

Femoral-head vascularity after hip surface arthroplasty

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Abstract

Background Iatrogenic devascularization of the femoral head is as an area of concern following hip resurfacing arthroplasty, with probable implications on short-term failure and long-term survival of the implant.

Materials and methods We assessed the vascularity of 25 resurfaced femoral heads in 20 patients by comparison with preoperative and postoperative Tc-99m methylene diphosphonate (MDP) bone scintigraphy images, the postoperative scans being done 9 months after the surgery.

Results Eight out of 25 hips (32%) showed <55% of their preoperative uptake at a mean of 9 months after surgery and were categorized as showing reduced vascularity.

Conclusion Our study reveals reduction in vascularity of the femoral-head remnant as a frequent occurrence after hip resurfacing. Our study also highlights the role of bone

scintigraphy as tool in assessing the vascularity of resurfaced femoral heads.

Keywords Femoral-head viability · Femoral-head vascularity · Hip resurfacing · Posterior approach · Tc-99m bone scintigraphy

Introduction

The current-generation hip hybrid surface arthroplasty with metal-on-metal bearings has produced promising short- and medium-term results [1–6] and has been growing in popularity over the last decade [6]. The advances in metallurgy and design implant design and in surgical technique are believed to be responsible for the renaissance of hip resurfacing. This bone-conserving procedure [7, 8] with additional advantages of easier revision [9, 10], preservation of proximal femoral bone density [11], reduced dislocation rates [2, 3], and more precise biomechanical reconstruction [12] holds promise as a viable alternative to total hip arthroplasty, especially in young, active individuals who are likely to outlive a primary hip arthroplasty. Being unique in concept and design, surface arthroplasty has its own set of unique complications. Fracture of the femoral neck [1, 6, 13–18], component loosening [1, 17, 18], osteonecrosis of the femoral head [17–22], metal ion hypersensitivity, and raised level of circulating metal ions [18, 23–25] are the most important complications of hip resurfacing. Osteonecrosis of the femoral head caused by the operative exposure and technique, with subsequent failure of the implant, has been a source of concern since the evolution of surface arthroplasty [17–22]. We assessed the vascularity of the resurfaced femoral heads by comparing preoperative and postoperative Tc-99m bone

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scintigraphy, with the acquisition of planar and single-photon-emission computed tomography (SPECT) images. This, to our knowledge, is the first study assessing semi-quantitatively the vascularity of the remnant head on Tc-99m bone scintigraphy images by comparison with pre-operative status, taking into account attenuation produced by the implant.

Materials and methods

We did a prospective, longitudinal, follow-up study of a consecutive cohort of 25 resurfaced hips in 20 patients (15 men and five women). Approval of the ethics committee and informed consent from all patients were obtained. The study was conducted in accordance with the principles contained in the Declaration of Helsinki. The primary diagnoses included avascular necrosis in 11 hips, ankylosing spondylitis in seven, rheumatoid arthritis in four, spondyloepiphyseal dysplasia in two, and seronegative inflammatory arthritis in one. Hips with avascular necrosis with cysts >1 cm in diameter detectable on radiographs were considered unsuitable for surface arthroplasty. The mean age of the cohort was 39 (range 19–72) years. All except one patient were younger than 55 years of age. All surgeries were performed by the senior author (RM). Surface arthroplasty was performed by the posterior approach with the release of the obturator internus and gemelli about 1 cm from their insertion, with the additional release of quadratus femoris, if required. Dissection in the region of the femoral neck was avoided to minimize damage to the retinacular vessels. The articular surface replacement (ASR) implant system (Depuy International Ltd, Leeds, UK) was used in all patients. After reaming the head, areas of sclerotic bone were drilled to improve cement penetration. Femoral-head cysts <1 cm in diameter were resected and filled with cancellous bone from the reaming residue. The prepared femoral head was carefully scrutinized to rule out lateral neck notching before implantation of the prosthesis. Before cement application, suction was applied through a vent on the femur at the level of the lesser trochanter. The trabecular bone of the head was cleaned by pulsed lavage to increase interdigitation of the cement. A small amount of high-viscosity hand-mixed cement (CMW, Depuy) was applied by finger packing to the reamed head, and all excess cement was removed from the most proximal surface of the prepared femoral head to ensure correct seating of the component. Patients were initiated on weight bearing from the second postoperative day.

