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Longitudinal Magnetic Resonance Imaging of Pseudotumors Following Metal-on-Metal Total Hip Arthroplasty

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ABSTRACT

The purpose of the study was to determine the natural history of pseudotumors following metal-on-metal total hip arthroplasty (THA) using magnetic resonance imaging (MRI). Initial MRI was conducted at a mean of 36 months postoperatively. Follow-up MRI was performed at a mean of 20 months after the detection of 24 asymptomatic pseudotumors. Pseudotumor size was determined on MRI. The mean pseudotumor size changed from 729 mm^2 to 877 mm^2. Pseudotumors increased in size in eight and decreased in six. Ten hips showed no changes. The bigger the pseudotumor size, the more likely the size would increase. In conclusion, pseudotumors frequently change in size. A single MRI study in the clinical decision-making process should be avoided and a longitudinal study should be performed.

Metal-on-metal bearings offer the theoretical advantages of decreased wear and increased functional outcome for younger and more active patients, but they have been associated with the development of pseudotumors [1–3]. Pseudotumors have been reported following metal-on-metal resurfacing or total hip arthroplasty (THA). These pseudotumors have been variously termed cysts, bursae, aseptic lymphocyte-dominated vasculitis-associated lesions (ALVAL) [4], adverse reactions to metal debris (ARMD) [5], and adverse local tissue reactions (ALTR) [6]. These lesions are the result of tissue reactions to metal debris with lymphocyte infiltration and soft tissue necrosis; however, their pathogenesis remains unclear. The prevalence of pseudotumors following metal-on-metal resurfacing or THA has been studied by a variety of investigators [7–13]. Recent studies demonstrated that pseudotumors can occur in asymptomatic hips after metal-on-metal hip resurfacing or THA [7,8,10,11]. In addition, the prevalence of pseudotumors is similar in well-functioning patients and patients with painful metal-on-metal hip implants [14]. Magnetic resonance imaging (MRI) provides sensitive screening of pseudotumors following metal-on-metal THA. MRI is ideally suited for assessment of these patients and complements standard clinical evaluation [15,16].

The natural history and longitudinal imaging findings of pseudotumors have yet to be fully analyzed. Our hypothesis was that pseudotumor size might change over time following metal-on-metal THA. This hypothesis was studied using serial MRI examinations. In addition, the relationships between the changes in pseudotumor size and serum cobalt and chromium ion levels were determined in these patients.

Patients and Methods

We performed large-diameter, metal-on-metal THAs using Cormet (Corin, Cirencester, UK) in 108 hips and Pinnacle (DePuy, Warsaw, IN, USA) in 80 hips. Screening for pseudotumors was performed using MRI after large-diameter, metal-on-metal THA. Every patient with metal-on-metal hip had a routine baseline screening MRI. MRI study was conducted on all subjects regardless of symptoms to ensure that asymptomatic pseudotumors could be detected. Thirty-six hips showed pseudotumors (24 Cormet and 12 Pinnacle). Twelve hips were revised after the first scan because of symptomatic pseudotumors. Subsequent MRI studies were performed only in the patients with pseudotumors at the index MRI. The patients without asymptomatic pseudotumors at the initial MRI did not undergo subsequent study. No patients were lost to follow-up between the index and subsequent study. Thus, 24 hips were studied longitudinally. Initial MRI was conducted at a mean of 36 months (range, 20–52 months) postoperatively. Follow-up MRI was performed at a mean of 20 months (range, 8–34 months) after the detection of 24 asymptomatic pseudotumors in 20 patients. There were 17 women and 3 men, with a mean age of 63 years and a mean body mass index (BMI) of 24.0 kg/m^2. The primary diagnoses were osteoarthritis in 18 patients and rheumatoid arthritis in 2 patients. A 1.5-Tesla scanner was used with T1-weighted spin-echo (SE), T2-weighted SE, and short tau inversion recovery (STIR) sequences (Signa; GE Medical Systems, Buckinghamshire, UK). Pseudotumors were classified as

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cystic (fluid), solid, and mixed types [10,17]. A minimum size of 10 mm was defined as pseudotumor. Fourteen hips were characterized as cystic type, and 10 hips were defined as mixed type. THA devices included 12 Cormet cup combined with CTi II stem (Corin) and 12 Pinnacle cup with S-ROM-A stem (DePuy). The Cormet cup was made of cobalt-chromium alloy with titanium porous coating for bone ingrowth. The CTi II stem, which was made of titanium alloy, had a proximal porous coating. The Pinnacle cup, which was made of titanium alloy, was a modular cup with titanium porous coating. Cobalt-chromium alloy liner was inserted in the cup. The S-ROM-A stem, which was made of a titanium alloy, was a modular stem with a proximal porous coating. The head was made of cobalt-chromium alloy in both implants. The mean head diameter of Cormet devices was 43 mm (40–48 mm). The head diameter for Pinnacle devices was 36 mm in all hips. The acetabular component inclination angle was measured on anteroposterior pelvic radiographs. The inclination angle was defined as the angle between the line joining the inferior teardrop points and the axis of the opening of the acetabular component. Acetabular anteversion was measured with computer software (Advanced CasePlan Digital Templating Planning Software; Stryker Orthopedics, Mahwah, NJ, USA) [18]. The mean inclination angle of the cup was 45° (30-57°) and the mean anteversion angle was 15° (4-22°).

