Heavy reading in heavy metal

Unraveling the mystery of hip tissue in metal on metal total hip arthroplasty

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Chapter 4

High prevalence of pseudotumors in patients with a Birmingham Hip Resurfacing prosthesis: a prospective cohort study of one hundred and twenty-nine patients


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ABSTRACT

Background
Recently, concern has emerged about pseudotumors (lesions that are neither malignant nor infective in the soft tissues surrounding total hip arthroplasty components) after hip arthroplasties with metal-on-metal bearings. Patients treated in our hospital for degenerative arthritis of the hip with a Birmingham Hip Resurfacing (BHR) prosthesis were invited to return for follow-up evaluation. The prevalence and clinical relevance of pseudotumors were investigated. Risk factors for pseudotumor formation were sought.

Methods
A single-center cross-sectional prospective cohort study was conducted and included all patients who received a BHR from 2005 to 2010 in Martini Hospital, Groningen, The Netherlands. Data were collected on patient and surgical characteristics, clinical hip outcome scores (Harris hip score and Oxford score), serum metal ion levels (cobalt and chromium), and radiographs. A computed tomographic scan (without metal suppression) was made. In patients who had a revision, tissue samples were histologically examined.

Results
Originally, there were 129 patients with 149 BHRs. Four patients (six hips; 4 %) were lost to follow-up. Our final cohort consisted of 125 patients (143 hips). From this final cohort, eleven patients (twelve hips) had a revision, and three of them (three hips) had the revision before the present study was conducted. Seven patients (eight hips; 5.6 %) had a revision because of a symptomatic pseudotumor. Survival analysis showed an implant survival rate of 87.5 % at five years (failure was defined as a revision for any reason). A pseudotumor was found on computed tomography in thirty-nine patients (forty hips; 28 %). Of those patients, ten (eleven hips; 28 %) had complaints involving groin pain and discomfort, a noticeable mass, or paresthesia. Symptomatic pseudotumors were significantly larger than asymptomatic pseudotumors (a mean volume of 53.3 cm³ compared with 16.3 cm³; p = 0.05). A serum cobalt level of >85 nmol/L was a predictor for pseudotumor formation (odds ratio, 4.9).

Conclusions
Pseudotumor formation occurred in 28 % of hips after an average follow-up of forty-one months. Most pseudotumors (72.5 %) were asymptomatic. Larger pseudotumors were associated with more complaints. Survival analysis showed an implant survival of 87.5 % at five years. Failure occurred in 5.6 % (eight) of 143 hips because of a symptomatic pseudotumor.
INTRODUCTION

In the mid-1970s, metal-on-polyethylene total hip arthroplasty components were used instead of the first-generation metal-on-metal total hip arthroplasty components. Because of good clinical results, the indication for hip replacement was widened and younger patients with end-stage degenerative arthritis were treated. Because of increased risk of polyethylene wear and subsequent prosthetic loosening, metal-on-metal total hip arthroplasty and metal-on-metal hip resurfacing arthroplasty were reintroduced. Hip resurfacing arthroplasty offers more hip stability, preserves the femoral neck and a portion of the femoral head, and optimizes stress transfer to the proximal part of the femur.¹

We believe that the best indication for metal-on-metal hip resurfacing arthroplasty is a young active man with end-stage degenerative arthritis and good bone quality. In such patients, survivorship of the components has been reported to be 99% at ten years and 98% at thirteen years of follow-up.² A recent systematic review of the metal-on-metal hip resurfacing arthroplasty devices has shown survival rates of 84% to 100%, with a mean duration of follow-up ranging from 0.6 to 10.5 years.³ The most frequent mode of failure was aseptic loosening in 3.5% of hips.

