■ HIP

Similar incidence of periprosthetic fluid collections after ceramic-on-polyethylene total hip arthroplasties and metal-on-metal resurfacing arthroplasties

RESULTS OF A SCREENING METAL ARTEFACT REDUCTION SEQUENCE-MRI STUDY

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Patients from a randomised trial on resurfacing hip arthroplasty (RHA) (n = 36, 19 males; median age 57 years, 24 to 65) comparing a conventional 28 mm metal-on-metal total hip arthroplasty (MoM THA) (n = 28, 17 males; median age 59 years, 37 to 65) and a matched control group of asymptomatic patients with a 32 mm ceramic-on-polyethylene (CoP) THA (n = 33, 18 males; median age 63 years, 38 to 71) were cross-sectionally screened with metal artefact reducing sequence-MRI (MARS-MRI) for pseudotumour formation at a median of 55 months (23 to 72) post-operatively. MRIs were scored by consensus according to three different classification systems for pseudotumour formation.

Clinical scores were available for all patients and metal ion levels for MoM bearing patients.

Periprosthetic lesions with a median volume of 16 mL (1.5 to 35.9) were diagnosed in six patients in the RHA group (17%), one in the MoM THA group (4%) and six in the CoP group (18%). The classification systems revealed no clear differences between the groups. Solid lesions (n = 3) were exclusively encountered in the RHA group. Two patients in the RHA group and one in the MoM THA group underwent a revision for pseudotumour formation. There was no statistically significant relationship between clinical scoring, metal ion levels and periprosthetic lesions in any of the groups.

Periprosthetic fluid collections are seen on MARS-MRI after conventional CoP THA and RHA and may reflect a soft-tissue collection or effusion.

Currently available MRI classification systems seem to score these collections as pseudotumours, causing an-overestimatation of the incidence of pseudotumours.

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In recent years several studies[1-3] have reported pseudotumour formation after metal-on-metal (MoM) total hip arthroplasty (THA). These studies raised concerns about the hazardous side-effects of these bearings and resulted in official safety alerts and market withdrawal of some designs of resurfacing hip arthroplasty (RHA).[4-6] These alerts included recommendations to screen patients with MoM bearings, using cross-sectional imaging such as ultrasound, CT and MRI. As a consequence, the presence of soft-tissue and fluid collections, muscle atrophy and oedema have been reported in relation to joint arthroplasties, which were not previously seen on conventional imaging.[7-9] These lesions have subsequently also been described in asymptomatic MoM arthroplasties.[1,7,10,11] The incidence of pseudotumour formation varies from 0.1% to 67%, and latterly it has increased.[1-3,9-13] Various classification systems have been introduced to evaluate and quantify these lesions but their ability to differentiate between benign and pathological lesions is unknown.[1,12,14,15] There is no consensus on the true incidence and clinical significance of many of the MRI findings which are generally referred to as pseudotumours.

Studies on the incidence of pseudotumours using CT or MRI in arthroplasties of the hip other than those with MoM bearings are scarce.[2,7] It could be hypothesised that identical periprosthetic lesions might be present on MRI in patients with bearings other than MoM and that these lesions could also be classified as pseudotumours by current classification systems.

Our objective was to determine the incidence of periprosthetic lesions diagnosed by metal artefact reducing sequence-MRI (MARS-MRI)

in patients from a closed randomised trial on RHA *versus* a 28 mm MoM THA, and to compare the findings with the incidence of periprosthetic lesions in a matched control group of asymptomatic patients with a ceramic-on-polyethylene (CoP) conventional THA. Periprosthetic lesions were graded by three classification systems for pseudotumour given in literature.

Patients and Methods

For this study, all patients included in a closed randomised controlled trial (RCT) comparing RHA (n = 36) with a 28 mm conventional MoM uncemented THA (MoM THA) (n = 28)[16] were cross-sectionally analysed with MARS-MRI during follow-up. These patients were compared with a matched control group of patients with a CoP THA (n = 33).

