MRI is Predictive of Adverse Tissue Reaction in Failed Metal-on-Metal Hip Arthroplasty

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Target Audience. Radiologists, orthopaedic surgeons, and scientists with an interest in the a predictive capabilities of magnetic resonance imaging (MRI) to preoperatively identify patients indicated for revision of a metal-on-metal (MOM) total hip arthroplasty.

Purpose. Early reports on modes of failure of MOM hip arthroplasties focused on mechanical causes related to high implant wear and surgical factors. In recent years, there have been increasing reports of MOM failures secondary to adverse local tissue reactions (ALTR). Identifying these failures early is critical to preventing tissue damage and poor outcomes after revision. Blood serum metal ions have been used as a screening test to diagnose ALTR but have low sensitivity and specificity. Conventional radiographs, CT, and ultrasound, are easy to acquire, but are limited by poor soft tissue contrast or variable penetration, respectively. Magnetic resonance imaging (MRI) produces superior soft tissue contrast without utilizing ionizing radiation, and results in higher accuracy in assessing peri-implant bone loss (1). The goal of this study was to develop an MRI classification system to predict ALTR in patients who underwent preoperative MRI and subsequent revision surgery.

Methods. We retrospectively reviewed 68 patients (70 hips) with failed MOM total hip arthroplasties (THAs) and hip resurfacing arthroplasties (HRAs) who underwent preoperative MRI and subsequent revision surgery. Median time to revision was 36 mo. Forty-six of the 70 hips were large diameter (>38mm) MOM THAs with monoblock cups. The remaining 24 hips were HRAs. <u>MRI</u>: Images were acquired on a 1.5T clinical scanner (GE Healthcare, Waukesha, WI), using an 8 channel phased-array cardiac coil. Tri-planar 2D fast-spin-echo (FSE) proton density scans in the were acquired to assess hip morphology and local anatomy: TE=25ms, TR=5000ms, ETL=15-24, FOV=22-26cm, acquisition matrix=512x(256-384), RBW=±125kHz, slice thickness=3mm, slice spacing=0mm. MAVRIC images were acquired with similar parameters. MR images were used to assess the variables of: synovitis (solid or fluid type, volume, maximum synovial thickness, decompression, low signal intensity deposits), soft tissue edema, osteolytic volume, neurovascular compression, abductor disruption, and presence of lymph nodes. Synovitis was defined as fluid signal intensity or mixed fluid and solid-appearing material within, or directly communicating with, the pseudocapsule of the hip. Osteolysis was defined as well-demarcated intermediate signal intensity material replacing the normal high signal intramedullary fat. The maximal thickness of the synovial lining was measured using axial FSE images. <u>Histology</u>: Synovial tissues were obtained intra-operatively and were prepared and stained with standard H&E protocols. Histological evaluation was performed using a 10 point aseptic lymphocytic vasculitis associated lesion (ALVAL) score (2) to assess tissue reaction. The ALVAL score is a summation of individual grades assigned to the integrity of the synovial lining, presence and extent of inflammatory cell infiltrates, necrosis and tissue organization. <u>Statistics</u>: A Fisher's exact test was performed to evaluate the if ALVAL patients (ALVAL score ≥ 5) had a greater proportion of evaluated features. A Spearman rank correlation coefficient was performed to correlate synovial thickness and volume with the ALVAL score. A random forest (RF) analysis was used to identify the sensitivity and specificity of selected MRI characteristics in detecting ALVAL. The RF method is a machine-learning based decision analysis tool which uses bootstrapping methods to simulate the effect of each MRI characteristic on the outcome of interest for each patient in an iterative manner.

