THE ORTHOPAEDIC FORUM

Risk Stratification Algorithm for Management of Patients with Metal-on-Metal Hip Arthroplasty

Consensus Statement of the American Association of Hip and Knee Surgeons, the American Academy of Orthopaedic Surgeons, and The Hip Society

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Metal-on-metal (MoM) bearings were reintroduced over the last two decades because of their lower volumetric wear rates in comparison to conventional metal-on-polyethylene bearings[1]. This has the potential to substantially reduce wear-induced osteolysis as the major cause of failure. Other proposed advantages of MoM hip arthroplasty include greater implant stability due to use of large-diameter femoral components, and bone conservation (for hip resurfacings). It has been estimated that since 1996 more than 1,000,000 MoM articular couples have been implanted worldwide[2]. However, with increasing clinical experience, the national joint registries have recently reported the failure rate of total hip arthroplasty (THA) with MoM bearings to be two to threefold higher than contemporary THA with non-metal-on-metal bearings[3,4]. Moreover, adverse periprosthetic tissue reactions involving the hip joint have emerged as an important reason for failure in MoM patients.

The information provided in this consensus paper is intended as an aid to the orthopaedic surgeon in the assessment and management of patients with MoM bearings. It is recognized that each patient may have specific circumstances or features that may require individualized approaches, and this document is not intended to be proscriptive in any fashion. In addition, it is recognized that there is insufficient high-quality evidence in this area to develop a formal guideline for optimal management of patients with MoM THA based on a systematic review of the literature. Thus, a document based on a consensus of experienced practitioners is in order given the state of the published literature.

Adverse Local Tissue Reaction Risk Stratification Algorithm for Evaluating Patients with Metal-on-Metal Hip Arthroplasty

A painful MoM hip arthroplasty has various intrinsic and extrinsic causes (Table I). As with all painful THAs[5], a thorough clinical history, a detailed physical examination, as well as radiographic and laboratory tests are essential to delineate potential

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TABLE I Differential Diagnosis for the Painful MoM Hip Arthroplasty

Extrinsic to the hip
Spine disease: stenosis; disc herniation; spondylolysis or spondylolisthesis
Peripheral vascular disease
Hernia (femoral, inguinal)
Peripheral nerve injury (e.g., sciatic, femoral, meralgia paresthetica)
Malignancy or metastases
Metabolic bone disease (e.g., Paget's disease, osteomalacia)
Complex regional pain syndrome
Psychological disorder
Intrinsic to the hip
Intracapsular/implant-related:
Infection
Loosening
Instability/subluxation
Periprosthetic fracture
Adverse soft-tissue reaction
Extracapsular:
Trochanteric bursitis
Iliopsoas tendonitis
Rectus femoris tendonitis

cause(s) of pain in patients with MoM hip arthroplasty[6]. A systematic risk stratification recommendation for multiple modes of failure, including adverse local tissue reactions, based on the currently available evidence, is presented here to optimize management (Tables II, III, and IV). The algorithm presented in this review will continue to develop as further evidence becomes available. For patients who have a stemmed total hip or surface replacement device that has been recalled by the manufacturer, this risk stratification scheme still applies. In addition, the surgeon should inform patients about the recall, and direct them to information from the manufacturer (on their website) regarding the recall and suggested follow-up.

Clinical Evaluation

A complete history is essential to evaluate patients with MoM hip arthroplasty. The temporal onset, duration, severity, location, and character of the pain help narrow the differential diagnosis. A history of delayed wound healing and pain after dental or gastrointestinal procedures all hint of possible periprosthetic joint infection. Other symptoms such as a feeling of swelling or fullness about the hip, and mechanical symptoms of crepitus, clicking, clunking, or squeaking should be elicited. A clinical history of metal allergy manifested as a dermal reaction to metal jewelry may also be helpful in assessing potential hypersensitivity reactions as positive lymphocyte transformation tests to nickel have been reported in MoM hip arthroplasty patients with a clinical history of metal allergy[7]. Furthermore, a thorough review of systems should be noted for any potential systemic symptoms as case reports of neurological and cardiac dysfunction have been reported in the literature[8].