Patients enrolled in the RCT between June 2007 and April 2010 were randomly assigned by a computer-generated variable block to receive either a RHA or a MoM THA. This study was designed to compare the functional results and metal ion blood levels of patients after RHA *versus* MoM THA. One criterion for inclusion in the RCT was age < 65 years. Further details are given in the previous paper.[16]

As part of this study, all patients included in the RCT who had not undergone revision during the follow-up period were invited to complete questionnaires and undergo MARS-MRI scans. They were matched by computer to asymptomatic patients with a primary CoP THA, without a prior infection, from a database of patients who underwent this procedure between June 2007 and April 2010 in the same hospital. Matching was performed on period of follow-up within a margin of three months and gender using a computer program (Mathlab 2012A, The MathWorks Inc, Natick, Massachusetts).

Of the patients included in the RCT, six had required revision during follow-up. For these patients the pre-revision MRI, when available (two of six), was analysed and scored according to an identical protocol by two radiologists (BW, MG) who were blinded to the cause of revision. The operation note of the revision surgery (four of six) was used for patients without an available MRI to determine whether a pseudotumour was considered to be present macroscopically. All revisions were performed by the senior author (JS) with a broad clinical experience in adverse reactions to metal debris. A summary of the inclusion and subsequent follow-up of patients in the RCT is given in the Consolidated Standards of Reporting Trials statement (Fig. 1).

Approval from the regional ethics committee from the Radboud University Nijmegen Medical Centre for the RCT was obtained (number LTC 419-071206, Committee Human Research number (CCMO) 2007/015; EudraCT trial register number 2006-005610-120). The original study did not include cross-sectional MRI screening or a matched control group. This was addressed with additional ethical approval (number LTC 939/190713, Committee Human Research number NL 44703.091.13, registration number 2013/221). All patients provided informed consent. This study was performed in compliance with the Helsinki Declaration of 2008.[17]

All operations were performed through a posterolateral approach by an experienced surgeon (JS) who undertook > 100 THAs annually. The surgical details have been described previously.[16] In the RHA group, a cobalt-chromium (CoCr) alloy RHA was implanted (Conserve Plus; Wright Medical Technology, Arlington, Tennessee) with a median femoral head diameter of 49 mm (42 to 54). In the MoM THA group, an uncemented tapered stem and a threaded titanium acetabular shell with a polyethylene insert and an integral metal liner was implanted (Zweymuller Alloclassic stem and Zweymuller Alloclassic CSF cup; Zimmer Orthopaedics, Warsaw, Indiana) together with a metal (CoCr) 28 mm head (Metasul; Zimmer Orthopaedics). The CoP THA group received an identical femoral component and acetabular shell but the latter was lined with a polyethylene insert and articulated with a ceramic 32 mm modular head (Biolox Delta, Zimmer Orthopaedics). All groups received identical antibiotic, thrombosis prophylaxis and rehabilitation programmes.

Imaging studies were performed using a 1.5-T MR scanner (Philips, Best, Netherlands) and a 16-channel body coil. A standard MARS protocol was used with four sequences, transverse T1-weighted images, transverse T2-weighted images, coronal short tau inversion recovery images and coronal T2-weighted images.

MRI was contraindicated in two patients. One in the RHA group had a neurostimulation device and one in the MoM THA group had a cochlear implant. These patients underwent CT scanning with a standard protocol on a 40-slice CT scanner (Brillance 40, Philips, Best, The Netherlands).

MRI and CT scans were interpreted by consensus between a musculoskeletal radiologist (MG) with ten years of experience and a radiologist with three years of experience (BW), both blinded to patient data and symptoms. Periprosthetic lesions were scored according to three classification systems; the Anderson score,[12] the system of Hart et al[1] and a system described by Boomsma et al[13] (Table I). Lesions were considered to be a pseudotumour if the criteria of at least one of these systems was met: an Anderson score 'C',[12] a Boomsma grade > III[13] and every lesion that satisfied the criteria of Hart et al.[1] The volume of the pseudotumour was calculated using post-processing software in our Picture Archive Communication System (Sectra, Linköping, Sweden) by outlining the circumference of the lesion on each slice. The inclination angle of the acetabular component was measured with reference to the inter-teardrop line on standardised anteroposterior pelvic radiographs.

