Hip resurfacing – what is its role in modern orthopaedics?

INTRODUCTION

A decade ago, the current generation of hip resurfacing arthroplasty (HRA) seemed destined to fail again, as the earlier generation had.[1] Some metal-on-metal (MoM) designs were associated with adverse reactions to metal debris and a high risk of revision surgery.[2] HRA has now returned to the headlines as high-profile athletes have undergone resurfacing with safe implants,[3] with some returning rapidly to the pinnacle of their sport,[4] including high-impact activities.[5] Yet, total hip replacement (THR) remains the mainstay of management for end-stage hip arthrosis, and outcomes are generally excellent: THR has a low rate of revision[6] and high patient satisfaction.[7] Is the current generation of HRA really a worthwhile alternative to THR? We evaluate the current evidence for performing HRA and review the guidelines for monitoring patients with MoM implants.

HISTORY AND CURRENT USAGE OF HIP RESURFACING

Hip resurfacing was introduced in several forms and materials in the early to middle parts of last century: Hey Groves' ivory femoral peg, Smith-Petersen's mould arthroplasty (initially of made of glass and later of Vitallium), and Wiles' bolt-on stainless steel femoral component were the first iterations. With the benefit of hindsight, these implants had obvious flaws, either in design, materials, inconsistent manufacturing, poor fixation, or a combination of these factors. Another round of devices, in UK, Europe, and the USA failed in the 1970s for the same reasons, including Charnley's polytetrafluoroethylene (Teflon) and Freeman's metal-on-polyethylene double cup implants. Two implants were introduced in the late 1990s which are still in clinical use: Derek McMinn introduced the Birmingham Hip Resurfacing (BHR, Smith & Nephew, Tennessee, USA) (Figure 1) – a modification of the McMinn hip (Midland Medical Technology, UK) – while Harlan Amstutz introduced the Conserve Plus (Wright Medical Technology, Tennessee, USA).

These devices couple a cementless monobloc acetabular component with a cemented stemmed femoral component. These were soon followed by a slew of lookalike MoM implants, including the widely used and ill-fated Articular Surface Replacement (ASR, DePuy (Johnson & Johnson), New Jersey, USA) whose registry ten-year revision rate is as high as 45%[8] (Figure 2).

The ASR was recalled in 2010 because of early failure secondary to poor design: compared to the BHR, the ASR acetabular component is more sub-hemispherical (e.g. for a 50 mm head, BHR arc is 162° vs ASR 151°), and there is a smaller radial clearance between the femoral and acetabular components (BHR > 100 µm vs. ASR < 75 µm). Therefore, the articular contact patch is closer to the rim of an ASR acetabular component,[9] leading to edge loading and runaway wear,[10] a complication that is not unique to HRA. This effect is exaggerated in smaller sizes – the wear scar reaches the rim even when put in at 45° of inclination. The USA Food and Drug Administration (FDA) and the UK Medicines and Healthcare products Regulatory Agency (MHRA) highlighted that any large MoM bearing resurfacing or total hip arthroplasty is at risk,[8,11] and particularly those implanted in steep inclination.[10] While this risk caused the withdrawal of most HRA implants, high-volume HRA surgeons using the BHR or Conserve Plus report 96 to 99% survivorship at ten years,[12–17] easily meeting the National Institute of Health and Care Excellence (NICE) revision threshold of 0.5% for each year.[18]

INDICATIONS

Surgeons who perform hip resurfacing typically reserve it for younger patients with good femoral head bone stock and high functional goals, such as sport or manual labour. By preserving the femoral neck, HRA is a more conservative surgery than THR. In the event of failure – most commonly due to metal-related pathology, but also secondary to loosening and femoral neck fracture – a femoral stem is inserted. On the

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Fig. 1. Smith & Nephew Birmingham Hip Resurfacing (BHR) device.

