

Overview of metal-on-metal hip joint replacements, recognizing the signs and symptoms of failure

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Abstract

Metal-on-metal total hip replacement and metal-on-metal hip resurfacing implants came into the orthopaedic zeitgeist in the early 2000s, reaching their peak usage around 2006 (1). Metal-on-metal hip joint replacements were designed to be more durable to withstand the rigors of younger patients. Unfortunately, by 2006 the promising initial data regarding metal-on-metal hip joint replacements was engulfed by figures reporting increased rates of joint revision (1). This revision data led to product recalls and a move away from using metal-on-metal implants in total hip replacements and hip resurfacing operations. Nevertheless, many patients still have these components in-situ, which makes it important for physicians to understand the background of metal-on-metal components, how they fail and what investigations should be arranged in order to recognize component failure as early as possible.

One of the most dependent factors for the failure of metal-on-metal hip joint replacements is inflammatory pseudotumour, which develop more frequently around metal-on-metal hip arthroplasty components, compared to metal-on-polyethylene components. The development of pseudotumours is thought to be the nidus for metal-on-metal implant failure, because the pseudotumour destroys the soft tissue, which is in turn thought to lead to aseptic loosening and, increased wear rates on the articulating components. 70% of patients who develop a pseudotumour will require a hip joint arthroplasty revision operation (2, 3). Recognizing impending implant failure early reduces the soft tissue destruction around the implant, and makes revision of the total hip replacement, if required, technically easier to perform and more likely to be successful. Where a physician suspect's metal-on-metal total hip replacement failure, we recommend physicians order serum cobalt concentration level tests, a plain X-Ray and a CT of the local area, looking for signs of implant failure. If signs are found, the patient should be referred back to their orthopaedic surgeon for further opinion and management.

Aim

The controversy that has surrounded metal-on-metal (**MoM**) hip joint replacements is well known. Increased rates of revision and other adverse reactions have not only seen the use of MoM hip joint implants decline dramatically since their peak usage in 2006 (1, 4, 5), but have also resulted in product recalls, and class-actions against manufacturers (6, 7).

This article provides clinicians with background about the reason MoM hip joint implants were developed, outlines the reasons for their failure and provides advice in relation to the investigation of patients with MoM hip joint implants, presenting with suspected implant failure.

Background

On average, patients who undergo an elective total hip joint replacement (**THR**) are older than 55, with a mean age of 68 (4, 5). However, according to the 2016 Australian Orthopaedic Association National Joint Replacement Registry report, 13% of all THRs in Australia were performed on patients 55 years or younger (1).

As a consequence of vocational and lifestyle demands, patients younger than 55 years place a higher demand on their THR. Further, they will live longer and be more likely to have a higher body mass index (**BMI**) than previous generations. The combination of these factors means that the THR implants used in this patient population need to be able to withstand higher forces, and be durable over a longer period of time. It was this clinical need, which prompted the development of MoM hip joint implants.

In 2005, encouraging five year follow up results for the Birmingham MoM hip joint replacement implants emerged (8), promoting confidence that MoM hip joint

replacements were the answer to prolonging the time to revision of hip joint replacements. In 2006, use of all MoM hip joint replacements hit a peak of approximately 22% of all hip joint replacements (4, 9). However, following this peak, reports of higher rates of revision, aseptic loosening and the presence of metal debris, among other adverse reactions, started to emerge (1). This led to a gradual reduction in the overall number of MoM hip joint replacements used, as well as the withdrawal of the DePuy Articular Surface Replacement (**ASR**) and the Zimmer Durom hip resurfacing systems from the market. In 2015, MoM hip joint resurfacing components, accounted for 4.3% of all primary hip joint replacement, and conventional MoM hip joint replacements made up 1.8% of total hip joint replacements in Australia (1).

The number of people who have had MoM hip joint replacements is significant. From 2003 to 2011, 7.75% of all THRs in the joint registry of England and Wales had MoM weight bearing surfaces (10). In the USA Bozic, Kurtz S Fau - Lau (11) found 35% of hip arthroplasty operations between 2005 to 2006 used MoM hip joint implants. It is therefore apparent that physicians will treat many patients with MoM hip joint implants in-situ, making it important for them to understand the clinical investigation process for a patient with possible MoM hip joint implant failure.