Comprehensive neurovascular examination is necessary to rule out neurogenic and vascular causes of pain. Inspection of the skin should note previous scars and signs of infection. Careful palpation should be performed around the hip to detect any soft-tissue masses. Range of motion should be examined to determine the positions that may elicit the patient's pain, clunking, or catching as reproduction of pain on active hip flexion and passive hip extension may suggest iliopsoas tendinitis. Abduction strength must be assessed as loss of strength may suggest adverse muscle involvement.

TABLE II MoM 'Low' Risk Group

'Low' Risk Group Stratification	
Patient factors	Patient with low activity level
Symptoms	Asymptomatic (including no systemic or mechanical symptoms)
Clinical examination	No change in gait (i.e., no limp, no abductor weakness)
	No swelling
Implant type	Small-diameter femoral head (<36 mm) modular MoM THA; hip resurfacing in males <50 with osteoarthritis
Radiographs (2 views ± serial for comparison when available)	Optimal acetabular cup orientation (40° ± 10° inclination for hip resurfacing)
	No implant osteolysis/loosening
Infection work-up (ESR, CRP, ± hip aspiration)	Within normal limits
Metal ion level test (if available)	Low (<3 ppb)
Cross-sectional imaging (if available): these studies include MARS MRI; ultrasound or CT when MRI contraindicated or MARS protocol not available	Within normal limits
Treatment recommendation	Annual follow-up

TABLE III MoM 'Moderate' Risk Group

'Moderate' Risk Group Stratification	
Patient factors	Male or female
	Dysplasia (for hip resurfacing)
	Patient with moderate activity level
Symptoms	Symptomatic
	Mild local hip symptoms (e.g., pain, mechanical symptoms)
	No systemic symptoms
Clinical examination	Change in gait (i.e., limp)
	No abductor weakness
	No swelling
Implant type	Large-diameter femoral head (≥36 mm) modular or nonmodular MoM THA
	Recalled MoM implant
	Hip resurfacing with risk factors (female with dysplasia)
	Modular neck device
Radiographs (2 views ± serial for comparison when available)	Optimal acetabular cup orientation
	No implant osteolysis/loosening
Infection work-up (ESR, CRP, ± hip aspiration)	Within normal limits
Metal ion level test	Moderately elevated (3-10 ppb)
Cross-sectional imaging (MARS MRI; ultrasound or CT when MRI contraindicated or MARS protocol not available)	Presence of abnormal tissue reactions *without* involvement of surrounding muscles and/or bone
	Simple cystic lesions or small cystic lesions without thickened wall
Treatment recommendation	Follow-up in 6 months
Revision surgery	Consider revision surgery if symptoms progress, imaging abnormality progresses, and/or there are *rising* metal ion levels over 6 months

Radiographic Evaluation

After a complete history and physical examination, evaluation of an MoM hip arthroplasty should follow with a critical review of serial plain radiographs, focusing on signs of implant-related complications such as loosening or osteolysis, particularly in retro-acetabular, ischial, and pubic regions. For hip resurfacing implants, the presence of a radiographic sign of impingement (an indentation typically located in the lateral or anterolateral aspects of the femoral neck) should be noted. As the acetabular components with high inclination angle have been shown to demonstrate elevated serum[9] and joint fluid levels of metal ions and increased wear secondary to edge loading[10], it is important to measure the acetabular component orientation in both planes, including abduction angle relative to the pelvic horizontal on anteroposterior view. A shoot-through lateral is also helpful in assessing acetabular component anteversion.