Fig. 2. DePuy Articular Surface Replacement (ASR) device.

acetabular side, surgeons may insert a bipolar head of the right external dimension, avoiding having to remove the well-fixed cup with stress shielding behind it.[19] Recent data suggests that primary THR is expected to last 25 years in 58% of patients,[6] though the introduction of highly-crosslinked polyethylene in the late 1990s[20] is likely to improve on this further. Revision THR is associated with significantly greater morbidity and inferior function.[21] NICE therefore considers HRA a suitable choice for patients who are likely to live longer than THR is likely to last,[18] as they are likely to require another operation. HRA is also indicated for hip arthrosis in the presence of pre-existing metalwork in the femoral medullary canal which precludes a metaphyseal stem (Figure 3).[22]

BIOMECHANICS AND FUNCTION

Hip arthroplasty in general seeks to restore hip joint function. With HRA, this can be intuitively achieved by maintaining the shape and structure of the femoral head and neck. Length and offset are thus more reliably restored, compared to THR,[23] with a more anatomical pattern of femoral loading.[24] Proximal femoral stress shielding is reduced with maintenance of bone mineral density.[23,25] By more closely restoring the femoral head size, HRA restores capsular biomechanics and jump-distance,[26] and in registries HRA is associated with a two- to four-times reduced risk of early dislocation when compared to THR.[8]

Gait analysis is considered one of the gold standard functional tests after arthroplasty. Patients with HRA have a gait which is almost indistinguishable from that of age-matched patients without hip disease.[27] Compared to patients with THR, HRA confers a more normal gait[28] and a higher top walking speed.[29,30] In those with a HRA in one limb and THR in the other, the HRA limb accepts more weight and pushes off with greater force than the other side.[31] In a randomized clinical trial, HRA reproduced a symmetric gait at higher speeds, while patients with THR loaded their healthy hip excessively, sparing the leg with the replaced hip.[32] Importantly, however, HRA does not confer an advantage over THR for standing balance[30,33,34] or gait symmetry at comfortable walking speeds.[30,35]

In the scientific literature, case series of patients after HRA are reported as returning to high impact activities,[36] including extreme triathlons[5], though the majority will take up low-impact sports.[37] For THR, there is a general consensus between British and American surgeons[38,39] – the majority allow intermediate-impact sports such as cycling, but few support return to high-impact sports such as jogging. There are few direct comparisons of return to sport between patients with HRA and THR. Meta-analysis of studies using the UCLA hip score[40] shows that patients who have undergone hip resurfacing are more likely to return to a high level of activity compared to THR,[23] though randomized studies which used Oxford Hip Scores or Harris Hip Scores have been unable to detect a difference[41] as both procedures score so highly due to well-established ceiling effects.

INDICATIONS FOR HIP RESURFACING AND RISK FACTORS FOR FAILURE

For all patients and including withdrawn implants, the ten-year cumulative revision rate of HRA is 8-11% which is inferior to THR (4-7%).[8,42] There is uncertainty around whether the difference in revision rates between THR and HRA are due to failure of the resurfacing implants or because: 1) it is likely that people who undergo HRA are more active, which reduces the longevity of their implants,[18] and 2) surgeons' threshold for converting a symptomatic HRA to THR may be lower than revising a primary THR to revision THR.

Adverse reactions to metal debris (ARMD) generated from the MoM HRA bearing surface include effusions, local soft tissue destruction and osteolysis with subsequent aseptic loosening, and non-infected and non-malignant soft tissue masses – which have been termed pseudotumours.[43] ARMD is the most common indication for converting HRA to THR, followed by aseptic loosening and femoral neck fracture.[42].

Analysis of registry data has identified certain HRA implants at high risk of failure: while the BHR, Conserve Plus and Adept (MatOrtho) implants have ten-year revision rates between 5-8%; the ASRs is 26-40%.[8,42] Patient-related, independent risk factors for revision are small femoral component size, developmental dysplasia of the hip (DDH), and decreased bone mineral density.[44] HRA is generally contraindicated in females because they are more likely to be smaller and have DDH, thus increasing the risk of edge-loading. This causes run away wear of the MoM bearing and is associated with ARMD.[45] Females are also more likely to develop osteoporosis, resulting in femoral neck fracture around the resurfacing implant.[46] Large bone defects, secondary to osteonecrosis or cysts, are considered relative contraindications.