How are the key performance indicators for hip joint replacements monitored?

National joint registries have been founded over the last 20-30 years, to monitor joint replacement operations, in countries including Sweden, Australia, Canada, and the UK. The main outcome measure of these registries is the time

between primary joint replacement, and the revision of the same joint, if required (1).

The clinical indicators for hip joint replacement revision (which are common to all joint replacements – infection, implant loosening, and implant failure) are recorded at the time of revision surgery. The type of implant, and the age and sex of the patient are also recorded at this time. When this data is recorded and triangulated in 98% of hip joint replacement operations (1), powerful statistical analysis of the key performance indicators for hip joint replacement operations is obtained.

What is the primary key performance indicator for hip joint replacements?

The key performance indicator for hip joint replacements is the time between primary joint replacement and revision of the same joint. This is the primary key performance indicator because revised hip joint replacements have worse functional and clinical outcomes than primary hip joint replacements. This is because revision hip joint replacements are more technically challenging due to the native anatomy having been previously changed. To reduce the rate of revision, surgeons match the demographics of the patient with the durability of the implant, either from primary trials or, more commonly, from joint registry data (if available).

What were the perceived benefits of MoM hip joint replacements?

Data from the Australian orthopaedic association national joint registry (1) and Langton, Joyce (12) demonstrates that most people who have joint replacement operations are older than 55, with 93% of this population undergoing the procedure for treatment of osteoarthritis. However, as mentioned above, there are a significant proportion of people who need hip

arthroplasty operations who are under 55 years old.

The gold standard for THRs is metal-on-cross-linked polyethylene articulating implants (**MoP**). MoP THR is comprised of a metal femoral head, which articulates with a cross-linked polyethylene cup. This combination has been the most reliable component combination people over 55 years for many years (1). MoM hip joint replacements use hardened cobalt-chrome alloy as the articulating weight-bearing surfaces. Due to the physical properties of cobalt-chrome alloy, it was thought that this alloy would have the improved durability and toughness that younger more active patients require.

Manufactures developed two distinctly different MoM hip joint replacements. Firstly, a conventional MoM THR in which a metal acetabular cup articulates with a metal femoral head, on a femoral stem, which sits inside the femoral intramedullary canal. Secondly, the MoM hip resurfacing implant (**HRI**), which is used in hip resurfacing operations. HRIs also comprise two components: the acetabular cup (which is fundamentally the same as the acetabular cup used in THR operations) and the femoral head (where a metal cap covers the articulating surface, resurfacing the degenerative articular cartilage).

Compared to THR, resurfacing operations conserve native bone. This is particularly beneficial for younger people undergoing hip joint replacement, as they are likely to outlive their prosthesis (meaning they will likely need a joint revision operation), and the anticipated joint revision operation will be less challenging because the native anatomy is less disturbed, and there is more bone stock left in-situ to affix a revision THR into. The evidence

does not support this theory, in fact, the outcomes of converting hip resurfacing implants to conventional THRs are much the same as revising primary conventional THRs (13).

Another theoretical benefit of MoM hip joint replacements, is the physiological and biomechanical advantage of a larger femoral head size. A larger head size was thought to load the femoral head in a more physiological pattern. This would simulate anatomical joint mechanics, reduce wear rate, and have a lower dislocation rate (14, 15). It was also for these reasons, that MoM hip arthroplasty implants were thought to be a more beneficial component choice for younger patients, compared to MoP components.

Revision rates of MoM hip joint implants compared to metal on cross-linked polyethylene

In 2015, more than 40% of hip replacements in Australia were configured using a MoP THR (1), with similar frequencies reported in the Swedish and UK joint registries. The overall revision rate in Australia for MoP hip joint replacements is 1.5% within the first year, 4.3% at 10 years, and 5.8% at 15 years (1). These figures confer with a multi-joint registry systematic review (16). Comparing MoM hip joint replacement revision rates to the gold standard MoP hip joint replacement illustrates the difference in performance between MoP and MoM hip joint replacements. The 10 year revision rate for a MoM hip joint replacements with a femoral head size larger than 32 millimeters, is 22% (1). For all MoM THRs the 10 year revision rate is 6.4%, and for hip resurfacing MoM hip joint replacements the 10-year revision rate is 9.5%.

