Metal Artifact Reduction Sequence MRI Abnormalities Occur in Metal-on-polyethylene Hips

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Abstract

Background To determine the importance of MRI abnormalities in metal-on-metal (MoM) bearings, it is important to understand the baseline features of this diagnostic tool in conventional metal-on-polyethylene (MoP) bearings.

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Questions/purposes What are the frequency, size, and types of MRI-documented adverse local tissue reactions in asymptomatic patients with MoP bearings?

Methods We recruited 50 patients 5 years after a MoP total hip arthroplasty from a pool of patients in our joint registry who had a Harris hip score of > 90. To be included, patients had to be without pain and have adequate radiographs. Our data set included 50 asymptomatic patients with MoP bearings who underwent a metal artifact reduction sequence MRI.

Results MRI abnormalities were seen in 14 of 50 (28%) asymptomatic patients who were studied. Thirteen of the 14 abnormalities were cystic thin-walled lesions with a mean of 18 cm³ (range, 1–79 cm³).

Conclusions MRI abnormalities were noted in nearly one-third of asymptomatic patients with MoP bearings. Decisions concerning revision of MoM bearings should not be based on isolated MRI findings because MRI abnormalities are commonly seen regardless of bearing type. A number of factors should determine the need for intervention including pain, mechanical symptoms, abductor weakness, component type, component position, and ion levels as well as MRI findings.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Metal-on-metal bearings (MoM) were heralded as a solution for two of the most common problems in hip arthroplasty in the last decade, instability and osteolysis. The promise of improved stability and diminished wear led to widespread acceptance of MoM bearings in THA.

Table 1. Demographic characteristics and implant details for study sample

Patient number	Acetabulum type	Stem type	Liner type	Head size (mm)	Time in situ (years)
1	Pinnacle*	Summit	Pinnacle Marathon	28	8
2	Pinnacle	Summit	Pinnacle Marathon	28	11
3	Pinnacle	Luster	Pinnacle Marathon	28	7
4	Pinnacle	Summit	Pinnacle Marathon	32	7
5	Pinnacle	Luster	Pinnacle Marathon	32	7
6	Pinnacle	Summit	Pinnacle Marathon	28	9
7	Pinnacle	Summit	Pinnacle Marathon	28	8
8	Pinnacle	S-ROM	Pinnacle Marathon	28	9
9	Pinnacle	S-ROM	Pinnacle Marathon	28	8
10	Pinnacle	Summit	Pinnacle Marathon	26	6
11	Pinnacle	Summit	Pinnacle Marathon	32	7
12	Pinnacle	Summit	Pinnacle AltrX	32	6
13	Pinnacle	Summit	Pinnacle AltrX	32	6
14	Pinnacle	AML	Pinnacle AltrX	36	6
15	Pinnacle	Summit	Pinnacle Marathon	32	6
16	Pinnacle	Summit	Pinnacle Marathon	28	8
17	Tri-Lock*	Tri-Lock	—	—	8
18	Pinnacle	Summit	Pinnacle Marathon	28	10
19	Pinnacle	Summit	Pinnacle Marathon	28	7
20	Pinnacle	Summit	Pinnacle Marathon	36	9
21	Pinnacle	Summit	Pinnacle Marathon	28	8
22	Pinnacle	Summit	Pinnacle GVF	28	11
23	Pinnacle	Luster	Pinnacle AltrX	32	5
24	Pinnacle	Summit	Pinnacle AltrX	28	6
25	Pinnacle	Summit	Pinnacle Marathon	32	8
26	Biomet [†]	AML	Biomet ArCom	26	14
27	Pinnacle	Summit	Pinnacle Marathon	26	6
28	Pinnacle	Summit	Pinnacle AltrX	28	6
29	Harris-Galante [‡]	Multi-Lock	—	28	19
30	Pinnacle	Summit	Pinnacle GVF	28	11
31	Pinnacle	Summit	Pinnacle AltrX	32	6
32	Pinnacle	Summit	Pinnacle Marathon	28	9
33	Pinnacle	Summit	Pinnacle GVF	28	10
34	Pinnacle	Summit	Pinnacle Marathon	28	9
35	Pinnacle	Summit	Pinnacle Marathon	28	9
36	Pinnacle	S-ROM	Pinnacle Marathon	32	9
37	Pinnacle	Summit	Pinnacle Marathon	28	10
38	Pinnacle	Summit	Pinnacle GVF	28	11
39	Biomet	AML	Biomet ArCom	26	14
40	Pinnacle	Summit	Marathon	28	8
41	Pinnacle	Summit	Pinnacle Marathon	32	8
42	Pinnacle	Luster	Pinnacle Marathon	32	6
43	Pinnacle	Summit	Pinnacle AltrX	28	6
44	Pinnacle	S-ROM	Pinnacle Marathon	22	9
45	Pinnacle	Summit	Pinnacle Marathon	28	8
46	Pinnacle	S-ROM	Pinnacle Marathon	26	8
47	Pinnacle	Luster	Pinnacle GVF	28	10
48	Pinnacle	Luster	Pinnacle AltrX	32	7