ESR/CRP and Hip Aspiration

In contrast to metal-on-polyethylene (MoPE) THA, where elevation of both erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) have specificity for infection as high as 0.93[11], interpretation of elevated ESR and CRP should be done with caution in MoM hip arthroplasty patients as elevated ESR/CRP have been reported in non-infected cases of adverse soft-tissue reactions[12]. Synovial fluid white cell count greater than 3000 WBC/mL combined with predominant polymorphonuclear cells (>80%) has been reported to have the highest accuracy and sensitivity for infection in MoPE THA[13]. However, these parameters may not be applicable in MoM hip arthroplasty as adverse soft-tissue reactions (proven to be culture negative) often have white cell counts greater than 3000 WBC/mL combined with >95% polymorphonuclear cells. Although manual cell count (instead of automated cell count) should be obtained as tissue debris in suspension may lead to falsely elevated automated cell counts, no absolute quantity of cells can be suggested at this time. However, the higher the number of cells and the predominance of monocytes would warrant further investigation.

Sensitivity and Specificity of Metal Ion Levels in Predicting MoM Failure

Metal ions are released from the bearing surfaces and from modular connections by virtue of mechanically assisted crevice corrosion (MACC)[14]. Metal ion levels are influenced by factors such as the implant type, implant materials and design, diameter of the bearings, and positioning of the implant. In 2010, the British Medicines and Healthcare products Regulatory Agency issued a safety alert pertaining to all types of MoM hip implants and recommended cross-sectional imaging studies in patients with either cobalt or chromium ion levels above 7

TABLE IV MoM 'High' Risk Group

'High' Risk Group Stratification	
Patient factors	Female with dysplasia (for hip resurfacing)
	Patient with high activity level
Symptoms	Symptomatic
	Severe local hip and/or mechanical symptoms
	Systemic symptoms
Clinical examination	Change in gait (i.e., limp)
	Abductor weakness
	Swelling
Implant type	Large-diameter femoral head (≥36 mm) modular or nonmodular MoM THA
	Recalled MoM implant
Radiographs (2 views ± serial for comparison when available)	Suboptimal acetabular cup orientation
	Implant osteolysis/loosening
Infection work-up (ESR, CRP, ± hip aspiration)	Within normal limits
Metal ion level test	High (>10 ppb)
Cross-sectional imaging (MARS MRI; ultrasound or CT when MRI contraindicated or MARS protocol not available)	Presence of abnormal tissue reactions *with* involvement of surrounding muscles and/or bone
	Solid lesions
	Cystic lesions with thickened wall
	Mixed solid and cystic lesions
Treatment recommendation	Consider revision surgery

parts per billion (ppb or μg/L) (http://www.mhra.gov.uk/home/groups/dtsbs/documents/medicaldevicealert/con079162.pdf).

More recently, the sensitivity and specificity of the 7 ppb cut-off level have been reported to be 52% and 89%, respectively[15], indicating that the 7 ppb has relative poor ability to identify MoM failures. The lowering of the cut-off level to 5 ppb increases the sensitivity to 63% and lowers specificity to 86%. In measuring trace metals cobalt and chromium with concentrations in the parts-per-billion range, the risk of contamination is a major technical challenge. Adherence to stringent protocols is required from specimen collection using trace-element verified equipment to sample introduction to the analysis at a specialized laboratory[16]. While metal ion levels are a useful diagnostic test for assessing MoM hip arthroplasty, its role is limited to being an important adjunct to systemic clinical assessment and other investigative tools. Therefore, metal ion levels alone should not be relied on as the sole parameter to determine clinical recommendation for revision surgery. Furthermore, the correlation between cobalt or chromium serum, blood, or synovial fluid levels and adverse local tissue reactions observed at the time of revision surgery is incompletely understood[17], with metal ion levels reported to be unreliable predictors of periarticular soft-tissue damage at the time of revision surgery[18]. In addition, the interpretation of metal ion levels is confounded in patients who have other Co- and Cr-containing metallic implants, particularly bilateral MoM total hip or surface replacements. In light of the current limitations of the metal ion levels in guiding surgical intervention, research efforts are currently underway to identify diagnostic tests, such as biomarkers in synovial fluid that would be helpful in detecting periprosthetic necrosis prior to the occurrence of significant adverse local tissue reactions.

