Magnetic Resonance Imaging as Biomarker of Adverse Local Tissue Reactions in Total Hip Arthroplasty

Matthew F. Koff[1], Parina H. Shah[1], Alissa Burge[1], Mauro Miranda[1], Christina Esposito[2], Elexis Baral[2], Thomas W. Bauer[3], Allina Nocon[4], Kara Fields[4], Stephen Lyman[4], HSS Adult Reconstruction & Joint Replacement Division[5], Douglas Padgett[5], Timothy Wright[2], and Hollis G. Potter[1]

[1]Department of Radiology and Imaging - MRI, Hospital for Special Surgery, New York, New York, United States, [2]Department of Biomechanics, Hospital for Special Surgery, New York, New York, United States, [3]Department of Anatomic Pathology, Cleveland Clinic, Cleveland, Ohio, United States, [4]Healthcare Research Institute, Hospital for Special Surgery, New York, New York, United States, [5]Adult Reconstruction & Joint Replacement Division, Hospital for Special Surgery, New York, New York, United States

Target Audience: Radiologists, scientists and orthopaedic surgeons with an interest of magnetic resonance imaging of implants.

Purpose: Over 300,000 primary total hip arthroplasty (THA) procedures were performed in 2012 (1) and a majority of these will be widely successful in achieving pain reduction, allowing patients with advanced osteoarthritis or other disabling hip conditions to return to their normal activities of daily living. However, implant failure due to loosening, instability, and other implant- and surgeon-related factors does occur, making revision surgery necessary. Diagnostic tests such as radiography (2), magnetic resonance imaging (MRI) (3), and serum metal ion levels (4) are available for orthopaedic surgeons to assess patients with THA but it is unclear which test, or combination of tests, is optimal for predicting implant failure.

We previously developed an MRI evaluation protocol that is predictive of the pathologic adverse local tissue reactions (ALTRs) in patients with hip resurfacing arthroplasty (3), but it is unclear how this technique may be applied to THA patients with alternative bearing surface materials and modular components. Therefore, the purpose of this study was to perform an MRI evaluation of individuals with different THA bearing materials to determine which factors are predictive of abnormal synovial reaction to the implant.

Methods: This study had IRB approval and written informed consent was obtained. Sequential THA subjects undergoing revision surgery were enrolled. The types of THAs evaluated included: metal-on-metal (MOM), hip resurfacing (HRA), metal-on-poly (MOP), modular metal-on-poly (mMOP), ceramic-on-poly (COP), and ceramic-on-ceramic (COC). All subjects were scanned on 1.5T clinical MR scanners with an 8 channel phased array cardiac coil (GE Healthcare, Waukesha, WI). 2D-FSE images were acquired in the axial, sagittal and coronal planes (5); coronal 3D MAVRIC-SL and MAVRIC-SL STIR images (6) were also acquired. MR images were evaluated for the presence and type of synovitis, synovial thickness and volume, presence and location of synovial decompression, primary impression of synovium (normal, mildly abnormal, ALTR, infection, metallosis, polymeric, or old infection), and location of ALTR (3). The reader was blinded to type of implant bearing material. MR images were used to identify an intra-operative tissue sample site. Tissue samples were acquired during revision surgery and scored using Campbell's aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL) score, as well as the Natu (7) and Fujishiro (8) grading methods which evaluate the presence of necrosis, histiocytes, particle type and tissue particle load under high power (x400) field. Statistical Analysis: Continuous and categorical variables were compared between the 6 bearing surfaces using Kruskal-Wallis and Fisher exact tests, respectively. Post-hoc pairwise comparisons between MOM THA and the 5 other bearing surfaces were performed when the corresponding omnibus test produced a p-value < 0.05. P-values were adjusted for multiple comparisons using the Holm-Bonferroni step-down method (SAS V9.3, Cary, NC).

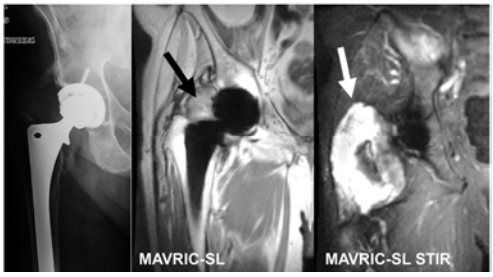

Figure 1. Radiograph, MAVRIC-SL and MAVRIC-SL STIR image showing thickening of the synovium (black arrow) and posterior synovial dehiscence (white arrow), indicative of a polymeric reaction in an individual with a metal on highly cross-linked polyethylene THA.

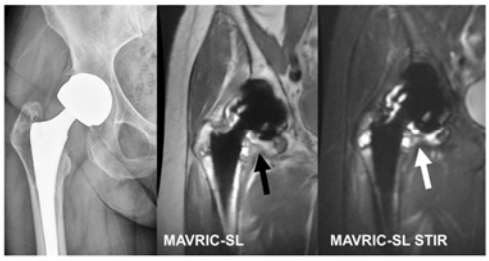

Figure 2. Radiograph, MAVRIC-SL and MAVRIC-SL STIR image showing an ALTR (arrows) and in an individual with a metal-on-metal THA.

Results: A total of 60 THAs have been evaluated to date: MOM (n=8), HRA (n=8), mMOP (n=21), MOP (n=16), COP (n=5), and COC (n=2). No differences of age, gender, or BMI among the types of THAs were found. The proportion of individuals with synovitis varied across THA type, p=0.030. Median values of synovial volumes and thicknesses were similar across all implant types. The distribution of primary impression of synovium categories varied by implant type, p<0.001. Specifically, MOM hips had a greater proportion of ALTR as the primary impression of synovium as compared to MOP, p=0.035, and the MOP hips had a greater proportion of polymeric as the primary impression of the synovium as compared to MOM hips, p=0.01. Differences in particle load, p=0.048, the presence of diffuse synovitis, p=0.012, and the presence of lymphoid aggregates, p=0.013 by implant type was found, however pairwise comparisons between MOM THA and each of the other bearing surfaces did not reach statistical significance.

Discussion: This study utilized MRI to evaluate the synovial reaction to THAs with different bearing materials. Differences in the synovial reaction to implanted materials were detected, and the histologic evaluation showed a trend towards corroboration of the MR findings. While the limited sample size of the COP and COC groups prevented definitive conclusions from being drawn, we may anticipate detecting synovial reactions due to previous reports of debris found in capsular tissue (9).

This study utilized an MR evaluation protocol that is composed of qualitative and quantitative metrics of the bony anatomy and synovial tissues (3). The repeatability of synovial and osteolytic volumes has been assessed (10), and the qualitative assessment evaluates individual anatomic features near a THA (e.g. bone and muscle) and combines these different factors to grade the joint (11). Grading individual anatomic features may permit detection of an implant specific synovial response. The strength of pre-revision MRI lies in its ability to define patients with ALTR and permits a targeted biopsy, thus providing the greatest yield for pathologic evaluation. The biopsy location was most commonly located in the inferomedial aspect of the head-neck junction, a location known for synovial reaction due to corrosion and wear debris. Future studies will evaluate the effect of additional metrics, including implant orientation, serum ion levels and quantitative implant wear analysis, to identify factors indicative of failure of THA.

Conclusion: THAs of different bearing materials produce detectable MR differences in the response of the local synovial tissue. Pre-revision MRI allows for accurate definition of the magnitude and quality of the synovial response and permits targeted biopsy.

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Acknowledgements: Research reported in this publication was supported by NIAMS/NIH (R01-AR064840). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.