Table 1. continued

Patient number	Acetabulum type	Stem type	Liner type	Head size (mm)	Time in situ (years)
49	Pinnacle	Summit	Pinnacle Marathon	28	7
50	Pinnacle	Summit	Pinnacle AltrX	28	6

* DePuy Orthopaedics, Inc. Warsaw, IN, USA; †Biomet, Inc. Warsaw, IN, USA; ‡Zimmer Holdings Inc. Warsaw, IN, USA

Unfortunately, the advent of adverse local tissue reactions (ALTRs) has diminished the enthusiasm for this bearing couple. Whether such ALTRs are seen in isolation or eventually became the failure mode for a large portion of these bearings remains unanswered.

However, because of the large number of MoM implants in service at this time, it is important for clinicians to be able to recognize a malfunctioning bearing when present. The key to successful management of MoM implants is to diagnose adverse tissue reactions before they occur. Diagnostic clues to malfunctioning MoM bearings include mechanical symptoms, muscle weakness, implant position, and implant track record. Diagnostic tests that are available include cobalt and chromium ion levels as well as metal artifact reduction sequence (MARS) MRI. Cross-sectional imaging in the form of MARS MRI is a relatively new mode of investigation in hip arthroplasty. However, to determine the importance of MRI abnormalities in MoM bearings, it is important to understand the baseline features of this investigational tool in conventional metal-on-polyethylene bearings.

The presence of pain has been used as a harbinger of bearing-related problems in the evaluation of any arthroplasty including MoM implants. However, the sensitivity of pain as diagnostic of bearing-related MoM problems has recently been challenged. Fehring et al. [4] noted a high frequency of ALTRs in asymptomatic patients with modular MoM THAs. In that study, also from our institution, the authors found that 26 of 83 (31%) asymptomatic modular MoM patients had ALTRs discovered on MARS MR images. Additionally, the cobalt and chromium ion levels were below the 7-ppB threshold in 92% and 85% of patients, respectively. Whether these asymptomatic patients with positive MARS MRI warrant surgical treatment remains unanswered. As we consider the frequency and importance of these events in patients with MoM bearings, it would be helpful to know more about how often they occur in asymptomatic patients with metal-on-polyethylene (MoP) bearings.

We therefore ask, what are the frequency, size, and types of MRI-documented ALTRs in asymptomatic patients with MoP bearings?

Patients and Methods

We determined our recruitment pool by a query of our joint registry of patients who were at least 5 years after a

Fig. 1 Breakdown of study sample is shown.

MoP THA and had a Harris hip score of > 90. These procedures were performed by multiple surgeons at the OrthoCarolina Hip and Knee Center (Charlotte, NC, USA) using a variety of approaches and implants; the mean follow-up was 100 months (range, 63–232 months) (Table 1). A total of 1213 patients had a MoP THA between May 1986 and February 2008 and 313 patients had a Harris hip score of > 90. Figure 1 illustrates the breakdown of potential study patients. These 313 potential study patients were sent a study recruitment letter and the research team followed up with recruitment phone calls. Additionally, the senior author recruited during routine office visits. These recruitment measures continued until 50 patients completed the study. During the study enrollment and informed consent visit, the research team verified that the patients met the following inclusion criteria: (1) patients who received a metal-on-crosslinked polyethylene total hip implant; (2) patients who were not experiencing groin pain, thigh pain, or pain with ROM of the hip; (3) patients who are at least 5 years after a primary THA; (4) the acetabular implant (cup) was placed in the appropriate positions, ie, an acetabular abduction angle < 50°.