Why do MoM hip joint replacements fail?

Since 2006, data from MoM hip joint replacements has suggested against their continued use (9, 17-19). Rahman, Amenabar (20) studied 19 patients with a mean follow up of 45 months post primary MoM hip joint replacement, whether THR or HRI and found that the main reasons for revision were aseptic loosening, adverse local tissue reaction (**ALTR**) and femoral head impingement. While these reasons for revision are common to all hip joint replacements, they have a higher incidence in MoM hip joint replacements.

Understanding the implant that has been used on a patient is clinically important. Not all MoM hip joint replacements are the same. For example the Articular Surface Replacement (**ASR**) has a five-year revision rate of 9.8%, compared with Birmingham Hip Resurfacing which has a revision rate of 1.5% at 10 years, and Conserve Plus which has a revision rate of less than 1% at five years (12). One of the hypotheses to account for this difference is the shallow acetabular component in the ASR, acetabular components that are thought to increase the edge loading on the femoral component. This, in turn, can mediate increased wear rate (15).

Furthermore, in relation to MoM HRIs, a multicenter trial of 4226 hips with a median follow-up of 66 months conducted by Langton, Joyce (21), found an inverse relationship between femoral head size and failure percentage. This means that the specifications of each MoM hip joint implant, dictate the amount of metal debris generated between the weight bearing surfaces, with the amount of metal debris generated, in turn having a relationship to the likelihood of implant failure.

Osteolysis and aseptic loosening

Aseptic loosening is the loosening of components in the bone, in the absence of infection. Aseptic loosening occurs more frequently in MoM hip joint replacements. This not only causes pain, but importantly, also changes the implant's position and wear pattern.

Particular to MoM hip joint replacements, is the production of metal debris, which flick off into the surrounding tissue. This metal debris is phagocytosed by macrophages in the surrounding soft tissue. Lohmann, Schwartz Z Fau - Koster (22) demonstrated a connection between macrophage activity and inhibition of osteoblast proliferation. This relationship is thought to account for the osteolysis around MoM hip joint replacement implants.

As a consequence of osteolysis, both aseptic loosening around the implant, and changes to the wear pattern of the implant, are thought to occur. These changes lead to an increased wear rate and altered joint kinematics (23). Once this process has begun, there is no way of conservatively managing the implant, and joint revision surgery is often required.

Aseptic loosening of the MoM hip joint replacement, generally presents as reduced patient function long after the immediate post-operative period. Increased pain, reduced function and, quality of movement, prompts the patient to present to their physician for investigation. A plain X-Ray is the first investigation indicated if aseptic loosening is suspected. Aseptic loosening is represented on X-Ray by a radiolucent line adjacent to the acetabular or the femoral implant.

Pseudotumour

Metal debris that is flicked from a MoM hip joint replacement into the surrounding soft tissue can also produce an adjacent inflammatory reaction in the soft tissue. Such local inflammation can cultivate a cystic or solid mass, commonly referred to as an inflammatory pseudotumour.

Although not exclusive to MoM hip joint implants, pseudotumour development has a high incidence in MoM hip joint implants Van Der Veen, Reininga (24) compared pseudotumour development in MoM THRs with pseudotumour development in MoP THRs, finding that pseudotumour was present in 53.7% of MoM THRs, compared to 21.8% of MoP THRs.

The development of inflammatory pseudotumour is mediated either by, a metal debris induced macrophage cytotoxicity or a type IV hypersensitivity reaction called aseptic lymphocyte-dominated vasculitis-associated lesion (25-27). Histology from revised and retrieval studies of MoM hip joint replacements confirms this theory. These two reactions are thought to be in response to chrome-cobalt metal debris (28). Even so, pseudotumour can also develop when there is very little amount of metal debris (21).

Because of the size and consistency of pseudotumours, their presence around the joint often changes the loading pattern of the articulating joint surfaces. Changing the loading pattern will consequently lead to an increased wear rate of the implant (29).

The development of an inflammatory pseudotumour is understood to be the most determinant factor leading to MoM hip joint replacement revision (2, 15, 25, 30).