All patients completed a Short Form-12, Oxford hip score questionnaire and a visual analogue scale (VAS) satisfaction score of 0 to 100 (worst to best). The Harris hip score[18] and the University of California at Los Angeles activity scale[19] were assessed by two members of the research staff (AH, PB) who collected and registered all the forms at the time of the MARS-MRI. Identical clinical

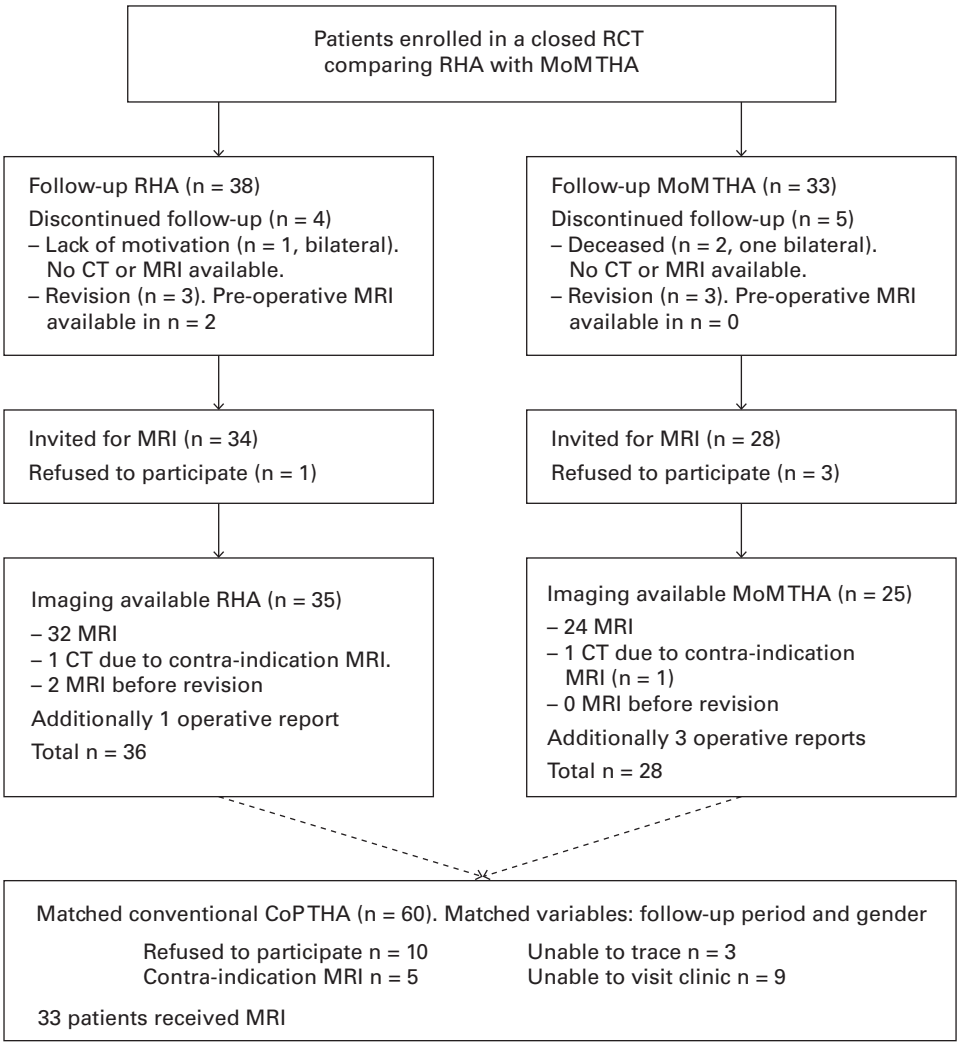

Fig. 1

Consolidated Standards of Reporting Trials statement. (RCT, randomised controlled trial; RHA, resurfacing hip arthroplasty; MoM, metal-on-metal; CoP, ceramic-on-polyethylene; THA, total hip arthroplasty).

outcome measurements were available pre-operatively and at six, 12, 24, 36 and 60 months for patients enrolled in the RCT. The latest available scores were used in those patients who underwent revision during follow-up.

CoCr serum levels were available for the patients enrolled in the RCT, including the latest metal ion levels of all patients who underwent revision during follow-up. Blood samples were collected pre-operatively and at three, six, 12, 24, 36 and 60 months post-operatively. The latest available metal ion level was used. Samples were collected according to a strict protocol to eliminate any form of metal contamination and analysis was undertaken using an inductively-coupled plasma mass spectrometer. The details have been reported previously.[16] The results were quantitatively reported if concentrations exceeded the detection threshold of 0.5 µg/l. All values below the limit of detection were registered as 0.1 µg/l for the purposes of statistical analysis.