Table 2. Data set of asymptomatic metal-on-polyethylene bearings

Patient number	Presence of MRI lesion	Lesion size (cm ³)	Lesion type	Cup	Stem	Osteolysis
1	Positive	79.4	1	Pinnacle*	Summit	No
2	Positive	14.4	1	Pinnacle	Summit	No
3	Positive	35.9	1	Pinnacle	Summit	No
4	Positive	7.2	1	Pinnacle	Summit	No
5	Positive	3.3	1	Pinnacle	Summit	No
6	Positive	4.46	1	Biomet [†]	AML	No
7	Positive	77.2	3	Harris-Galante [‡]	Multi-Lock	Yes
8	Positive	9.75	1	Pinnacle	Summit	No
9	Positive	2.5	1	Pinnacle	Summit	No
10	Positive	10.9	1	Pinnacle	Summit	No
11	Positive	14.7	1	Pinnacle	Summit	No
12	Positive	1.12	1	Pinnacle	Summit	No
13	Positive	4.2	1	Pinnacle	Luster	—
14	Positive	7.31	1	Pinnacle	Luster	—
15	Negative			Pinnacle	Summit	No
16	Negative			Pinnacle	Luster	No
17	Negative			Pinnacle	Summit	No
18	Negative			Pinnacle	Summit	No
19	Negative			Pinnacle	Summit	No
20	Negative			Pinnacle	Luster	No
21	Negative			Pinnacle	Luster	No
22	Negative			Pinnacle	Summit	No
23	Negative			Pinnacle	Summit	No
24	Negative			Pinnacle	Summit	No
25	Negative			Pinnacle	S-ROM	No
26	Negative			Pinnacle	Summit	No
27	Negative			Pinnacle	Luster	No
28	Negative			Pinnacle	Summit	No
29	Negative			Pinnacle	Summit	No
30	Negative			Pinnacle	AML	No
31	Negative			Pinnacle	Summit	No
32	Negative			Biomet	AML	No
33	Negative			Pinnacle	Summit	No
34	Negative			Pinnacle	S-ROM	No
35	Negative			Pinnacle	Summit	No
36	Negative			Pinnacle	Summit	No
37	Negative			Pinnacle	Summit	No
38	Negative			Pinnacle	Summit	No
39	Negative			Pinnacle	Summit	No
40	Negative			Pinnacle	Summit	No
41	Negative			Pinnacle	Summit	No
42	Negative			Pinnacle	Summit	No
43	Negative			Pinnacle	S-ROM	No
44	Negative			Pinnacle	Summit	No
45	Negative			Pinnacle	S-ROM	No
46	Negative			Pinnacle	S-ROM	No
47	Negative			Pinnacle	Summit	No
48	Negative			Pinnacle	Summit	No

Table 2. continued

Patient number	Presence of MRI lesion	Lesion size (cm ³)	Lesion type	Cup	Stem	Osteolysis
49	Negative			Pinnacle	Summit	No
50	Negative			Tri-Lock*	Tri-Lock	No

* DePuy Orthopaedics, Inc. Warsaw, IN, USA; †Biomet, Inc. Warsaw, IN, USA; ‡Zimmer Holdings Inc. Warsaw, IN, USA

The convenience sample of 50 patients was based on the financial resources available to cover the costs of conducting the study, which included MRI costs.

Five musculoskeletal radiologists read all images as part of routine care; the senior author (TKF) reread any images identified as positive in an attempt to generate consistency. However, no intra- or interobserver reliability testing was performed. The radiographic variables that were analyzed (by TKF) included implant type and the presence or absence of osteolysis or polyethylene wear (Tables 1, 2). MARS MRI findings that were documented included the presence or absence of a lesion as well as the size and volume of the lesion. A fluid collection was determined to be positive only if we could show on the MARS MRI that joint communication was present. The MRI lesions were graded according to the method of Hart et al. [5]. A Type 1 lesion was cystic and thin-walled. A Type 2 lesion was cystic and thick-walled, and a Type 3 lesion was solid.

Our data set included 50 asymptomatic patients with MoP bearings who had MARS MRIs and plain films within the last 18 months. Descriptive statistics, including mean, range, frequency, and proportion, were calculated for all study variables.

Results

Fourteen of 50 (28%) asymptomatic patients with MoP bearings had MRI abnormalities (Table 2). The mean lesion size was 18 cm³ (range 1–79 cm³). Of the 14 lesions, 13 were Type 1 lesions (cystic with thin walls), whereas one was a Type 3 solid lesion. The patient with this lesion was only patient with visible radiographic evidence of polyethylene wear and osteolysis. All of the MRI lesions were located in the peritrochanteric area.

Discussion

Identifying the patients in whom a MoM THA is likely to cause harm—whether from local tissue reaction, bone or soft tissue damage, or systemic effects—remains challenging. Similar to making a diagnosis of a periprosthetic infection, no single diagnostic clue is available to guide the clinician

when evaluating a patient with a MoM implant. Multiple factors are important, including the presence or absence of pain, abductor weakness, mechanical symptoms as well as the type and orientation of the components. Diagnostic studies that are helpful include serology to rule out infection and metal ion levels to identify a malfunctioning bearing. Cross-sectional imaging as a secondary test to identify ALTR when serum ion levels are elevated has been advocated to help the clinician decide on the necessity or timing of revision intervention. However, to determine the importance of MRI abnormalities in MoM bearings, it is important to understand the baseline features of this investigational tool in conventional MoP bearings. In this study, we therefore evaluated the frequency, size, and types of MRI-documented ALTRs in asymptomatic patients with MoP bearings.