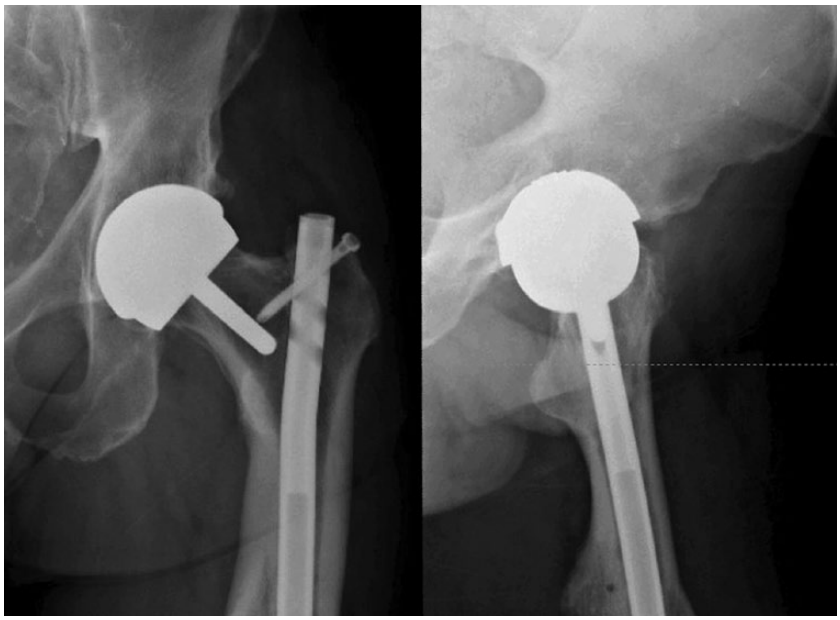

Fig. 3. Radiographs of patient with femoral intramedullary nailing performed for malunion of a fracture to. the femoral diaphysis, who has undergone hip resurfacing for hip arthrosis.

Improved patient selection dramatically reduces the risk of revision: registry data shows that males with osteoarthritis and large femoral heads (> 50mm) undergoing HRA have a ten-year revision rate of 5%.[42] When adjusted for age and sex, the risk of revision for femoral components with head size less than 44 mm was more than five-times greater than for femoral components larger than 55 mm. It is difficult to define the most appropriate age for HRA. Although the risk of revision is highest in those aged over 65 years, in the six months immediately after surgery (due to fracture), it is this group of older patients who have the lowest rate of revision after six months (most likely due to their lower activity levels).[42]

Surgical technical factors have also been shown to have an impact on outcome: notching or lengthening of the femoral neck, leaving exposed cancellous bone, and varus placement of the femoral component increase the likelihood of femoral neck fracture;[44] placement of the acetabular component in over 50°-55° inclination is associated with high levels of serum metal ions and resultant pseudotumours.[47] Therefore, HRA has a long learning curve – experienced hip surgeons may require over 100 cases before they reliably achieve accurate component position,[48] though this may be reduced with computer navigation.[49,50] In the Finnish arthroplasty registry, hospitals performing fewer than 100 resurfacings each year were associated with higher HRA failure rates.[51] In response, the French Department of Health only authorizes fellowship-trained surgeons performing over 50 HRA each year in specialist centres to perform resurfacing.[52] Since this change in 2013, the five-year revision rate in France is 1%.[53]

MONITORING METAL HIP RESURFACING FOR ADVERSE REACTIONS TO METAL DEBRIS

At least 14 MoM hip resurfacings designs have been recalled by their manufacturers since 2010 due to high rates of early failure. Flawed acetabular cup design resulted in too low a clearance between the femoral and acetabular components, which limited lubrication and increased wear. This clearance was worse in smaller cup sizes – typically used in female patients. The cups were also shallower than a hemisphere, so edge-loading could occur even when the cup was positioned at 45° inclination.[10] Any large MoM bearing is susceptible to ARMD, but these implant designs were at particularly high risk.