Statistical analysis. The variables were tested for normal distribution using the Shapiro–Wilk test. Owing to a relatively small number of patients and an even smaller number of those with a pseudotumour, none of the variables had a normal distribution. Therefore, the median and range were used for all variables and non-parametric tests were used. Differences between two groups were determined by the Mann–Whitney U test and the Kruskal–Wallis test for analysis of more than two groups. A sub-analysis was performed on the relation between periprosthetic lesions on MRI and clinical scores. For this sub-analysis, the whole study population was split into a group with lesions graded as 'pseudotumour' by one of the classification systems and those without a periprosthetic lesion. Secondly, the same relationship was analysed for each type of arthroplasty separately. Differences were considered statistically significant with a p-value < 0.05. IBM-SPSS Statistics version 20.0 (IBM Corp., Armonk, New York) was used for statistical

Table I. Used classification systems by Anderson et al[12], Hart et al[1] and Boomsma et al[13]

Grade	Description	Criteria
Anderson et al grading system		
A	Normal or acceptable	Normal post-operative appearances including seromas and small hematomas
B	Infection	Fluid-filled cavity with high signal T2 wall; inflammatory changes in soft-tissue; ± bone marrow oedema
C1	Mild MoM disease	Periprosthetic soft-tissue mass with no hyperintense T2W fluid signal or fluid-filled peri-prosthetic cavity; either less than 5 cm maximum diameter.
C2	Moderate MoM disease	Peri-prosthetic soft-tissue mass/fluid-filled cavity greater than 5 cm diameter or C1 lesion with either of following: (1) muscle atrophy or oedema in any muscle other than short external rotators or (2) bone marrow oedema: hyperintense on STIR
C3	Severe MoM disease	Any one of the following: (1) fluid-filled cavity extending through deep fasci, (2) a tendon avulsion, (3) intermediate T1W soft-tissue cortical or marrow signal, (4) fracture
Hart et al grading system		
1	Thin-walled	Content: Fluid-like; hypointense on T1,hyperintense on T2. Shape: flat, with walls mainly in apposition
2a	Thick-walled or irregular	Content: Fluid-like: hypointense on T1,hyperintense on T2. Shape: not flat, with > 50% of the walls not in apposition
2b	Thick-walled or irregular	Content: atypical fluid: hyperintense on T1, variable on T2. Shape: any shape
3	Solid throughout	Content: mixed signal. Shape: any shape
Boomsma grading system		
I	Normal or acceptable	Thickening of capsule up to 4 mm to 6 mm
II	Reactive	Thickening of capsule of > 6 mm, but not more than the neck of the prosthesis, with or without bulging and without eccentric enlargement with respect to the capsule
III	Mild MoM disease	Consists of a bulging capsule both anteriorly and posteriorly
IV	Moderate MoM disease	Represents eccentric bulging or enlargement of the capsule, which is often seen inferomedially to the prosthetic head
V	Severe MoM disease	Represents the so-called bursitis mimicker, often extending posterolaterally with extensive filling of the subtrochanteric bursa, or anteriorly by filling of the iliopectineal bursa, which can extend into the abdominal compartment