Recently, concern has emerged about soft-tissue reactions after metal-on-metal hip resurfacing arthroplasties.⁴ One reaction is pseudotumor formation, which may be due to an adverse immunological reaction to metal particles, but the exact mechanism remains unclear. These nanometer-sized metal particles can corrode in synovial fluid, forming cobalt and chromium ions. Uptake from the synovial fluid results in raised serum levels of cobalt and chromium ions. Cardiac and neurologic toxicity of cobalt has been described, although reports are scarce.⁵,⁶ Pseudotumors can be asymptomatic or have a wide variation in presentation, with pain and discomfort in the groin but also with spontaneous hip dislocation, a noticeable mass in the groin, a rash, or nerve palsy.⁷ Because of a high failure rate, the Articular Surface Replacement (ASR; DePuy, United Kingdom) has been withdrawn from the market.⁸

Because of the concerns of pseudotumor formation and possible systemic effects of elevated metal ions, all patients who had had a metal-on-metal hip resurfacing arthroplasty (Birmingham Hip Resurfacing [BHR]; Smith & Nephew, Birmingham, United Kingdom) were invited to return for follow-up evaluation. The purpose of this study was to investigate the prevalence of pseudotumors. We also analyzed whether we could find a risk factor for pseudotumor formation after metal-on-metal hip resurfacing arthroplasty.
MATERIALS AND METHODS

Study design
From January 2005 to November 2010, in the Martini Hospital, Groningen, The Netherlands, a BHR prosthesis was implanted in young patients with end-stage osteoarthritis of the hip. Exclusion criteria were previous surgery of the ipsilateral hip, known metal sensitivity, or osteoporosis (as determined on a dual x-ray absorptiometry scan). All procedures were performed with a metal-on-metal BHR femoral head and acetabular shell. Three different orthopaedic surgeons (including one of us [C.L.E.G.]) performed the surgery.

A single-center cross-sectional prospective cohort study was conducted following approval of our institutional medical ethics committee. All patients with a BHR were recruited. Informed consent was obtained. Patient characteristics (sex, age, body mass index, cup size, and duration of follow-up) were determined, as well as the Harris hip and Oxford scores. An anteroposterior radiograph was made, with special interest in the inclination of the acetabular component. Serum ion cobalt and chromium levels were determined, and a computed tomographic (CT) scan of the periprosthetic region was made. Indications for revision as well as the findings during the revision procedure were documented. Finally, retrieved tissue specimens in the revised hips were analyzed by a pathologist with expertise in pseudotumor characterization.

Metal ions
Blood samples were obtained via Venflon (Becton Dickinson, Helsingborg, Sweden), discarding the first 5 mL. All samples were frozen and sent to the same laboratory (Humicon, Maastricht, The Netherlands) for blinded analysis of whole blood and serum chromium and cobalt levels, using inductively coupled plasma mass spectrometry. To analyze the predictive value of metal ion levels for the prevalence of pseudotumors, all bilateral BHRs were removed from the analysis. The ion levels of 107 patients were evaluated.

CT scans
CT scans were performed on a sixteen-slice CT scanner (Philips; Best, The Netherlands). CT scans were viewed in a bone window to minimize artifacts resulting from metal implants. Window width to window-level values were set at 2000:650. The CT scans were performed without a metal suppression protocol. A CT grading system was used to describe the amount of synovial reaction postoperatively9 (see Supplement). In our study, grade IV or V findings, which consist of a solid, semisolid, or cystic eccentric extension of the capsule, resulting in an increase in the volume of the capsule that could not be attributed to an infection, malignancy, bursa, or scar tissue, were classified as a pseudotumor. There was no minimum size of the pseudotumors.
Thickened capsule with or without bulging (grade II or III) was recorded but was not considered to be a pseudotumor. The volume (V) of the pseudotumor was calculated by using the formula for elliptical volume:\[ V = 0.52 \times \text{height} \times \text{width} \times \text{depth}. \]

**Histological analysis**

All specimens were fixed in neutral buffered formalin (10 %). Tissue samples were embedded in paraffin and processed. Sections that were 3 mm thick were stained with hematoxylin and eosin and evaluated histologically. Tissue responses were classified by a surgical pathologist (A.T.M.G.T.) using the aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL) score described by Campbell et al.\(^\text{11}\)