There has been concern that cobalt and chromium ions may also have systemic effects, but population-based studies have demonstrated that there is no increased risk of cardiotoxicity[54] or cancer.[55,56] On the contrary, studies using data from the UK Office of National Statistics[57] and the UK National Joint Registry[58] have shown that substantially more patients are alive ten years after hip resurfacing, when compared to age- sex- and health-matched patients undergoing cemented or uncemented THR. The mechanism explaining how HRA delivers survival benefit is multifactorial. Matched patients with HRA have a lower risk of periprosthetic infection and lower probability of developing cancer in their lifetime.[57] When compared to cemented THR, HRA patients have fewer thromboembolic events.[57,58] Improved survival may also be related to changes in lifestyle after arthroplasty[23] or a selection bias which prevailed, despite adjusting for known confounders.

There is a limited evidence base and no international consensus to guide surgeons in the surveillance of MoM HRA and the optimal timing for surgical intervention,[59] so current practice is determined by nationally-led expert opinion and on an individual case basis ideally discussed in a specialist centre's multidisciplinary team.[60]

In the UK, the MHRA recommends that all 'high risk' HRA patients – females, males with femoral implant diameter < 48mm, and all patients with the ASR device – are reviewed annually, and that they provide an Oxford Hip Score assessment, and cobalt and chromium blood levels.[61] Plain radiography can identify features associated with ARMD (acetabular component high inclination and anteversion below 5°, femoral neck osteolysis, lucencies at the implant-bone interfaces)[62] and risk of femoral neck fracture (varus femoral component position, lengthened femoral neck),[44] but is generally insensitive to detect periprosthetic masses. Metal Artefact Reduction Sequence (MARS) MRI or ultrasound is indicated in all symptomatic patients, as well as those with abnormal radiographs, deteriorating Oxford Hip Scores, or rising blood metal levels. Blood metal ions < 2 µg/L are considered normal in unilateral MoM HRA. However, there is no consensus on a single threshold for risk of ARMD.[63] Asymptomatic high-risk patients with normal imaging and metal blood levels below 2 µg/L should be monitored, while symptomatic patients with large, solid, invasive, or destructive pseudotumours require early revision. The MHRA recommends less frequent surveillance in low risk patients: males with femoral implant diameter >48mm, and especially those with BHR or Adept implants (Figure 4).[61]

REVISION OF HIP RESURFACING

There is significant heterogeneity in presentation of ARMD,[64] and surgery ranges from revision of the femoral component alone (to a stem with a dual-mobility bearing) or removal of both components and conversion to conventional primary THR.[19,65] Uncemented revision implants

