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## Original Article

## Magnetic Resonance Imaging Predicts Adverse Local Tissue Reaction Histologic Severity in Modular Neck Total Hip Arthroplasty

Brian T. Barlow, MD <sup>a</sup>, Philippe A. Ortiz, BA <sup>a</sup>, Kara G. Fields, BS <sup>b</sup>, Alissa J. Burge, MD <sup>c</sup>, Hollis G. Potter, MD <sup>c</sup>, Geoffrey H. Westrich, MD <sup>a,\*</sup><sup>a</sup> Division of Adult Reconstruction and Joint Replacement Surgery, Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, New York<sup>b</sup> Epidemiology and Biostatistics Core, Hospital for Special Surgery, New York, New York<sup>c</sup> Department of Radiology and Imaging, Hospital for Special Surgery, New York, New York

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## ABSTRACT

**Background:** The association between advanced imaging, serum metal ion levels, and histologic adverse local tissue reaction (ALTR) severity has not been previously reported for Rejuvenate modular neck femoral stems.

**Methods:** A cohort of 90 patients with 98 Rejuvenate modular neck femoral stems was revised by a single surgeon from July 2011 to December 2014. Before revision, patients underwent multiacquisition variable resonance image combination sequence magnetic resonance imaging (MRI), and serum cobalt and chromium ion levels were measured. Histologic samples from the revision surgery were scored for synovial lining, inflammatory infiltrate, and tissue organization as proposed by Campbell. Regression based on the generalized estimating equations approach was used to assess the univariate association between each MRI, demographic, and metal ion measure and ALTR severity while accounting for the correlation between bilateral hips. Random forest analysis was then used to determine the relative importance of MRI characteristics, demographics, and metal ion levels in predicting ALTR severity.

**Results:** Synovial thickness as measured on MRI was found to be the strongest predictor of ALTR histologic severity in a recalled modular neck femoral stem.

**Conclusion:** MRI can accurately describe ALTR in modular femoral neck total hip arthroplasty. MRI characteristics, particularly maximal synovial thickness and synovitis volume, predicted histologic severity. Serum metal ion levels do not correlate with histologic severity in Rejuvenate modular neck total hip arthroplasty.

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The Rejuvenate Modular Hip Stem (Stryker Orthopedics, Mahwah, NJ) was voluntarily recalled in July 2012 after an elevated failure rate was noted during routine postmarket analysis [1,2]. Early reports demonstrated evidence of adverse local tissue reaction (ALTR) on magnetic resonance imaging (MRI) similar to what had been previously found in patients with metal-on-metal total hip arthroplasty (THA) implants. Certain series have shown that up to 30% of patients with Rejuvenate stems are symptomatic [3]. The diagnostic evaluation for an ALTR in a patient with a modular neck

THA is a combination of symptoms, most notably pain, chromium (Cr) and cobalt (Co) ion levels, and imaging [4]. Early identification of patients is critical as the level of tissue damage at revision is dependent on time of implantation. Currently, the diagnosis of ALTR is based on the overall picture of symptoms, metal ion levels, and imaging findings. The relative value of advanced imaging and serum metal ion levels in diagnosis has not been previously reported for a modular neck stem with an increased revision rate. The goal of the study was to identify whether prerevision MRI characteristics or serum metal ion levels correlated with histologically confirmed ALTR.

## Methods

From an institutional database, we identified 90 patients with 98 modular neck femoral stems from a single manufacturer revised

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\* Reprint requests: Geoffrey H. Westrich, MD, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021.

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by a single surgeon from July 2011 to December 2014. Eighty-six (95.6%) of these patients had the index THA at our institution.

Before revision, all patients underwent MRI optimized to reduce metal susceptibility artifact. Imaging was completed with 1.5-T scanners (GE Healthcare, Waukesha, WI) using either an 8-channel cardiac coil (GE Healthcare) or a 3-channel shoulder coil (MedRad, Indianola, PA). Three-plane high-resolution fast spin-echo images and additional multiacquisition variable resonance image combination (MAVRIC) inversion-recovery and intermediate-weighted images for advanced artifact reduction. The advantage of the MAVRIC sequence over traditional metal–artifact reduction sequences (MARS) is that it further mitigates frequency-encoding distortions, allowing for direct further artifact reduction and visualization of the trunnion with good signal-to-noise ratio [5]. All MR images were evaluated by 2 musculoskeletal radiologists (H.G.P. and A.B.). MR images were evaluated for the presence and type of synovitis, synovial thickness, synovial volume, pseudocapsular dehiscence, abductor disruption, low signal intensity deposits, osteolysis, soft tissue edema, lymphadenopathy, and neurovascular impingement. Synovitis was defined by the presence of intra-articular fluid and/or solid debris, with or without extra-articular decompression. Synovitis was qualified as fluid, solid, or mixed based on signal characteristics. Disruption of capsular attachments (pseudocapsular dehiscence) was noted as was decompression of the synovitis into the extra-articular soft tissues or bursae. Maximum synovial thickness was measured in coronal planes (Fig. 1). Osteolysis was defined on MRI by well-margined areas of osseous resorption adjacent to acetabular or femoral components. Volume of synovitis was calculated using a previously validated method of manual segmentation on coronal MAVRIC or axial fast spin-echo images (Fig. 2). The cross-sectional area of abnormality is



**Fig. 1.** Coronal fast spin-echo (FSE) image in a 64-year-old woman demonstrating measurement of maximum synovial thickness as designated by a caliper traversing the thickest portion of the synovium.



**Fig. 2.** Coronal multiacquisition variable resonance image combination FSE image in the same patient demonstrates measurement of synovial volume using a previously validated method of manual segmentation. Magnetic resonance imaging (MRI) features are consistent with severe adverse local tissue reaction; aseptic lymphocytic vasculitis–associated lesion (ALVAL) score at revision was 10.

measured on consecutive images and summed to obtain a total volume [6]. Metal debris was characterized by low signal intensity extracapsular deposits. Pelvic lymphadenopathy was defined by increased cross-sectional diameter (>1.0 cm) or loss of normal fatty hilum. Neurovascular compression was characterized by loss of normal surrounding fatty planes, and we assessed the sciatic, femoral, and obturator bundles. Hip abductors, gluteus medius, and gluteus minimus were examined for tendinosis or tearing and synovitic undermining of the tendon insertion. Tendinosis was defined as signal hyperintensity or thickening, whereas tears were defined as partial or complete and were most commonly seen at the trochanteric insertion.

Prerevision serum Co and Cr levels were obtained in 89 of 90 patients in this series. The single patient without serum metal ion levels had primary surgery and subsequent workup elsewhere. Blood collection was performed by trained phlebotomists in our clinic. All samples were sent to one of 2 laboratories (Quest Laboratories, Chantilly, VA or ARUP Laboratories, Salt Lake, UT) depending on each patient's insurance providers. Patients were encouraged to avoid diet and nutritional supplementation before blood draws. Whole blood samples were spun in centrifuge, and serum layer was placed into the appropriate trace element–free transport tube. The serum Co and Cr levels were measured using a quantitative inductively coupled plasma mass spectrometer [7].

All implants were revised at our institution by a senior surgeon (G.W.). All hips were symptomatic before revision. All primary and revision surgeries were completed via a posterolateral approach. All Rejuvenate implants were removed proximally in identical fashion. First, the pathologic soft tissues affected by the ALTR were resected and sent for culture and pathology. Next, the bone ingrowth surfaces were separated from the implant using a Midas

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