examination of tissue excised during surgery showed that the right hip was diffuse metal deposition (red arrow), while the left hip had adverse local tissue reaction (blue arrow).




A raw MAVRIC magnetic field map is shown (b) and demonstrates the large sweeping magnetic field induced by the implants. This unprocessed field overwhelms any subtle field shifts from metallic particle content in tissue surrounding the implant. A histogram-based threshold mask computed from the magnitude MAVRIC SL image was then applied to the field map to remove regions of low signal quality. Finally, the Projection onto Dipole Fields (PDF) background removal method [6] provided by the QSM MEDI Toolbox [7] was locally applied to the MAVRIC field map. This was done separately for each hip replacement. The results are shown in (d & f). It is clear that these maps show heightened off-resonance responses in both regions of confirmed particle deposits. In direct correlation with the surgical findings, the left side (f) shows a larger off-resonance response, which is indicative of more densely distributed particulate matter.

**Discussion:** The presented methods provide a means of metal particle assessment directly adjacent to metal implants. Processing of MAVRIC field maps using pre-processing methods tailored for QSM of the brain reveals clear off-resonant trends that correlate to surgical findings of particulate matter around the hip implants.

Rough quantifiable particulate estimates can be made from the presented data. The dense deposit in the left hip (f) correlates to a field shift of approximately 7 ppm. This is roughly 2X the chemical shift difference between fat and water (3.5 ppm) and provides a relative scale of cobalt-chromium particle concentration. For example, if a magnetic susceptibility of 1000 ppm is assumed for the present cobalt-chromium alloy [8], then this would indicate an average (homogenous) volumetric particulate density of roughly 1%. Future work will investigate modifying quantitative susceptibility mapping methods, which are traditionally applied to small susceptibility changes in the brain, to spatially quantifying the cobalt-chromium deposits. In conjunction, the presented methods will be applied to a larger cohort of surgically confirmed metallosis cases in order to correlate observed field shifts with observed severities of particulate deposition.

**Conclusion:** Traditional QSM-based background processing of MAVRIC field maps can be used to identify and potentially quantify metal particle deposits near total joint replacements.

**[1]** Ollivere et al, J. Bone. Joint Surg Br, 91: 1025-1030, 2009 **[2]** Nawabi et al, Clin Orthop Relat Res, 472:471-481 2014.
**[3]** Al-Hajjar et al, J Biomed Mater Res B Appl Biomater., 101:213-22 **2013** **[4]** Koch et al, MRM 61:381-90 2009 **[5]** Koch et al, MRM 65:71-82 2011,
**[6]** Liu et al, NMR in Biomed, 24:1129-36 2011 **[7]** http://weill.cornell.edu/mri/pages/qsm.html **[8]** Koch et al, Proc ISMRM 2008, p. 1180