Pseudotumor size was determined on MRI by manually outlining the greatest size of the mass. We measured the area of the pseudotumor using computer software (EV Insite Version 2.10.7.108; PSP Corporation, Tokyo, Japan). The scan areas were obtained from the same image for each comparison. Serum cobalt and chromium ion levels were measured in 9 patients with unilateral THA at the time of MRI. Blood samples (8 mL) were taken preoperatively and postoperatively using cobalt-free needles and glass tubes for trace metal analysis without additives for blood collection to avoid metal contamination. Cobalt levels were assayed using Inductively Coupled Plasma Mass Spectrometry (Perkin-Elmer SCIEX Elan 6100 DRC ICP-MS system; Perkin-Elmer Instruments, Norwalk, CT, USA) at Mayo Medical Laboratories (Rochester, MN, USA), and chromium levels were assayed using a graphite furnace atomic absorption spectrometer (Z-5700; Hitachi Ltd., Tokyo, Japan) with polarization-Zeeman absorption at Mitsubishi Chemistry Medience Co., Ltd. (Tokyo, Japan). Detection limits for each ion were 0.2 μg/L [19].

Changes in pseudotumor size and serum metal ion levels were evaluated. Two hips in one female patient were revised simultaneously because of the development of hip pain after subsequent MRI. The in situ durations were 4 years and 8 months in her left hip and 4 years and 1 month in her right hip. She was revised 2 years and 10 months after her initial MRI. Femoral head diameter was 44 mm in bilateral hip. The cup inclination was 44° in bilateral hip and the cup anteversion was 9° in her left hip and 5° in her right hip. This study was approved by the ethics committee of our institution, and all patients provided their informed consent.

Statistical analysis was performed using the Kruskal–Wallis test and chi square test to compare age, gender, BMI, head diameter, cup inclination, cup anteversion, and pseudotumor type among changes of pseudotumor size. We compared the pseudotumor size for the three groups (increase in size, no change, decrease in size) using Kruskal–Wallis test and Mann–Whitney U test. Wilcoxon signed-rank test was used to compare median serum metal ion levels over time. A P value < 0.05 was considered significant. StatView Version 5.0 (SAS Institute Inc., Cary, NC, USA) was used.

Results

The mean ± standard deviation pseudotumor size changed from 729 ± 408 mm^2 to 877 ± 754 mm^2. The minimum and maximum sizes at initial MRI were 103 mm^2 and 1665 mm^2, respectively. The minimum and maximum sizes at subsequent MRI were 54 mm^2 and 3085 mm^2, respectively. The median size changed from 709 mm^2 to 509 mm^2. Among the 24 hips, pseudotumors increased in size in eight (three cystic and five mixed) and decreased in size in six (four cystic and two mixed). Ten hips showed no changes in size (seven cystic and three mixed, Table 1). We found no significant differences between changes of pseudotumor size and patient characteristics including age, gender, BMI, head diameter, cup inclination, cup anteversion, and pseudotumor type (Table 2). While it is not statistically significant due to the small numbers in this series, there is a trend toward the cystic pseudotumors either remaining the same size or decreasing (79%), while the mixed type pseudotumors tend to increase in size (50%). The mean initial size of pseudotumor was bigger in pseudotumors with increased in size (1002 ± 309 mm^2) than in those with decreased in size (542 ± 295 mm^2, $P = .020$) or no change (622 ± 448 mm^2, $P = .041$). Bone edema was not found in every patient. In the patient who underwent revision, the pseudotumor size in her left hip increased from 833 mm^2 to 1895 mm^2 (mixed type), and the size in her right hip showed no change (608 mm^2, cystic type). Serum cobalt and chromium levels at the time of revision were 2.3 μg/L and 1.9 μg/L, respectively. The median serum cobalt ion levels at initial and follow-up MRIs were 2.0 μg/L and 1.8 μg/L, respectively. The mean ± standard deviation (range) levels of cobalt at initial and subsequent MRIs were 17.6 ± 46.7 μg/L (0.9 – 142.0 μg/L) and 17.6 ± 46.3 μg/L (0.7 – 141.0 μg/L), respectively. The median serum chromium ion levels at initial and follow-up MRIs were 2.0 μg/L and 3.1 μg/L, respectively. The mean ± standard deviation (range) levels of chromium at initial and subsequent MRIs were 10.7 ± 26.0 μg/L (0.5 – 79.9 μg/L) and 11.8 ± 28.3 μg/L (0.3 – 87.0 μg/L), respectively. No significant differences were observed in the serum levels of either metal between the initial and subsequent MRIs.

Table 1
Changes in Pseudotumor Size Over Time.