**Statistical analysis**

To assess differences in several variables between patients with and without a pseudotumor, t tests were used for continuous variables or the Mann-Whitney U test was used when the variables were not normally distributed. The chi-square test and the Fisher exact test were used for categorical variables. The prevalence of peri-articular masses in our patients was expressed in percentages. On the basis of logistic regression analyses, the potential risk factors, including age, sex, cup size, inclination, Harris hip score, Oxford score, and elevated metal ion levels, were initially studied in a univariate analysis. Only variables that demonstrated an association of \( p < 0.20 \) in univariate analysis were fitted in a multivariate logistic regression model. A best subset stepwise forward procedure was followed to develop a prediction model for peri-articular mass. Only significant factors in the final regression model were considered predictors. For all tests, a two-tailed significance level of \( p < 0.05 \) was used.

**Source of funding**

There was funding from Smith & Nephew for the CT imaging and measurement of serum cobalt and chromium levels. Only the contributors had full access to the study data.

**RESULTS**

From 2005 to 2010, 149 BHR prostheses were implanted in 129 patients. The mean duration of follow-up (and standard deviation) was 41 ± 16.2 months (range, ten to eighty-two months). Four patients (six hips; 4 %) were not available for follow-up. Before this study was conducted, three BHR prostheses (in three patients) were revised; two were revised because of impingement and one was revised because of a pseudotumor. These prostheses had already been analyzed with serum ion levels and CT and were therefore included in the study population, although one of these patients
did not have a clinical prerevision score available. Therefore, the final cohort consisted of 125 patients (143 hips).

The patients had an average age (and standard deviation) of 53.5 ± 6.8 years (range, twenty-one to seventy-three years) at the time of the index surgery. Seventy BHR prostheses (47 %) were in female patients. Eighteen patients had a bilateral hip resurfacing. In thirty-nine patients (forty hips; 28 %) the CT scan revealed a pseudotumor (Fig. 1). Twenty-seven (67.5 %) of the hips with a pseudotumor had a grade-IV lesion, and thirteen hips (32.5 %) a grade-V lesion.

Of the multiple variables analyzed, age, sex, body mass index, cup size, inclination, and follow-up time did not differ significantly between the patients with and without a tumor (Table 1). Both cobalt and chromium levels were elevated in patients with a pseudotumor.

The chance of having a pseudotumor was significantly higher (odds ratio, 4.9) in patients with an elevated serum cobalt level of >85 nmol/L. An increase in cobalt or chromium ions of 1 nmol/L increased the chance of a pseudotumor by 1.3 %. A serum cobalt level of > 85 nmol/L was found in eighteen patients (twenty-three [21.1 %] of 109 hips) with a BHR acetabular cup inclination of ≥ 45° (range, 45° to 67°) and in two patients (two [5 %] of forty hips) with a cup inclination of < 45° (range, 30° to 44°); the difference was significant (p = 0.024).

**Table 1** Characteristics of Patients with a Revised BHR Prosthesis

<table>
<thead>
<tr>
<th>Findings</th>
<th>V</th>
<th>IV</th>
<th>III</th>
<th>II</th>
<th>I</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudotumor</td>
<td>27</td>
<td>48</td>
<td>72</td>
<td>19</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Impingement</td>
<td>13</td>
<td>26</td>
<td>47</td>
<td>63</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Loose cup</td>
<td>12</td>
<td>49</td>
<td>20</td>
<td>11</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>ASLVDAS score</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td>9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Harris Hip Score</td>
<td>64</td>
<td>36</td>
<td>1109</td>
<td>190.1</td>
<td>54.3</td>
<td>73</td>
</tr>
</tbody>
</table>