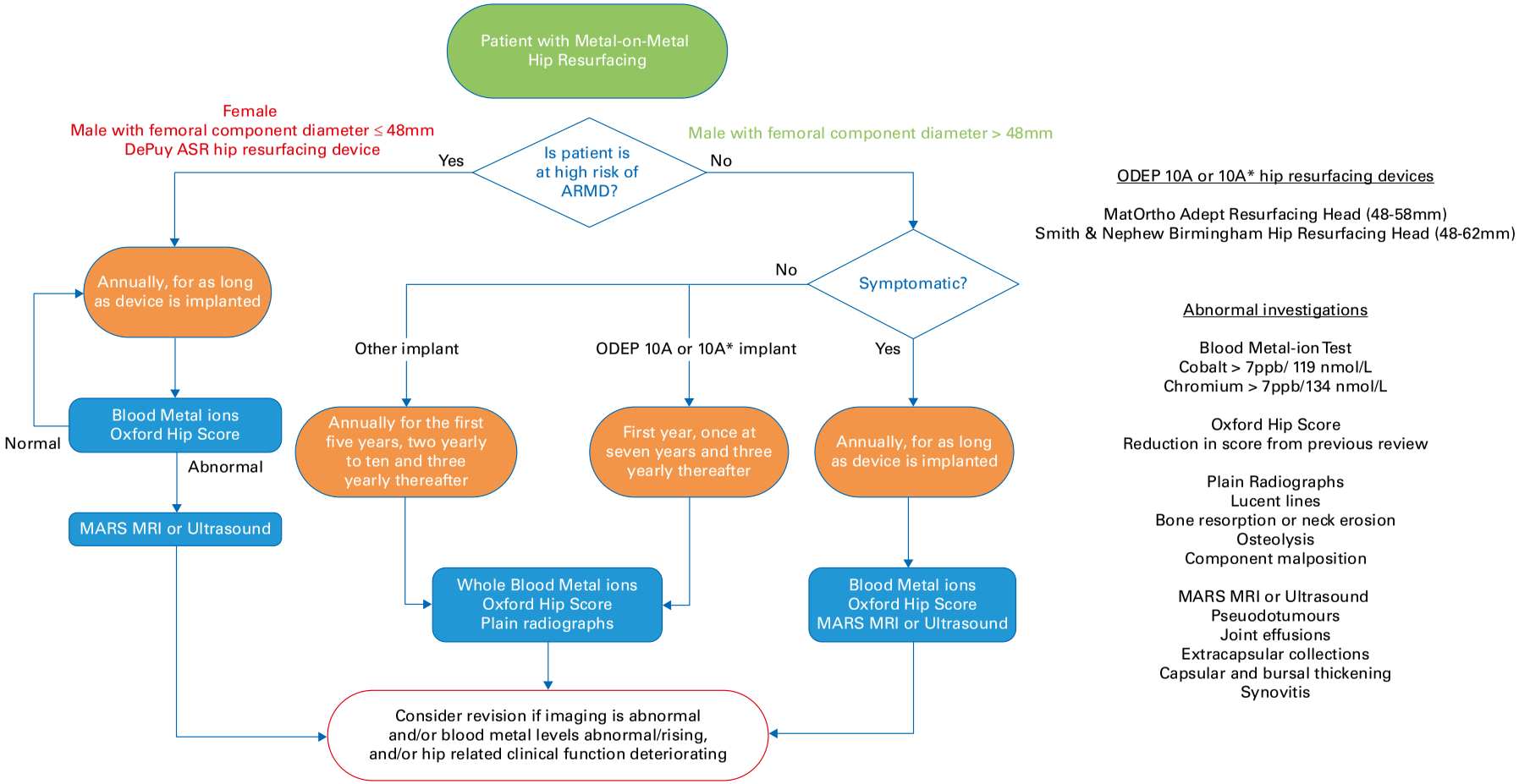

Fig. 4. Flowchart to appropriate investigate and manage patients who have undergone metal-on-metal hip resurfacing.

with augments, cages, and/or grafting may be required in the setting of acetabular bone loss[59] while dual-mobility heads or constrained acetabular liners may be useful when there is extensive soft tissue destruction.[66] Clinical function and re-revision rates after revision HRA for ARMD are no different to surgery indicated for other reasons such as fracture or infection.[67]

THE NEXT GENERATION OF HIP RESURFACING IMPLANTS

The risk of ARMD from MoM bearings has prompted the development of alternative materials for hip resurfacing. Previous efforts at metal-on-polyethylene HRA have failed due to volumetric wear,[68] but hip resurfacing using current generation highly cross-linked polyethylene (XLPE) with a cemented metal femoral implant has been recently shown to deliver excellent function and 3% revision at eight years' follow-up.[69] Three clinical trials of other novel hip resurfacing implants have commenced in the last two years: two ceramic-on-ceramic uncemented HRA[70,71] and a metal-on-polyethylene hybrid HRA.[72]

CONCLUSION

Hip resurfacing preserves much of the femoral head and neck and restores femoral head size. It has some advantages over hip replacement: enhanced stability, a more normal gait, greater possibility for participation in high demand activities, lower mortality, and easier femoral revision. Resurfacing is limited by technical difficulty. Femoral neck fracture and adverse reactions to metal debris are particular complications and more common in smaller patients. However, both implant and patient survival and function are superior when performed on suitable patients by experienced surgeons using safe implants. Recognising this risk and benefit profile – and the excellent performance and longevity of modern total hip replacement – resurfacing should be discussed as an option for younger and more active patients with end-stage hip arthrosis.

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 DOI: 10.1302/2048-0105.91.360742