MoM, metal-on-metal; STIR, short tau inversion recovery

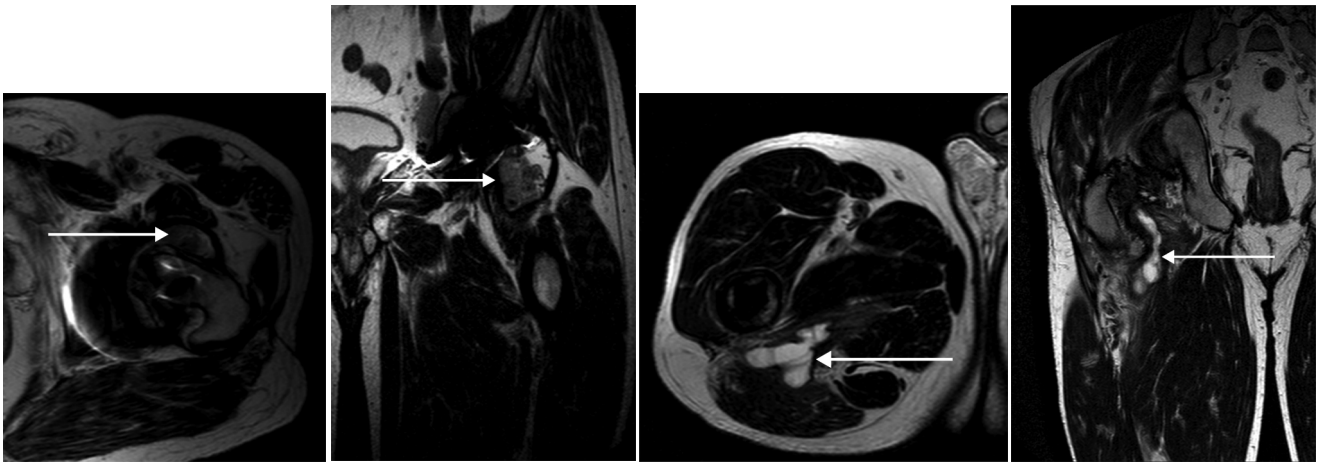

Fig. 2a Fig. 2b Fig. 2c Fig. 2d

MRIs showing the compilation of typical lesions (indicated by arrow) graded as pseudotumour on the selected classification systems. Images a) and b) show a resurfacing hip arthroplasty graded Anderson C2, Hart 3 and Boomsma IV; and images c) and d) show a ceramic-on-polyethylene total hip arthroplasty graded Anderson C3, Hart 2a and Boomsma V.

analysis. No power analysis was performed owing to the fact that the number of patients included in the RCT determined the total number of patients.

Results

The demographic data are summarised in Table II. Patients in the CoP THA group were significantly older than those in the RCT (p = 0.001, Kuskal–Wallis test).

Lesions classified as 'pseudotumour' or 'MoM disease' by any of the three MRI scoring systems were seen in six patients in the RHA group (17%), in one in the MoM THA group (4%) and in six in the CoP THA group (18%) (Fig. 2). These differences were not statistically significant (p = 0.19, Kruskal–Wallis test). From the relatively small number of patients in each group, the statistical power of these findings is, however, limited. For that reason detailed

Table II. Demographic data presented as medians with ranges

	RHA (n = 36)	THA MoM (n = 28)	THA CoP (n = 33)	p-value
Gender (males)	19	17	18	0.809
Age* (yrs)	57 (24.1 to 64.8)	59 (37.0 to 64.7)	63 (38.6 to 70.5)	0.001
Follow-up (mths)	55 (36 to 72)	56 (23 to 69)	54 (40 to 72)	0.861
Pseudotumour	6	1	6	0.194
HHS	98 (62 to 100)	100 (59 to 100)	97 (64 to 100)	0.616
OHS	14 (12 to 34)	14 (12 to 43)	13 (12 to 27)	0.426
VAS satisfaction*	91 (0 to 100)	85 (18 to 100)	95 (23 to 100)	0.045
UCLA	8 (3 to 10)	7 (4 to 10)	7 (4 to 10)	0.294
SF-12 physical component	100 (0 to 100)	100 (25 to 100)	75 (0 to 100)	0.244
SF-12 mental component	80 (50 to 100)	80 (30 to 100)	80 (40 to 100)	0.850
Cobalt serum (ng/L)	1.3 (0.1 to 22.10)	0.8 (0.1 to 2.4)	NA	0.087
Chromium serum † (ng/L)	1.8 (0.1 to 29.9)	0.5 (0.1 to 2.6)	NA	< 0.001
Cup angle (°)	45 (30 to 62)	48 (31 to 62)	46 (31 to 60)	0.223

* Significant difference between the groups, Kruskal–Wallis test
† Significant difference between the groups, Mann–Whitney U test
RHA, resurfacing hip arthroplasty; THA, total hip arthroplasty; MoM, metal-on-metal; CoP, ceramic-on-polyethylene; HHS, Harris hip score; OHS, Oxford hip score; VAS, visual analogue scale; UCLA, University of California at Los Angeles; SF-12, Short-Form 12; NA, not applicable

information on all patients with a periprosthetic lesion, including clinical scores, acetabular component inclination, metal ion levels and the grading of the three MRI classification systems, is given in Table III.