Ultrasound and Magnetic Resonance Imaging

As ultrasound is not affected by metal artifacts[19], ultrasound is a useful tool to detect the presence of a soft-tissue mass adjacent to an MoM implant[20]. It can differentiate solid lesions from cystic lesions, and can also be used to guide biopsy and aspirations. Ultrasound has been used to screen a large number of asymptomatic MoM patients in order to establish prevalence of asymptomatic pseudotumors[21]. However, this imaging technique remains operator dependent and its utility may be limited in evaluating the deep structures.

Metal artifact reduction sequence magnetic resonance imaging (MARS MRI) has the capacity to produce high-resolution images of the periprosthetic tissues in patients with MoM hip arthroplasty. Image distortion due to susceptibility artifact generated by the ferromagnetic property of the cobalt-chromium implant is reduced with various modifications of pulse sequence[19]. Modified MRI has been demonstrated to be the most accurate test to detect the wear-induced synovial response predating the presence of osteolysis on radiographs or standard MRI[22]. MARS MRI is an important cross-sectional imaging modality in detection of adverse local soft-tissue reactions. MRI can delineate anatomical extension boundaries of periprosthetic fluid collections and solid masses, as well as detection of

any compression of juxtaposed neurovascular structures, which is of particular importance in preoperative planning. It also allows evaluation of the surrounding soft-tissue envelope such as the integrity of hip abductor and gluteal musculature[23]. Therefore, early application of MRI may be an important tool that allows early detection of adverse soft-tissue reactions. As wear-induced synovitis has been observed in both symptomatic and asymptomatic MoM patients, a prospective study is currently underway to monitor these patients longitudinally. Metal artifact reduction technique continues to be refined with the development of new imaging optimization protocols. Therefore, the utility of MARS MRI in evaluating patients with MoM hip arthroplasty is likely to have an increasing role in the clinical decision-making process.

Frequency of Follow-up

The frequency of follow-up examinations needs to be tailored to the individual patient based on the risk stratification category and intervening clinical course. Annual follow-up is recommended for patients with an MoM total hip or surface replacement arthroplasty. Patients in the moderate risk category and patients electing to forego surgery in the high-risk category should be followed at four to six month intervals. Follow-up evaluation should include a careful history and physical and plain radiography. In addition, the orthopaedic surgeon should consider repeat MARS MRI testing and metal ion analysis, depending on the individual patient's signs, symptoms, radiographs, and clinical course.

Implant Retrieval Analysis

For those patients who undergo revision surgery of their MoM bearing, it is recommended that the implant be evaluated at a center experienced in implant retrieval analysis of such devices. The mechanism of failure of the hip reconstruction can be ascertained by a gross and microscopic evaluation of the implant in concert with clinical, radiographic, and histopathologic findings. Delineating the mechanism(s) of failure will provide valuable information to surgeons, manufacturers, and implant designers.

Summary

There should be a low threshold to perform a systematic evaluation of patients with MoM hip arthroplasty as early recognition and diagnosis will facilitate the initiation of appropriate treatment prior to significant adverse biological reactions. A painful MoM hip arthroplasty has various intrinsic and extrinsic causes, and a systematic treatment approach based on the currently available data is presented to optimize management of MoM patients. The risk stratification algorithm presented will continue to develop as further evidence becomes available providing additional insights. While specialized tests such as metal ion analysis are useful modalities for assessing MoM hip arthroplasty, over-reliance on any single investigative tool in the clinical decision-making process should be avoided. Future research focusing on validation of the current diagnostic tools for detecting adverse local tissue reactions as well as optimization of MoM bearings and modular connections to further diminish wear and corrosion is warranted.

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