**Fig. 1.** *Axial CT image of a patient (Cases 5 and 10) with bilateral pseudotumors after bilateral resurfacing arthroplasty showing inferomedial eccentric enlargement of the hip capsule (red circle) toward the obturator foramen on the left (grade IV) and extensive filling of the iliopectineal bursa (red circle) on the right (R) side of the patient (grade V)*
Table 1. Associations of Variables with Pseudotumor Formation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group with Pseudotumor*</th>
<th>Group without Pseudotumor*</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age† (yr)</td>
<td>54.6 (40-65)</td>
<td>53.2 (21-73)</td>
<td>0.26</td>
</tr>
<tr>
<td>Females (%)</td>
<td>49</td>
<td>46</td>
<td>0.86</td>
</tr>
<tr>
<td>Body mass index† (kg/m²)</td>
<td>27.7 (20.5-37.6)</td>
<td>26.5 (19.8-37.3)</td>
<td>0.09</td>
</tr>
<tr>
<td>Cup size† (mm)</td>
<td>56.8 (50-64)</td>
<td>56.4 (50-66)</td>
<td>0.56</td>
</tr>
<tr>
<td>Inclination† (deg)</td>
<td>50.5 (37-65)</td>
<td>49.6 (30-67)</td>
<td>0.54</td>
</tr>
<tr>
<td>Follow-up time† (yr)</td>
<td>2.57 (0.6-5.6)</td>
<td>2.45 (0.8-6.8)</td>
<td>0.62</td>
</tr>
<tr>
<td>Serum cobalt† (nmol/L)</td>
<td>94.4 (17-930)</td>
<td>47.5 (14-311)</td>
<td>0.06</td>
</tr>
<tr>
<td>Serum chromium† (nmol/L)</td>
<td>106.8 (13-918)</td>
<td>56.2 (10-202)</td>
<td>0.10</td>
</tr>
<tr>
<td>Median Oxford score (range)</td>
<td>16 (14-42)</td>
<td>16 (14-61)</td>
<td>0.56</td>
</tr>
<tr>
<td>Median Harris hip score (range)</td>
<td>97 (51-100)</td>
<td>98.5 (36-100)</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*There were thirty-nine patients (forty hips) with a pseudotumor and eighty-six patients (103 hips) without a pseudotumor. †The values are given as the mean, with the range in parentheses.

Of the thirty-nine patients (forty hips) that had a pseudotumor on CT, ten (eleven hips; 28%) had complaints. All ten patients (eleven hips) had pain and discomfort in the groin. Three patients (four hips) had a noticeable mass, and one of these patients had neurologic complaints (paresthesias in the distribution of the lateral femoral cutaneous nerve). These patients had an average Harris hip score of 70 points. Twenty-nine patients (twenty-nine hips; 73 %) had an asymptomatic pseudotumor (average Harris hip score of 97.8 points; range, 91 to 100 points). Eight patients (nine hips; 9 %) without a pseudotumor on CT had complaints; these patients had an average Harris hip score of 69.5 points (range, 36 to 84 points). Symptomatic pseudotumors (mean volume, 53.3 cm³) were significantly larger than asymptomatic pseudotumors (mean volume, 16.3 cm³) (p = 0.05). Of the eighteen patients who had bilateral hip resurfacing with BHR implants, one had a pseudotumor bilaterally and three had a pseudotumor unilaterally, one of which was symptomatic. The mean serum level (and standard deviation) of cobalt was 86.8 ± 70.4 nmol/L (range, 33.9 to 310.6 nmol/L) in the eighteen patients with BHR implants bilaterally compared with 54.6 ± 97.2 nmol/L (range, 13.6 to 930.0 nmol/L) in the patients with BHR implants unilaterally.