In order to ensure meaningful comparison of preoperative and postoperative scintigraphy images, the attenuation of radiation produced by the ASR system was estimated by

an *in vitro* study. A hollow plastic tube was filled with a radionuclide at concentration of 5 $\mu\text{Ci/ml}$, and one end of the tube was covered by the ASR system. The whole of this assembly was immersed in the radionuclide at a lower concentration of 0.5 $\mu\text{Ci/ml}$ to simulate the background soft-tissue radiation. The assembly was scanned using a dual-head gamma camera with high-resolution collimator (Fig. 1), and planar and SPECT images were acquired. The images were analyzed using the eNTEGRA (GE, Haifa, Israel) nuclear medicine workstation. Gamma radiation counts per pixel were obtained (1) from the portion of the plastic tube covered by the implant and (2) from the portion of the region of the plastic tube not covered by the implant. The ratio of the above counts would represent the percentage of radiation that is allowed to pass through it by the implant. The study was repeated three times and the mean ratio obtained. We found that the ASR system allowed 35% [mean 35% (33.4–37.2%, $n = 3$)] of radiation to pass through it.

In the study participants, three-phase Tc-99m methylene diphosphonate (MDP) bone scintigraphy was performed

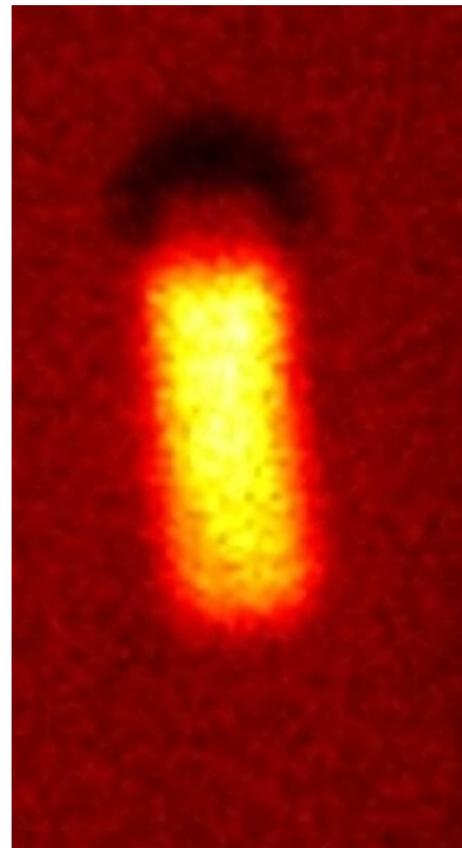


Fig. 1 A hollow plastic tube filled with radionuclide and covered at one end by the ASR system. The assembly scanned using a dual-head gamma camera shows the attenuation produced by the implant at the end covered by it. Counts revealed that only 35% of the radiation passed through the implant

preoperatively and postoperatively at 9 months after the surgery. Twenty mCi of Tc-99m-labeled MDP was injected intravenously and a standard three-phase bone scintigraphy carried out, with the acquisition of planar and SPECT images. The delayed images were obtained after an interval of 3 h following radionuclide injection. The femoral head was divided into four quadrants, and a region of interest (ROI) curve was drawn in each quadrant. The gamma radiation count per pixel in each quadrant was obtained. The measurements were done thrice in each quadrant and mean value computed. All measurements were made by the same author (CSB) in a blinded manner using the eNTEGRA system. Counts from the femoral-head remnants (covered by the ASR system) in the postoperative images were multiplied by 2.85 (which is equal to $1/0.35$) to correct for attenuation produced by the implant. The ratio of counts from the resurfaced femoral head (after correction for attenuation produced by the implant) to counts from the femoral head in the preoperative scintigraphy image was computed. Radioactive tracer uptake in the resurfaced head was expressed as a percentage of preoperative uptake. Microvascular perfusion being a chief determinant of radionuclide uptake [26], a decrease in postoperative

uptake compared with preoperative uptake would imply reduced vascularity of the remnant head. In addition to bone scintigraphy evaluation, the Harris Hip Score (HHS) was calculated preoperatively and postoperatively at 9 months by the same author (AK) to assess patients' clinical status. Postoperative anteroposterior and lateral radiographs were obtained routinely in all patients. The coronal plane orientation of the femoral component was noted, and those with valgus orientation of the femoral stem $>10^\circ$ with respect to the central axis of the femoral neck were deemed to have high valgus positioning.

