Over one-million patients worldwide have received metal-on-metal (MoM) hip replacements (hip resurfacing (HR) and total hip replacement (THR)).\(^1\) Good to excellent ten-year outcomes have been reported with certain HR devices by both designing and independent centres.\(^2-4\) However high short-term failure rates have been observed with other HR devices and stemmed MoM THR.\(^5-7\)

Adverse reaction to metal debris (ARMD) is the sequela of large amounts of metal debris released from MoM hip bearings due to wear and corrosion.\(^8\) The subsequent local tissue reactions seen in ARMD often result in the formation of destructive soft-tissue masses, termed pseudotumours, which may require revision surgery.\(^9\) Theoretically all MoM hips are at risk of failure due to ARMD. This risk appears to increase with time since implantation, with ARMD appearing more common in MoM THR compared to HR due to the additional metal wear debris that can be generated at the trunnion-head interface in THRs and other modular junctions.\(^5-7\)

In the light of MoM hips developing ARMD in recent years the Medical and Healthcare products Regulatory Agency (MHRA) have issued guidance with regard to the investigation and management of these reactions, and the market withdrawal of certain devices with unacceptably high failure rates.\(^10,11\) The high short-term morbidity reported in a previous study\(^12\) has led to the MHRA and orthopaedic experts recommending early revision surgery for ARMD.\(^11,13\) Of concern, in England, Wales and Northern Ireland the prevalence of ARMD revision surgery is increasing with ARMD accounting for 13.2% (\(n=1,330\)) of all revisions performed in 2012.\(^14\)

Since these recommendations for early revision were made, a number of studies have been published which report outcomes of patients following revision surgery for ARMD. The present article provides an update on outcomes following ARMD revision surgery and assesses prognostic factors of outcome.

**ARMD revision outcomes**

A recently performed systematic review\(^15\) of the literature identified six-studies\(^12,16-20\) reporting outcomes of 216 hips revised for ARMD. This demonstrated variable, but generally high, complication (4% to 68%) and re-revision rates (3% to 38%). The four main causes of morbidity amongst these studies were:

- **Dislocation** Large ARMD lesions can require extensive soft-tissue debridement. This can ultimately compromise hip stability and lead to dislocation following revision. Options at the time of ARMD revision include the use of large femoral head sizes (typically 36 mm) or dual-mobility cups.\(^17,19\)

- **ARMD recurrence** This may occur for two reasons. The first is that the ARMD lesion is not completely excised at the initial revision and/or metal debris is not completely removed. This may be due to surgical error or because part of a large ARMD lesion was intentionally left in situ given its proximity to important neurovascular structures. The second reason for ARMD recurrence is retention of a MoM junction. This can either be due to exchange to another MoM articulating surface,\(^16\) or the presence of a modular MoM junction such as the stem trunnion and femoral head (for example when exchanging to a metal-on-polyethylene bearing). Indeed all six studies reporting outcomes following ARMD revision surgery observed at least one case of ARMD recurrence during follow-up.\(^12,16-20\)

- **Aseptic component loosening** As ARMD can be associated with significant bone loss at the time of revision\(^12\) it is likely a number of cases of aseptic loosening are related to poor host bone available for implant fixation and failure of osteointegration. One study observed a high rate of aseptic acetabular loosening despite the lack of bone defects in MoM THRs revised for ARMD.\(^19\) This may represent a design issue with the specific acetabular components used for the revisions or a mechanism yet to be identified.

- **Deep infection** This may occur due to: (1) the need for repeated hip surgery or, (2) incomplete excision of the ARMD lesion with residual metal debris remaining in the soft-tissues. Although the biologic activity of such reactive tissue remains unknown, surgeons have highlighted serious concerns that leaving a necrotic tissue dead space may lead to subsequent deep infection.\(^19\) The high complication and re-revision rates following ARMD revision are of concern because:

  1. The outcomes reported are generally at short-term follow-up (mean follow-up time ranged from 21 to 61 months in the six published studies)\(^12,16-20\)
  2. Most MoM hips have been implanted in young and active patients given this is one of the selection criteria when considering this type of bearing articulation.\(^2-4\) A poor result from an early revision at a young age is likely to significantly affect a patients subsequent quality of life and activity levels.
3. The outcomes reported for ARMD are inferior to those previously observed following revision of MoM hips for other indications (such as fracture and aseptic loosening).\textsuperscript{12,21,23} In addition it is important to recognise that only one study has formally assessed outcomes following revision of stemmed THRs for ARMD (19 hips).\textsuperscript{10} Therefore future studies reporting outcomes of ARMD revision surgery should include stemmed MoM THR patients as well as aim to achieve medium-term follow-up.