Other terms that have been used to describe this phenomenon are, metallosis (31) and ALTR (32).

The clinical presentation of pseudotumour is variable. Presenting complaints include pain in the groin and buttock, swelling around the hip with a reduction in function and sometimes, instability or dislocation.

Type of MoM hip joint replacement implants

Gender differences

The revision rate after MoM hip joint replacement is different for males and females. Females are more likely to require joint revision after a primary MoM hip joint replacement (33, 34). Studies on this difference are limited to retrospective analyses, which make the cause for the gender difference difficult to accurately determine. One hypothesis centers on the head-to-neck ratio (**HNR**) of the femoral component. The head-to-neck ratio is the ratio between the size of the femoral head, in diameter, and the size of the femoral neck in width, with women tending to have an increased HNR to men. Increased HNR has the advantage of allowing increased hip joint range of motion, while concurrently decreasing the likelihood of hip joint impingement (also called notching of the femoral neck against the acetabular cup). However Grammatopoulos, Pandit (33) found that upon revision of MoM HRIs, patients who had a HNR of > 1.3 before primary hip joint resurfacing replacement, had a significantly increased rate of pseudotumour development compared to controls. The relationship between women having a higher HNR and the development of pseudotumour could partially account for the difference in revision rate of MoM HRIs between genders.

Clinical findings suggestive of implant failure

The mean presenting time post-primary MoM hip joint replacement for retrospectively diagnosed implant failure is 17 months (35). Therefore, patients presenting around this time period with relevant symptoms should raise the attention of their treating physician.

The most common presenting symptom with MoM hip joint replacements is pain on weight bearing, with such pain most commonly located in the groin and/or buttock area, radiating down the thigh (12, 15).

Late dislocation, following MoM hip joint replacement is also suggestive of implant failure. Generally, hip joint dislocation following joint replacement occurs in the weeks immediately following the operation. However, the increased rate of development of pseudotumour and aseptic loosening in MoM hip joint replacements can lead to the development of hip joint dislocations in the years following the primary operation. Symptoms preceding implant or hip joint instability include clicking, clunking, and the feeling of instability (30) (35).

Left untreated, pseudotumour has been reported to disturb the neurovascular structures of the thigh, in particular femoral nerve impingement and femoral artery narrowing and even stenosis (2). In such cases, patients would present with classic peripheral vascular disease symptoms in the anterior thigh (claudication, numbness and weakness). Patients presenting with these symptoms should be referred directly back to their orthopaedic surgeon for further investigation and management.

Investigations to undertake if patient presents with signs and symptoms

A robust succinct algorithm for the investigation of patients presenting with suspected implant failure does not currently exist. However, a systematic review by Reito, Lainiala (36), recommend a combination of serum chrome-cobalt level tests, total body ion levels tests, and a plain X-Ray looking for aseptic loosening and cross-sectional imaging, as the most effective way to diagnose MoM hip joint replacement failure, before referring patients back to their orthopaedic surgeon.

As an inflammatory pseudotumour progresses, so does the soft tissue destruction. A progression of soft tissue destruction around MoM implants during failure is associated with more complications after revision, when compared to MoP revision surgery (2). In addition, is that we know that around 70% of patients who present with pseudotumour around a MoM hip joint replacements will undergo revision surgery (2, 3). Recognition of implant failure in young patients with pseudotumour and impending implant failure, as soon as possible is critical, as the revision of a MoM hip joint replacements with extensive soft tissue destruction around it, is likely to be more difficult to execute.

Some of the suggested investigations are discussed further below.

Pathology

Measuring chrome-cobalt levels in patients who have a MoM hip joint replacement is common practice, however it is not necessarily a good indicator of implant failure (37). A serum chrome-cobalt ratio of 1.71, has a sensitivity of 62% and a specificity of 72.4% in identifying male patients with MoM associated hip joint osteolysis (37). This association was not found for women with MoM hip joint

replacements (37). Furthermore, cohort studies have failed to demonstrate a correlation between raised chrome-cobalt levels and pseudotumour (38). It is still unclear if patients with very high chrome-cobalt levels should have their MoM hip joint replacements revised, independent of clinical dysfunction (15).