Three patients (three hips) had a revision before this study was conducted, and an additional eight patients (nine hips) had a revision at the time of the final follow-up (Table 2). The average time to revision was thirty-six months (range, nine to seventy-two months). Eight patients had a pseudo-tumor. Specimens of these eight pseudotumors were analyzed. Macroscopically, five patients had a solid or cystic soft-tissue mass with white or yellowish or brown discoloration (Fig. 2). Three patients had a gray soft-tissue mass, mostly anteriorly to the hip.
Table 2. Characteristics of Patients with a Revised BHR Prosthesis

<table>
<thead>
<tr>
<th>Case</th>
<th>Harris Hip Score*</th>
<th>Serum Cobalt (nmol/L)</th>
<th>Grade of Pseudotumor on CT†</th>
<th>Indication For Revision</th>
<th>Timing Revision of (mo)</th>
<th>Histopathological Findings (ALVAL Score)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>NA</td>
<td>57.7</td>
<td>V</td>
<td>Pseudotumor</td>
<td>40</td>
<td>7</td>
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<tr>
<td>25</td>
<td>82</td>
<td>55.7</td>
<td>IV</td>
<td>Impingement</td>
<td>20</td>
<td>-</td>
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<tr>
<td>35</td>
<td>91</td>
<td>81.5</td>
<td>II</td>
<td>Impingement</td>
<td>9</td>
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<tr>
<td>4</td>
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<td>156.1</td>
<td>IV</td>
<td>Pseudotumor</td>
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<td>5#</td>
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<td>47.5</td>
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<td>Loosening cup</td>
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<td>7</td>
<td>80</td>
<td>54.3</td>
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<td>73</td>
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<td>9</td>
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<td>1109</td>
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<td>1</td>
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<tr>
<td>10#</td>
<td>79</td>
<td>190.1</td>
<td>IV</td>
<td>Pseudotumor</td>
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<tr>
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<td>158</td>
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<td>Pseudotumor</td>
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<tr>
<td>12**</td>
<td>64</td>
<td>156.1</td>
<td>II</td>
<td>Pseudotumor</td>
<td>49</td>
<td>4</td>
</tr>
</tbody>
</table>

*NA = not available. †CT = computed tomography. ‡ALVAL = aseptic lymphocyte-dominated vasculitis-associated lesion score. §Revision was done before patient was invited back to participate in the current study. #The hips were in a patient with bilateral involvement. **The hip was revised because of progressive pain without a pseudotumor on CT. On revision, the hip showed excessive metallosis.

**Histological findings in the pseudotumors showed two reaction patterns**

In four of the eight hips, pseudotumors had a thick acellular area of eosinophilic fibrinoid material lining the pseudocysts. Deeper in the tissue, often sharply demarcated, were thick dense aggregates of lymphocytes. Acute inflammation was not observed. Only focally, macrophages filled with metal particles were seen. These pseudotumors were classified as high ALVAL scores (7, 8, 8, and 9, respectively). The patient with the bilateral pseudotumors had ALVAL scores of 8 and 9. The histological findings in patients with high ALVAL scores were thought to represent a metal hypersensitivity reaction (Fig. 3). In the other four patients, pseudotumors were histologically dominated by macrophages with intracytoplasmic phagocytosed metal particles. The aforementioned organization of acellular eosinophilic areas with lymphocyte aggregates was not observed. These pseudotumors were classified as low ALVAL scores (1, 3, 4, and 4, respectively). The patient with BHR implants bilaterally with a unilateral symptomatic pseudotumor had an ALVAL score of 4. The histological findings in patients with low ALVAL scores are thought to represent a high wear reaction (Fig. 4).
Chapter 4

Fig. 2. Intraoperative image of a pseudotumor. After the femoral head was resected, yellow-grayish villous tissue appeared at the anterior side of the acetabulum. The pound sign indicates the pseudotumor, and the asterisk indicates the acetabular cup of the BHR implant.