Generally there were no differences in the grade of periprosthetic lesions between the three groups, as is shown in Table III. Relatively high grade 'pseudotumours' were encountered irrespective of the group and classification system. Two patients had a lesion that was not scored as a 'pseudotumour' or 'MoM disease' by all three classification systems. One patient in the RHA group and one in the CoP THA group was classified as having a Boomsma grade II lesion,[13] which represented a reactive lesion. Solid lesions (n = 3) graded as a Hart et al[1] grade 3, were exclusively seen in the RHA group.

The median volume of the lesions was 16 mL (1.5 to 35.9) with no statistical difference in volume between groups (p = 0.2, Kruskal–Wallis test). Lesions were seen in nine men and four women, but this gender difference was not significant (p = 0.29, Mann–Whitney U test). The median inclination angle of the acetabular component of patients with a lesion was 44° (33° to 57°). Again no significant difference in this angle could be established between patients with or without a lesion on MRI (p = 0.20, Mann–Whitney U test).

Overall good clinical scores were seen without significant differences between the three groups (Table II). The only significant difference was in the median VAS satisfaction scores; this was significantly lower for the MoM THA group with a score of 85 (18 to 100) compared with 91 (0 to 100) and 95 (23 to 100) for the RHA and CoP THA groups respectively (p = 0.045, Kruskal–Wallis test). More detailed information on the clinical scores at different time intervals for the patients in the RCT has previously been reported.[16]

No statistically significant difference was encountered between the clinical scores and characteristics of the periprosthetic lesions overall (p ≥ 0.13, Mann–Whitney U test) and in the different prosthesis groups separately (p ≥ 0.07, Mann–Whitney U test). However, it is acknowledged that the groups are relatively small for statistical sub analysis.

Revision because of a destructive pseudotumour occurred in two patients in the RHA group (5%) and in one in the MoM THA group (3%); all three at 36 months postoperatively. The remaining revisions were related to osteonecrosis of the femoral head in one patient in the RHA group and two with recurrent dislocation in the MoM THA group. MRI scans before revision for pseudotumour formation were available in both patients in the RHA group and were used for retrospective grading. Of the remaining four patients with a revision, one large destructive pseudotumour in a MoM THA patient was described in the operation notes as an unanticipated finding. This was the only pseudotumour encountered in the MoM THA group.

Median serum cobalt levels, including the levels in the six patients who underwent a revision for RHA and MoM THA, after a median of 55 months (36 to 72) and 56 months (23 to 69) were 1.3 ng/mL (0.1 to 22.1) and 0.8 ng/mL (0.1 to 2.4), respectively. In contrast to cobalt, the difference in median serum levels of chromium was significant with 1.8 (0.1 to 29.9) for the RHA group and 0.5 (0.1 to 2.6) for the MoM THA group (p < 0.001). No statistically significant difference was encountered between metal ion levels in patients with periprosthetic lesions and those without (Cobalt p = 0.06; Chromium p = 0.068, Mann–Whitney U test).

Discussion

This study illustrates that periprosthetic lesions seen on MARS-MRI and classified as 'pseudotumours' by currently available scoring systems, are not exclusively seen in MoM hip arthroplasties. We found the incidence of periprosthetic lesions to be equally distributed between the RHA (17%) and CoP THA (18%) groups, whereas these lesions were

Table III. Clinical scores, metal ion levels, volume and MRI grading of the patients diagnosed with a pseudotumour