Results

Eight of 25 hips showed $<55\%$ of the preoperative uptake, whereas 17 of 25 hips showed $>70\%$ of the preoperative uptake in bone scintigraphy studies done 9 months after the resurfacing procedure (Table 1). None of the hips showed between 55% and 70% of the preoperative uptake. In the absence of any previous data on what constitutes a critical reduction in vascularity, we categorized those showing $<55\%$ of the preoperative uptake as those exhibiting

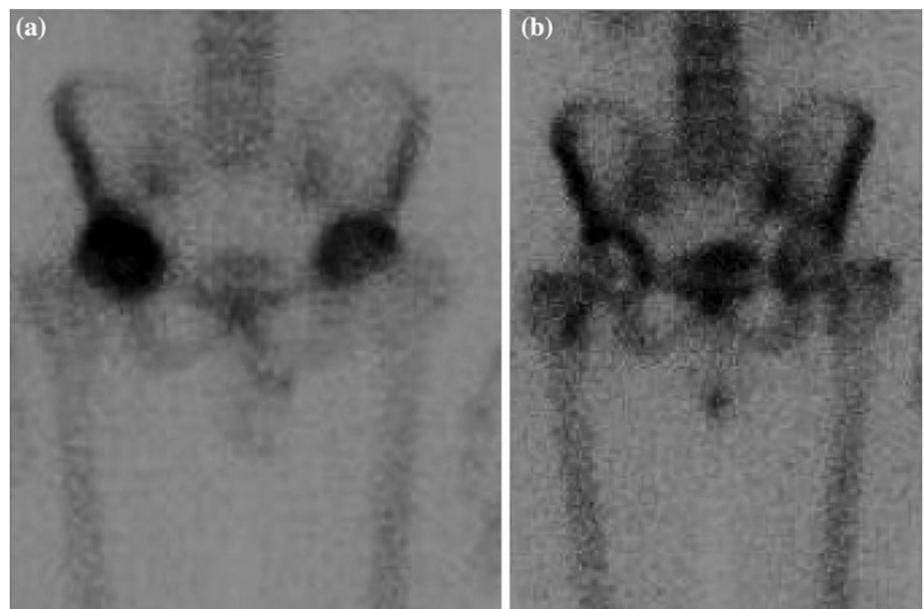
Table 1 Results

Patient no.	Diagnosis	Age	Postoperative count (% of preoperative count)	Vascularity
1	Ankylosing spondylitis	40	47.8	Reduced
2	Osteonecrosis	28	80.1	Preserved
3	Osteonecrosis	49	52.2	Reduced
4	Ankylosing spondylitis	40	76.6	Preserved
5	Osteonecrosis	40	99.5	Preserved
6	Osteonecrosis	41	46.5	Reduced
7	Osteonecrosis	41	29.3	Reduced
8	Spondyloepiphyseal dysplasia	35	35.1	Reduced
9	Spondylo-epiphyseal dysplasia	35	106.4	Preserved
10	Osteonecrosis	28	48.2	Reduced
11	Ankylosing spondylitis	36	31.1	Reduced
12	Rheumatoid arthritis	46	109.1	Preserved
13	Rheumatoid arthritis	46	80.1	Preserved
14	Osteonecrosis	19	102.3	Preserved
15	Ankylosing spondylitis	26	38.0	Reduced
16	Osteonecrosis	43	114.7	Preserved
17	Osteonecrosis	49	113.4	Preserved
18	Osteonecrosis	72	72.9	Preserved
19	Ankylosing spondylitis	38	116.0	Preserved
20	Ankylosing spondylitis	38	74.2	Preserved
21	Rheumatoid arthritis	46	84.5	Preserved
22	Osteonecrosis	52	104.0	Preserved
23	Ankylosing spondylitis	26	117.0	Preserved
24	Rheumatoid arthritis	42	90.6	Preserved
25	Seronegative inflammatory arthritis	36	94.4	Preserved

Fig. 2 Preoperative bone scintigraphy image and radiograph of a patient with ankylosing spondylitis (a); postoperative images 8 months after surgery (b). Surface arthroplasty was planned on the right side but could not be carried because the left hip could not be dislocated. The resurfaced head showed 38% of the preoperative uptake (after correction for attenuation) and was categorized as showing reduced vascularity