Fig. 3. Low-power photomicrographic image of ARMD (adverse reactions to metal debris), demonstrating the dense, deep eosinophilic (pink) fibrinoid material lining the pseudocyst (upper and lower area), with the thick dens (blue) lymphoid aggregates, composed of lymphocytes and plasma cells, between the fibrinoid material. The white arrow indicates lymphocytic aggregates, and the black arrow indicates fibrinoid necrosis and tissue organization (hematoxylin and eosin stain, original magnification, x25)
Survival analysis shows a survival rate of 87.5% at five years (Fig. 5). Failure was defined as revision for any reason. A BHR was revised because of a symptomatic pseudotumor in 5.6% (eight) of 143 hips.

**Fig. 4.** High-power photomicrographic image of ARMD (adverse reactions to metal debris), showing the lymphoid aggregates in the cases of ARMD. The lymphoid aggregates are predominantly composed of lymphocytes and plasma cells (hematoxylin and eosin stain; original magnification, x400).

**Fig. 5.** Kaplan-Meier survivorship curve for the BHR prosthesis. Failure was defined as revision for any reason.

Prevalence of pseudotumors in BHR
A pseudotumor is a lesion in the soft tissues surrounding a total hip arthroplasty implant that is neither malignant nor infectious in nature. The diagnosis is made on the basis of clinical and radiographic criteria. Histologically, the terms ALVAL (aseptic lymphocyte-dominated vasculitis-associated lesions) or ARMD (adverse reactions to metal debris) are given. ALVAL is commonly thought to represent an immune reaction to metal particles. This reaction can develop even with low wear.

In our study population, the prevalence of pseudotumors was high (28 %). Most of the pseudotumors (72.5 %) were asymptomatic. Recently Williams et al. found a 25 % prevalence of pseudotumors detected by ultrasound in twenty asymptomatic hips after a resurfacing arthroplasty. To our knowledge, our study is the first to investigate the prevalence of pseudotumors in a cohort of asymptomatic patients who had a metal-on-metal hip resurfacing arthroplasty. Different researchers, however, have described revision rates because of symptomatic pseudotumors after metal-on-metal hip resurfacing arthroplasty. The Canadian Hip Resurfacing Study Group described a prevalence of 0.1 % of hips that required revision because of a pseudotumor. Carrothers et al. described a 0.3 % revision rate. Ollivere et al. described a revision rate of 3.1 % after five years. Kwon et al. described a revision rate of 6.5 %. Results from registries in Australia, England, Wales, and New Zealand have also demonstrated an increased rate of revision for any reason after metal-on-metal total hip arthroplasty and metal-on-metal hip resurfacing arthroplasty. In our series, which had an overall revision rate of 8.4 %, most revisions (eight hips; 5.6 %) were performed because of a symptomatic pseudotumor.

Pseudotumor formation has been described mainly in studies involving metal-on-metal hip arthroplasties, although case reports of patients with metal-on-polyethylene bearings have also described such lesions. Glyn-Jones et al. found female sex and young age to be significant risk factors for pseudotumor formation. Carrothers et al. also found a significantly higher prevalence of revision in women (5.7 %) than in men (2.6 %) (p < 0.001). In our study, sex and cup size were not predictors of pseudotumors. Because of the concerns with regard to pseudotumor formation and possible systemic effects of elevated metal ions, all patients (including patients with a recently placed BHR implants) were invited to return for a follow-up evaluation. This accounts for the wide range of follow-up time (mean, 41 ± 16.2; range, ten to eighty-two months). The duration of follow-up did not prove to be a predictor. Six pseudotumors developed between 1.5 and two years postoperatively, suggesting patient susceptibility is an important etiological factor.

Some studies have suggested that edge-loading, resulting from adverse cup orientation, leads to more wear. A recent study by Matthies et al. showed a rate of pseudo-
tumor formation in hips with well-positioned metal-on-metal hip replacements to be similar to that in hips with replacements positioned outside the safe zone.\textsuperscript{22} Inclination angle did not prove to be a predictor in our study. An important limitation of our study is the lack of measurement of the acetabular anteversion. Conventional postoperative images could not all be retrieved because of a switch from analogue to digital imaging. Furthermore, many axial images were of poor quality and without enough penetration to quantify acetabular anteversion. CT reconstructions to address the anteversion are not possible because of the fact that the thin slices that were initially produced were not stored, to save space on the server. Reformatting the thick slices was not possible.