	Prosthesis	Imaging	Pseudotumour characteristics	Acetabular component inclination angle (°)	HHS	OHS	ULCA	Co serum	Cr serum	Volume (ml)	Anderson score	Hart score	Boomsma
1	RHA*	MRI	Mixed fluid and solid. Bulging of the capsule anteriorly and posteriorly	37.5	91	16	7	2.0	3.0	23.7	C2	3	IV
2	RHA	MRI	Fluid filled. Bulging of the capsule and extension in the m. pectineus	34.8	94	16	7	2.9	3.0	26.4	C3	2a	V
3	RHA	MRI	Fluid filled. Bulging of the capsule anteriorly and posteriorly	42.7	100	13	10	0.9	1.9	10.6	C1	2a	III
4	RHA	MRI	Fluid filled. within normal anatomic boundaries of the capsule with focal bulging of the posterolateral capsule	43	96	15	9	1.5	2.2	24.9	C1	2a	IV
5	RHA	MRI	Mixed fluid and solid. Anterior bulging	49.4	100	13	10	0.6	0.1	12.0	C1	3	II
6	RHA*	MRI	Mixed fluid and solid. Bulging of the capsule anteriorly and posteriorly and eccentric bulging posterolateraly	32.8	78	25	8	21.2	16.0	NA	C2	3	IV
7	MoM THA*	Report	Milky-like fluid from bursa. Intra-operative frozen section and cultures revealed no infection	51.2	59	43	4	1.6	1.3	NA	NA	NA	NA
8	CoP THA	MRI	Fluid filled. No bulging of the capsule	42.5	96	12	9	NA	NA	1.5	C1	2a	II
9	CoP THA	MRI	Fluid filled. Bulging of the capsule and focal extension into the adductors	44.1	90	16	9	NA	NA	35.9	C3	2a	V
10	CoP THA	MRI	Fluid filled. Eccentric bulging of the posterolateral capsule	46.1	96	20	6	NA	NA	14.3	C2	2a	IV
11	CoP THA	MRI	Fluid filled. Bulging of the poserolateral capsule into the trochanteric bursa	45.7	100	12	10	NA	NA	11.7	C2	2a	V
12	CoP THA	MRI	Fluid filled. bulging of the posterolateral capsule into the trochanteric bursa	56.5	98	13	7	NA	NA	6.4	C2	2a	V
13	CoP THA	MRI	Fluid filled. Bulging of the capsule anteriorly and posteriorly	48.7	98	13	7	NA	NA	7.9 ml	C2	2a	III

* Revision during follow-up
HHS, Harris hip score; OHS, Oxford hip score; ULCA, University of California, Los Angeles; RHA, resurfacing hip arthroplasty; MoM, metal-on-metal; NA, not applicable; CoP, ceramic-on-polyethylene

less commonly identified in the MoM THA group (4%). Solid periprosthetic lesions were exclusively seen in the RHA group, while all other lesions were bulging periprosthetic fluid collections. Nevertheless, the three classification systems graded most lesions as a 'pseudotumour' or 'MoM disease'.

In recent years, numerous cross-sectional studies have described solid masses and fluid collections in patients with MoM implants. The masses and fluid collections were mainly classified as adverse reaction to metal debris, pseudotumour or MoM disease and have been reported in symptomatic and asymptomatic patients.[1,2,7-10] Cross-sectional imaging studies on non-MoM bearings are, however, rare. Thus there remains some uncertainty about the clinical relevance of these findings.

In 2011, Williams et al[2] reported on pseudotumour formation in asymptomatic patients with either a RHA (n = 20), MoM THA (n = 31) or metal-on-polyethylene (MoP) THA (n = 24) screened by ultrasound. In their study, 4% of the patients with a MoP THA had a cystic mass and 8% had an isolated fluid collection. This incidence was lower than that for MoM RHA (30%) and large head MoM THA (42%).

Mistry et al[7] reporting on ten patients with an asymptomatic MoP and 12 patients with a MoM bearing, who were screened with MARS-MRI at a mean follow-up of 46 and 70 months, respectively, found eight periprosthetic fluid collections, of which one occurred in the MoP group.

Periprosthetic lesions, quantified as pseudotumour or MoM disease using currently available MARS-MRI scoring systems were encountered in our study. The incidence and grades of these lesions were similar in RHA and the CoP THA, at 17% and 18% respectively.

The lesions seen in our study were graded as 'pseudotumour' or 'MoM disease' when they met the criteria of at least one of the three classification systems. Every lesion was scored

as an Anderson grade 'C'[12] varying from mild to severe MoM disease. Additionally, every lesion could be classified by the score of Hart et al[1]. One lesion in the RHA group and one in the CoP group was scored as a Boomsma grade II lesion.[13] These were the only two patients who were not graded as pseudotumour by all three scores. In an earlier study of Bisschop et al,[10] only Boomsma grade IV and V lesions were considered to be clinically relevant. Applying a similar restriction to our study population, an incidence of pseudotumour of 11% in the RHA group and 12% in the CoP group would still have been encountered, once again resulting in similar incidences of pseudotumour. Obviously, the only solid lesions met were in the RHA group. However, perhaps only lesions scored as a Hart et al grade 3 are really clinically relevant.