Fig. 3 Preoperative bone scintigraphy image of a patient who underwent resurfacing of both the hips (a); postoperative image at 6 months after surgery (b). The right femoral head showed 116% of the preoperative uptake, whereas the left showed 74% of the preoperative uptake (after correction for attenuation). Both resurfaced heads were categorized as showing preserved vascularity



reduced vascularity (Fig. 2) and those showing $>70\%$ as those with preserved vascularity (Fig. 3) on the basis of clustering seen in our study. Thus, eight of 25 hips (32%) were categorized as exhibiting reduced vascularity. Of these, four had osteonecrosis with secondary osteoarthritis, three inflammatory arthritis, and one spondyloepiphyseal dysplasia as the primary diagnosis. There were no cases of lateral neck notching or high valgus positioning. Mean postoperative HHS was 96 (range 85–100) in those showing reduced vascularity compared with 95 (range 85–100)

in those showing preserved vascularity. There were no complications – namely, femoral-neck fracture, component loosening, or pain of unknown cause.

Discussion

Osteonecrosis of the femoral head remnant is postulated as a causative mechanism in femoral-neck fracture and femoral component loosening, the two most common modes of

failure following hip resurfacing [17]. Evidence of osteonecrosis has been found in failed resurfacings by various authors [17–22]. Insult to the vascular supply of the remnant head might occur at various steps of the resurfacing procedure [27]. Using the posterior approach results in sacrifice of the deep branch of the medial circumflex femoral artery, the chief source of blood supply to the majority of the femoral head. The retinacular vessels may be damaged during head preparation with the reamers at their point of entry into the vascular foramina at the junction of the head and neck. The retinacular vessels can also be damaged because of lateral neck notching, excess valgus positioning of the femoral component, or during removal of osteophytes around the neck. Freeman postulated that most of the blood supply to the arthritic femoral head comes from intraosseous vessels rather than the subsynovial vessels at the surface of the femoral neck [28]. This change in the pattern of blood supply is believed to offer protection against osteonecrosis after hip resurfacing. However, when in the arthritic process the blood-flow pattern changes and to what extent it changes is not known. Intraoperative measurements of blood flow using laser Doppler flowmetry and of oxygen concentration using electrodes have convincingly demonstrated the adverse influence of the surgical approach and head preparation on the vascularity of the femoral head [29–31]. A reduction in oxygen concentration in the femoral head of up to 60% with the exposure and a further 20% reduction with head preparation were demonstrated by Steffen et al. [29] using electrodes inserted into the femoral head during hip resurfacing. Beaulé et al. [30] measured blood flow in the femoral head in 14 hips undergoing total hip replacement surgery, which had simulation of neck notching after a lateral approach. Ten of the 14 arthritic femoral heads demonstrated >50% decrease in femoral blood flow, highlighting the effect of notching on the blood supply to the femoral head. In a separate study, Beaulé et al. [31] assessed the impact of femoral-head preparation during hip resurfacing on blood flow to the femoral head. They used the trochanteric flip approach of Ganz to ensure that extraosseous supply was not compromised by surgical exposure and any reduction in blood flow to the femoral head (measured using laser Doppler flowmetry) could be attributed to damage caused by femoral-head preparation. Nine of ten hips with osteoarthritis showed a mean reduction in blood flow by 70%. Posterior approach has been shown to have a more detrimental effect on femoral-head vascularity than the anterolateral and trochanteric flip approaches [32, 33]. However, bone scintigraphy evaluation of patients who had undergone resurfacing by the posterior approach, performed at a mean 26 months postoperatively by McMahan et al. [34], revealed no evidence of reduced vascularity in the remnant head. Similarly, PET

evaluation of patients who had undergone resurfacing by a modified anterolateral approach, performed at a mean of 20 months postoperatively, revealed no evidence of reduced vascularity in the remnant head [35]. These studies probably indicate that the femoral heads had maintained their vascularity or had become completely revascularized by the natural healing process of creeping substitution by 20–26 months. Thus, a scintigraphy study done as late as 20 months after surgery, with the healing process in a devascularized head at an advanced stage, may not identify the resurfaced heads that sustained a vascular insult at the time of the surgery. We assessed the vascularity of the remnant head at an earlier time period of 9 months, with due consideration for the time required for the subsidence of postoperative changes. Bone scintigraphy studies in asymptomatic patients with cemented total hip replacement have revealed that raised postoperative activity around the shaft of the prosthesis, but for a small area near the tip of the prosthesis, subsided by 6 months from the surgery [36]. In the absence of studies assessing the duration for which postoperative changes persist on bone scintigraphy after hip resurfacing, data from studies on cemented total hip replacements were extrapolated. Demonstration of femoral-head remnant viability in this time period also assumes importance in view of the evidence of osteonecrosis found in cases with late fracture of the femoral neck at a mean duration of 12.4 months after surgery [17].