**Prognostic factors of outcome following ARMD revision**

The poor outcomes initially reported following ARMD revision were thought to be related to the significant soft-tissue damage observed at revision.\textsuperscript{12} This led to recommendations promoting early revision surgery in ARMD patients.\textsuperscript{11,12} However, significant soft-tissue destruction may be due to a more aggressive lesion rather than advanced disease. This illustrates the importance of knowledge of the natural history of how ARMD lesions develop and evolve with time, for which there is presently little available evidence.\textsuperscript{24,25}  

Formal identification of factors associated with poor outcomes following ARMD revision would allow algorithms to be developed for the management of these patients. This would require detailed correlation of clinical and radiological findings with postoperative outcomes following ARMD revision. None of the six ARMD outcome studies\textsuperscript{12,16-20} have formally assessed such prognostic factors, presumably due to the small cohort sizes and therefore inadequate statistical power of such an analysis. Therefore future studies should be designed and powered sufficiently to answer these questions.

However there have been some findings of clinical importance from the present literature relating to prognostic factors of outcome following ARMD revision:

- **Inferior outcomes for ARMD**  
  An earlier study demonstrated significantly inferior clinical and functional outcomes in HRs revised for pseudotumour compared to HRs revised for other indications and matched patients undergoing primary non-MoM THR.\textsuperscript{12} These findings are important for surgeons to consider when consenting patients prior to ARMD revision to guide expectations of postoperative outcome.

- **Soft-tissue fluid collections and pseudotumours**  
  In a recent study of 32 MoM hips revised for ARMD, significantly inferior functional outcomes were demonstrated in patients with solid pseudotumours.\textsuperscript{18} These findings are in agreement with the previous study described above.\textsuperscript{12} In contrast a larger study which included 48 hips revised for ARMD observed a soft-tissue fluid collection did not significantly affect outcome following revision arthroplasty.\textsuperscript{17} Although this variation between studies may relate to the extent of soft-tissue destruction encountered, it is important to remember other factors may have contributed such as differences in implants used, surgical technique, and patient populations.

- **Experience improves ARMD revision outcomes**  
  A study analysing outcomes of 113 HRs revised by a single surgeon for a range of indications observed significantly reduced complication and re-revision rates in patients with soft-tissue fluid collections when they compared their early results (17 hips revised) to more recent results (32 hips revised).\textsuperscript{17} The authors considered this improvement was related to a combination of increasing surgical experience in managing patients with ARMD, the development of a clinical management algorithm, performing earlier revision surgery, the use of large ceramic heads, and better patient education.\textsuperscript{17} Indeed the poor outcomes reported in patients with ARMD lesions in an early study by Grammatopolous et al were based on the first 16 revisions performed at a time when little was known about this clinical entity.\textsuperscript{12} It would therefore seem sensible that patients with ARMD should undergo surgery at centres experienced in this type of revision arthroplasty.

- **Single component revision may be an option in ARMD**  
  A recent study reported promising outcomes following 90 single-component HR revisions for ARMD with low complication (4%) and re-revision (3%) rates at a mean of 61 months follow-up.\textsuperscript{20} The author promoted the use of this technique as an alternative to revision THR. However the evidence that already exists suggests this approach should not be adopted universally given registry\textsuperscript{26} and experienced HR surgeons\textsuperscript{17} have observed inferior outcomes with acetabular component only revisions. In addition, worse outcomes have been demonstrated in patients revised for ARMD when retaining a MoM hip bearing.\textsuperscript{18,27} Further work is therefore needed to identify if a subgroup of patients with ARMD may benefit from single component revisions.

**Conclusion**

Currently no clear recommendations exist regarding when to perform ARMD revision surgery, therefore it remains unclear as to whether and when hips should be revised. Limited good quality evidence exists regarding clinical outcomes following ARMD revision, though this suggests early morbidity is generally high. Limitations of the studies published thus far include small patient cohorts with short-term follow-up and lack of inclusion of MoM THR. In addition little is known about prognostic factors of outcomes following ARMD revision.

**Future work**

Future outcome studies must involve large patient cohorts undergoing ARMD revision which should include both MoM HRs and THRs with at least medium-term follow-up. This will identify factors associated with poor outcomes following ARMD revision.
Such information would allow the formulation of an evidence-based approach providing thresholds for revising patients with ARMD and assist decision making regarding the type of revision surgery required. This should subsequently improve outcomes for patients following ARMD revision but also reduce the number of potentially unnecessary revisions currently being performed and the risks associated with such procedures.

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