Owing to the similar incidence of periprosthetic lesions in the RHA and CoP groups, the question of whether all periprosthetic lesions which are identified are 'real' pseudotumours arises. Some fluid collection is normal after any kind of THA without any destructive characteristics and without signs of infection in patients with good function and without pain. This is illustrated by the fact that in spite of the high grading on the different MRI classification systems, nine of 13 periprosthetic lesions were small (< 25 ml) fluid collections, in the presence of good clinical results and low metal ion levels. Therefore, we feel that there is a need for better MRI classification systems to reflect clinically relevant pseudotumours where a high grade actually corresponds with pathological and clinically relevant lesions. The presence of solid lesions, muscle damage and thickened capsule should be emphasised in seeking to define clinically relevant pseudotumours, as has been previously suggested.[20,21]

There remains no consensus on the most appropriate way of following up patients who have undergone a MoM arthroplasty and the indications for cross-sectional imaging remain unclear. Concerning the form of imaging, ultrasound, CT and MRI are used. Garbuz et al[22] showed that ultrasound and MARS-MRI performed equally well, with no significant difference in sensitivity or specificity between them. In addition to the uncertainty of which method of imaging should be adopted and the indications for cross-sectional imaging, the interpretation of the findings is also a matter of debate. Furthermore, the size of periprosthetic lesions changes over the course of time.[23,24] Serial MRI may have an important role in differentiating benign from pathological lesions.

We acknowledge the limitations of our study. Revisions were included in the two randomised MoM implant groups to maximise the follow-up for possible pseudotumour formation. In contrast, the matched control group of CoP THA patients originated from a series without complications which may have resulted in some bias towards a better clinical outcome in this group. However, the absence of major differences in clinical outcome between the groups suggests that this did not have a great influence.

Secondly, patients in the control group were significantly ($p < 0.001$) older than those in the RCT (Table II). Initially patients were matched on three parameters: follow-up, gender and age. However, because of the relatively young age of the patients included in the RCT and a limited number of patients in our database, we had difficulty matching on all three parameters. Nevertheless, the mean age was only five years greater in the CoP group than in the RHA group. In our opinion the length of follow-up is the most important parameter, since pseudotumours tend to develop over time. Accordingly, matching by age was relegated to the last criterion.

Thirdly, grading the pseudotumours was performed by consensus without inter- or intra-observer reliability scoring. We accept the possibility that the junior radiologist might have deferred to the judgement of the senior radiologist. Nevertheless, we note that clinically relevant studies on this topic have almost exclusively been performed using a consensus.[1,10,25] In addition, Chang et al[26] found that there was only a moderate agreement (kappa 0.439) between two readers using the Anderson score.[12]

Fourthly, the number of periprosthetic lesions encountered in each group was relatively low for statistical testing. Owing to the low numbers, no conclusions can be drawn on clinical scores and grade of the lesions between the different prostheses groups.

Finally, no histological matching of aseptic lymphocyte-dominated vasculitis-associated lesion scores with the imaging findings was available in the patients who underwent a revision. The combination of MRI and histology would probably have given a better reflection of the true incidence but with only six revisions in our series, no true correlation between MRI findings and histology would have been possible.

We conclude that periprosthetic lesions can be identified in some arthroplasties of the hip with both MoM and CoP bearings when screened by MARS-MRI. A similar number of lesions in the RHA and CoP groups were graded as 'pseudotumour' or 'MoM disease' by three currently used systems of classification for pseudotumour. However, a substantial proportion of these lesions appear to reflect a benign collection of fluid or effusion without clinical significance. Despite the fact that pseudotumour formation after MoM arthroplasty of the hip remains a serious concern, currently available MRI scoring systems probably overestimate the incidence of clinically relevant pseudotumours post-operatively.

Author contributions:
P. Bisseling: Study protocol, inclusion, assessment of clinical scores, data-analysis, writing the paper.
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