Pseudotumor Size	Number of Hips	Types of Pseudotumor		
		Cystic	Solid	Mixed
Increased	8	3	0	5
Decreased	6	4	0	2
No change	10	7	0	3
Total	24	14	0	10

Discussion

A survey of pseudotumors after metal-on-metal hip resurfacing in Canadian academic centers demonstrated that a surgically confirmed pseudotumor developed after four of the 3432 arthroplasties, for a prevalence of 0.10% [9]. Pseudotumor prevalence, including asymptomatic cases, has been reported to range from 4% to 69% when patients are screened after metal-on-metal hip resurfacing or THA [7,9,10,12–14,20,21]. However, the use of routine imaging, metal ion testing, and indications for revision have not yet been established. A

Table 2
Comparison of the Patient Characteristics and Results Between Changes of Pseudotumor Size.

		Pseudotumor Size			P
		Increased	Decreased	No Change	
		n = 8	n = 6	n = 10	
Age	Mean (years)	63	57	66	0.085
Gender	% Female (%)	88	100	70	0.275
Body mass index	Mean (kg/m^2)	25.8	22.3	23.3	0.271
Head diameter	Mean (mm)	38.5	38.7	40.8	0.292
Cup inclination	Mean (°)	45.8	40.3	47.4	0.223
Cup anteversion	Mean (°)	14.4	17.4	13.4	0.323
Pseudotumor type	% Cystic (%)	38	67	70	0.340

longitudinal study of pseudotumors could be useful to understand their natural history. Therefore, the changes over time were assessed in patients with previously MRI-detected pseudotumors. Eight hips (33%) were found to continue to increase in size. Size reduction despite no intervention was seen in six pseudotumor masses (25%). It is difficult to explain why these masses increased or decreased in size. The present study demonstrated that the initial size of pseudotumor was bigger in pseudotumors with increased in size than in those with decreased in size or no change. We found that the bigger the pseudotumor size, the more likely the size would increase. And we might predict that bigger pseudotumors would tend to increase in size. In addition, the mixed type pseudotumors would tend to increase in size. A previous study showed that serum cobalt and chromium ion levels were significantly higher in hips with pseudotumor than in hips without pseudotumor [10]. Metal wear at the bearing surfaces and at the head and stem taper interface was the main source of metal ion debris. However, serum cobalt and chromium ion levels did not correlate with pseudotumor extent in this study.

The present study has some limitations. First, we studied the small number of patients. Second, natural history of pseudotumors could not be predicted absolutely. It would be desirable to identify the predictive value of a specific pseudotumor size threshold beyond which revision should be considered. Third, it is likely that in some patients with cystic pseudotumor its presence is not a result of an abnormal tissue reaction but rather fluid accumulation.

Ebreo et al [22] studied serial MRIs after small-diameter, metal-on-metal THA, and a total of 239 MRIs of 80 patients was classified as A (normal), B (infection), or C1–C3 (mild, moderate, severe metal-on-metal-related abnormalities). On subsequent MRIs, six initially normal scans (9.5%) showed progression to a disease state; 15 (15%) of 103 THAs with sequential scans demonstrated worsening disease on subsequent imaging. Almousa et al [23] performed follow-up ultrasound after the detection of 9 asymptomatic pseudotumors (six large-head, metal-on-metal THAs and three hip resurfacing arthroplasties). The pseudotumors increased in size in six (four solid and two cystic). Two pseudotumors (one solid and one cystic) disappeared completely. One solid pseudotumor decreased in size. In the large-head, metal-on-metal THA group, four pseudotumor masses (three solid and one cystic) increased in size. Two pseudotumors completely disappeared with no intervention. Nawabi et al [17] reported that pseudotumor size on MRI correlated with the histologic score (ALVAL score [24]) in patients with revised metal-on-metal hip prostheses. The patients with an ALVAL score of 5 or greater were more likely to have a mixed type of pseudotumor with higher maximal synovial thicknesses and synovial volumes.

Guidelines recommending follow-up of asymptomatic patients undergoing metal-on-metal hip arthroplasty have already been published [25]; however, indications for operative revision have yet to be established. A number of studies have suggested that pseudotumors are the result of an adverse response to metal wear debris and elevated metal ion levels in patients with metal-on-metal hip prostheses [2,10,26]. In contrast, other studies demonstrated that pseudotumors were not associated with increased wear or metal ion levels [27,28]. The present study failed to clarify the relationships between the changes in pseudotumor size and serum metal ion levels. Delay of revision may be associated with extensive soft-tissue damage and hence poor clinical outcomes [25]. It is desirable to assess the changes in pseudotumor size over time. The present study is the first, to the best of our knowledge, to examine the natural history of pseudotumors following large-diameter, metal-on-metal THA using MRI.

In conclusion, the present results suggest that pseudotumors frequently change in size in asymptomatic patients, and our hypothesis was verified. A single MRI study in the clinical decision-making process should be avoided, and a longitudinal study of pseudotumors with MRI, which could help clarify their natural history, should be performed.

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