We chose CT for follow-up evaluation because a previous study showed no higher sensitivity for magnetic resonance imaging than for CT, and the use of ultrasound is, in our opinion, less suitable for double reading.\textsuperscript{23} The CT classification used for describing the synovial reaction is currently under investigation for its reliability regarding interobserver variation.\textsuperscript{24}

High serum levels of cobalt and chromium alone are not necessarily an indication for revision, although cardiac and neurological toxicity of cobalt has been described.\textsuperscript{3,6} Patients in our study with very high serum ion levels, however, were at risk of having a pseudotumor on CT scan. Serum ion levels can therefore be used as a screening tool.

Several groups have reported good clinical results after metal-on-metal hip resurfacing arthroplasty.\textsuperscript{2,3,25,26} Follow-up evaluation of these patients was by means of clinical examination and radiographs. We investigated our study population by means of CT scan, so we were able to see more abnormalities. Further follow-up will determine whether these abnormalities are of clinical importance. The survival rate of 87.5\% at five years in our study population is based on 125 patients (143 hips) and can be considered low according to the NICE (National Institute for Health and Clinical Excellence) guidelines (≥ 90\% survival after ten years).\textsuperscript{27} The survival rate decreases aggressively after five years, but only twenty-three hips had a follow-up period of more than five years.

In conclusion, our results show that pseudotumor formation occurs in 28\% of patients as seen on CT scan after an average follow-up interval of forty-one months. Most pseudotumors (72.5\%) are asymptomatic. Symptoms are pain and discomfort in the groin, a noticeable mass in the groin, and paresthesia. Larger pseudotumors are associated with more symptoms. Failure of the BHR implant occurred in 8.4\% of the patients (5.6\% due to a symptomatic pseudotumor) after an average follow-up of forty-one months. No risk factor for pseudotumor formation was identified. In our opinion, patients with a symptomatic pseudotumor should have a revision, and patients with a BHR with complaints need to be screened for a pseudotumor. Serum cobalt and chromium ion levels may be used for screening, but we find CT to be the best technique for diagnosing pseudotumors. Further follow-up of our patients with asympto-
tomatic pseudotumors will provide more information on whether these pseudotumors progress over time and become symptomatic.
REFERENCES


SUPPLEMENT

Table showing the grading system for postoperative findings on computed tomographic scans of patients with metal-on-metal hip arthroplasty components

Table. CT Grading System for Postoperative Findings in Patients with Metal-on-Metal Hip Arthroplasty Components*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal or acceptable</td>
<td>Thickening of capsule up to 4-6 mm</td>
</tr>
<tr>
<td>II</td>
<td>Reactive</td>
<td>Thickening of capsule of &gt;6 mm, but not more than the neck of the prosthesis, with or without bulging and without eccentric enlargement with respect to the capsule</td>
</tr>
<tr>
<td>III</td>
<td>Mild metal-on-metal disease</td>
<td>Consists of a bulging capsule both anteriorly and posteriorly</td>
</tr>
<tr>
<td>IV†</td>
<td>Moderate metal-on-metal disease</td>
<td>Represents eccentric bulging or enlargement of the capsule, which is often seen inferomedially to the prosthetic head</td>
</tr>
<tr>
<td>V†</td>
<td>Severe metal-on-metal disease</td>
<td>Represents the so-called bursitis mimicker, often extending posterolaterally with extensive filling of the subtrochanteric bursa, or anteriorly by filling of the iliopsoas bursa, which can extend into the abdominal compartment</td>
</tr>
</tbody>
</table>

*The grading system is from the study by Boomsma et al.⁹.
†In the present study, hips with grade-IV or V findings were considered to have a pseudotumor.

DISCLOSURE

One or more of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of an aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work.