This study has a number of limitations. First, it was a retrospective review, and only a very small subset of patients who underwent surgery during the period in question qualified for inclusion (Fig. 1); in particular, nearly two-thirds of the patients who had surgery during that time did not have a Harris hip score registered in our database. Loss to followup of this magnitude and exclusion of patients with lower hip scores should cause us to read the estimates of frequency and severity of these events cautiously; they may in fact be higher. Second, the majority of implants (94%) were from one manufacturer, and so it is not clear to what degree it may generalize to other implant designs. Additionally, the MR images were read by five different musculoskeletal radiologists, and no intra- or interobserver reliability testing was performed; however, for consistency, each of the positive MRIs was reviewed by one of the authors (TKF). Finally, this study is limited by the number of patients in the cohort. The cost of MRI cross-sectional imaging is substantial and limited the number of patients we could study. However, we feel that we have an adequate sample size when dealing with a group of patients whose lack of symptoms does not warrant the routine use of this study.

Recently the presence of pain as a harbinger of bearing-related problems has been challenged. In a previous report from our center, we noted a high frequency of ALTR on MRIs in asymptomatic patients with modular MoM implants and ion levels below the 7-ppB threshold. The 31% prevalence found in this previous study [4] was

surprising to us stimulating us to seek out the prevalence of MRI abnormalities in conventional MoP bearings. We felt that only until we had a firm understanding of MRI findings in asymptomatic MoP bearings could we apply such findings to the decision-making process involved in evaluating MoM bearings. The evidence concerning MRI findings in conventional MoP bearings is limited. Multiple case reports have documented periacetabular masses associated with polyethylene wear debris and osteolysis in metal-on-plastic bearings [7, 8, 12, 14–16, 18]. These aggressive periarticular granulomatous masses were usually diagnosed on pelvic CT or ultrasound rather than MRI in an era of poor-quality polyethylene. Recently MARS MRIs have been used to document ALTRs after MoP total hips that have no discernible reasons for symptoms [2, 6, 9, 10, 13, 17]. These reports have focused on metallosis presumably as a result of corrosion at the head and neck junction or the neck-stem modular junction in modular stems. All of these patients were symptomatic on presentation [2, 6, 9, 10, 13, 17]. Williams et al. [20] reported abnormalities through ultrasound in three of 24 asymptomatic patients with MoP bearings. These authors subsequently performed a followup ultrasound study of these lesions at a mean of 26 months and found that two of three abnormal fluid collections had disappeared [1].

MRI has become the leading imaging modality in the evaluation of ALTRs after THA as a result of its accuracy in identifying soft tissue abnormalities [11, 19]. In one study, early intraarticular synovitis was identified on MARS MRI in nine of 21 asymptomatic metal-on-plastic or ceramic-on-plastic patients [3]. The significance of this intraarticular synovial reaction remains unknown and stands in contrast to the extraarticular lesions with joint communication seen in our series of patients with MRI abnormalities after MoP hips.

The value of any diagnostic test has to be interpreted with the knowledge of what is normal. We have shown that in nearly one-third of asymptomatic MoP patients, MRI abnormalities are present. The 28% prevalence rate is similar to the 31% prevalence we previously reported in evaluating asymptomatic modular MoM patients with MARS MRI [4]. All lesions in both studies were noted in the peritrochanteric region. However, a distinguishing feature between both study groups was the average size and type of cystic lesion. In the current study, the average lesion size was 18 cm³ compared with 45 cm³ in the MoM study. Additionally, all abnormalities in the current study were thin-walled cystic lesions, whereas approximately two-thirds of the abnormalities in the MoM study were cystic, thin-walled and one-third were cystic, thick-walled lesions [4].

We have shown that MARS MRI abnormalities are not uncommon regardless of bearing type. Therefore, decisions

concerning the necessity of revision for a patient with a MoM bearing should not be based on an isolated MRI finding. A number of factors should enter into the decision to determine the appropriateness of surgical intervention. These include the presence or absence of pain, mechanical symptoms, abductor weakness, component type, component position, ion levels as well as the MRI findings. Future studies should focus on the natural history of MRI abnormalities to determine if they increase, decrease, or stay the same size.

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