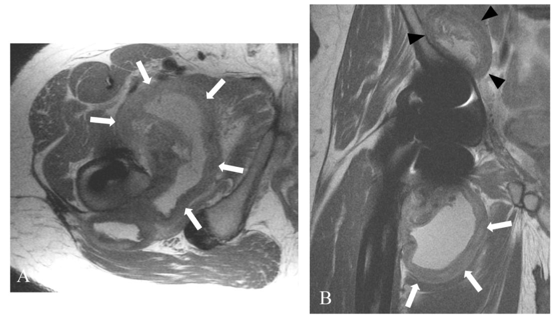

Figure 1. (A) Axial FSE image in a 57 y.o. male with MOM THA shows synovial expansion and thickening (white arrows) with decompression. (B) Corresponding coronal FSE shows a large volume of synovitis inferiorly (white arrows) and superiorly (black arrowheads). The combination of a large volume of fluid-solid type synovitis, a greatly thickened synovial lining, and disruption of the abductors is suggestive of a high ALVAL score. Confirmation was obtained at revision surgery, and the histologic analysis resulted in an ALVAL score of 9.

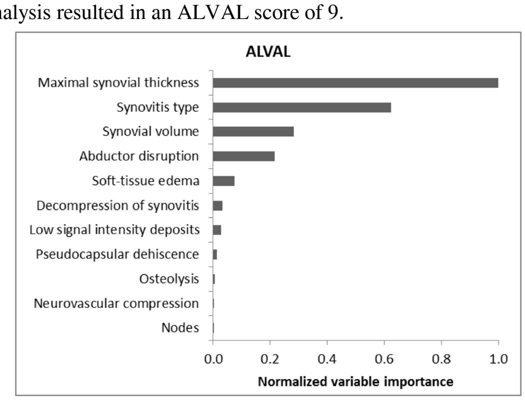

Figure 2. Random forest analysis demonstrates the importance of MRI characteristics in predicting the presence of ALVAL. Normalization is to the best predictor, assigned the value of 1.

Results. When comparing patients with ALVAL (score$\geq$5) to patients with a low probability of ALVAL (score<5), the ALVAL cases were more likely to have a mixed pattern of synovitis, with higher maximal synovial thicknesses and synovial volumes as determined on MRI ($p < 0.001$, Fig. 1). Decompression of synovitis, low-signal intensity deposits, soft-tissue edema, pseudocapsular dehiscence, abductor disruption and neurovascular compression were all significantly more likely to be present on MRI in cases of ALVAL (Fig. 2). A strong correlation was found between maximal synovial thickness and ALVAL score (ρ=0.81), as well as between synovial volume and the ALVAL score (ρ=0.74). RF analysis determined that maximal synovial thickness was the strongest predictor for the diagnosis of ALVAL. The type and volume of synovitis were also strong predictors of ALVAL. An MRI predictive model was generated from the RF analysis for the detection of ALVAL and severe tissue damage. We found a sensitivity and specificity of 94% and 87% respectively for detecting ALVAL.

Discussion. This study was performed to establish a predictive MRI diagnostic tool to preoperatively identify ALTRs in patients indicated for revision surgery. Patients with an ALVAL score of $\geq$ 5 were more likely to have a mixed pattern of synovitis (solid and fluid), with higher maximal synovial thicknesses and synovial volumes. The detected sensitivity and specificity of our methods results are a large improvement over the predictive ability of blood cobalt and chromium ion levels for identifying a failing hip, with sensitivity of 63% and specificity of 86% (3). Previous studies have used MRI to evaluate soft-tissue lesions around MOM hip replacements, but none have used quantitative MRI features or compared findings between groups formed on a histological diagnosis (3, 4). Our study is in contrast to recent MRI studies which found no distinguishing features between symptomatic and asymptomatic tissue lesions (3, 5). We may attribute this finding to differences of MR grading protocols. Future studies will evaluate different types of hip implant bearing materials and correlate the results to quantitative wear analysis.

Conclusion. MRI is highly sensitive and specific in identifying patients with failing MOM hip arthroplasties secondary to ALVAL. Our proposed MRI classification provides an objective tool to identify at-risk patients and ultimately aid the surgeon in proceeding towards timely revision surgery.

References. 1. Walde TA et al. Clin Orthop Relat Res 2005;138. 2. Campbell P et al. Clin Orthop Relat Res 2010;468:2321. 3. Hart AJ et al. J Bone Joint Surg Am 2012;94:317. 4. Toms AP et al. Clin Radiol 2008;63:49. 5. Sabah SA et al. J Arthroplasty 2011;26:71. **Acknowledgements**. Institutional research support was provided by General Electric Healthcare.