Plain X-Ray

Plain X-Ray may not be useful in the early stages of MoM hip joint replacement dysfunction. Signs of failure that are appreciable on plain X-Ray, such as osteolysis, implant loosening, and soft tissue reactions, are often late signs of failure, and would likely be preceded by symptoms. This said, plain X-Rays of the pelvis anterior-posterior, the hip joint anterior-posterior and lateral and weight-bearing views are good starting points for physicians to commence investigating implant failure. Moreover, these X-Rays are a good reference when referring the patient back to his or her orthopaedic surgeon.

Ultrasound

Ultrasound is a useful imaging modality for diagnosing adverse local tissue reactions (39). It can be used to visualize each side of the hip joint, looking for masses or cystic lesions (15). Garbuz, Hargreaves (40) conducted a cohort study which demonstrated that ultrasound had a sensitivity of 100% and specificity of 96% for diagnosing inflammatory pseudotumour. The study group consisted of 40 patients at an average of 54 months post MoM THR. The caveat to these results is that the reliability of ultrasound depends on the experience of the operator to visualize arthroplasty related pseudotumour. Given this can sometimes be difficult to do, in some cases an ultrasound may not show inflammatory pseudotumour, when it is in fact present.

If your clinic has experienced musculoskeletal ultra-sonographers, ultrasound can be relied upon for its sensitivity. However, in most cases, further investigation is needed before excluding the diagnosis of inflammatory pseudotumour.

Computed Tomography

Computed tomography (CT) is a good further investigation if osteolysis is suspected on X-Ray (41). CT is mainly ordered by orthopaedic surgeons for preoperative planning before revision surgery, rather than by physicians to work a patient up to diagnose MoM hip joint replacement failure.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) is the gold standard when investigating MoM hip joint implants for suspected failure. MRI has a sensitivity of 96% and a specificity of close to 100% for the diagnosis of inflammatory pseudotumour (40, 42).

Furthermore, Anwender, Cron (43) conducted a pilot study investigating the tissue perfusion detected on dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI). Evidence of increased tissue perfusion kinematics around the MoM THR, seen on DCE-MRI, was concordant with aseptic lymphocyte-dominated vasculitis-associated lesion found on histology samples taken during revision surgery (43). MRI could therefore be chosen as the most reliable, sensitive and specific investigation modality for investigating MoM hip joint implant failure.

Possible associated clinical consequences

Morin and Daniel (44) investigated the health consequences of serum chromium cobalt concentration levels on Quebec beer-

drinks in the 1960s. In a now famous study titled Quebec beer-drinkers' cardiomyopathy: etiological considerations, found that beer drinkers developed fibrosis of their myocardium in a sudden episode. The context was that, cobalt sulfate was added to beer from 1965, in order to increase the stability of the beer foam. A concentration relationship was found between the amount of beer containing cobalt sulphate and the likelihood of developing Quebec beer-drinkers cardiomyopathy. The practice of adding cobalt to beer stopped shortly after the paper was published, and the incidence of beer-drinking related cardiomyopathy ceased. Jump forward to 2016, where research is being conducted to investigate the possible link between MoM hip joint implant related, serum chromium-cobalt levels and cardiomyopathy. A case study in 2016 has demonstrated the development of cardiomyopathy in a patient with a MoM hip joint replacement (45).

Conclusion

Since the peak MoM hip joint replacement use in 2006, there has been a dramatic reduction in the use of MoM THRs and HRIs in joint registries across the world. MoM hip joint replacement failure remains an important issue for physicians to understand, because there remain many people with MoM hip joint replacements in-situ. MoM hip joint replacements fail because of interrelated factors including increases to weight bearing surface wear rate, development of inflammatory pseudotumour, and implant loosening. Not every one of these factors, however, is required to result in MoM hip joint replacement failure.

In the absence of a well-established investigation algorithm, it is important for physicians to know and document the type of implant their patients have, and

understand the basic framework for investigating patients, when they present with signs or symptoms suggestive of implant failure. Any patient presenting post MoM hip joint replacement, with ipsilateral hip or buttock pain on weight bearing and/or clicks and clunks, should be investigated for the possibility of implant failure by their physician.

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