Our study revealed reduced vascularity as a frequent occurrence in resurfaced femoral heads. In the absence of lateral neck notching or excess valgus positioning in any of our patients, the use of the posterior approach and damage to the retinacular vessels during femoral-head preparation by reaming might have been the responsible for reduced vascularity noted in our patients. There were no clinically evident complications at the short follow-up available. However, evaluation of the influence of reduced vascularity on occurrence of complications and survival of the prosthesis need a longer follow-up.

Masking of the femoral-head remnant by the implant creates difficulty in assessing the status of the femoral-head remnant. Magnetic resonance imaging (MRI) and radionuclide bone scintigraphy have been widely used as imaging modalities in the diagnosis of osteonecrosis. However, in a patient who has undergone hip resurfacing, the presence of the implant creates artifacts despite the fact that the implant is MR-compatible and precludes the use of MRI to assess the vascularity of the remnant head. The use of laser Doppler flowmetry to measure the blood flow or insertion of electrodes in the remnant head to measure oxygen concentration are invasive procedures and not feasible in the postoperative period. In this context, radionuclide bone scintigraphy assumes importance as a method of evaluating the vascularity of the remnant head.

We, by means of our *in vitro* study, found that 35% of the gamma radiation passes through the ASR implant and is detectable on scintigraphy. In a study by McMahon et al. [34], the attenuation was measured by an *in vitro* study that found that 74% of the radiation passed through the implant. The implant used in their study was the BHR system. The differences in the design and metallurgy of the two implants are likely to have caused the different attenuations observed in the two studies.

Limitations

Small sample size and short follow-up limit the conclusions that can be drawn from our work. The other limitation was the absence of a control group (in the form of a cohort of patients operated through anterolateral or trochanteric flip approach) that might have shown the influence, if any, of posterior approach on the remnant head vascularity. Preponderance of bilateral hip disease rendered comparison with the contralateral hip inapplicable in a majority of the cases. The inclusion of patients of diverse etiologies, in whom the disease process might have an influence on tracer uptake, was another limitation. However, as each patient served as his or her own control, we believe that assessment of vascularity of the resurfaced heads relative to the preoperative status rendered the interpretations meaningful. The distribution of etiology in our cohort, with the absence of primary osteoarthritis as the primary etiology in any of them, is similar to the distribution noted in reports on total hip arthroplasty from our population [37–40] and is reflective of the relative rarity of primary hip osteoarthritis in our population. The issue of inclusion of patients with osteonecrosis with secondary osteoarthritis was carefully analyzed. Decreased uptake on bone scintigraphy is a feature seen only in the early stages of osteonecrosis, whereas those in advanced stages with secondary osteoarthritic changes are known to exhibit increased rather than decreased uptakes on bone scintigraphy [41]. Patients with osteonecrosis were in an advanced stage of the disease with secondary osteoarthritic changes at the time of surgery. None of them showed reduced uptakes in the preoperative images. Hence, in patients with osteonecrosis, decreased uptake on postoperative scintigraphy is attributable to the devascularization induced by the operative procedure rather than to the disease process. Therefore, inclusion of patients with osteonecrosis is unlikely to have caused the decreased uptake noted postoperatively in our study group.

We conclude that reduction in vascularity of the femoral head remnant is a frequent occurrence after surface arthroplasty of the hip and is therefore a matter of concern in those undergoing hip resurfacing. Longer follow-up of a larger patient cohort is required to draw a clinically useful

inference. Our study also highlights the role of bone scintigraphy in assessing vascularity of the femoral-head remnant. In conjunction with studies on blood flow and oxygen concentration in the femoral head during hip resurfacing, our study supports the need for continued emphasis on vascularity-sparing techniques during resurfacing until the implications of devascularization of the remnant head on implant survival and complication occurrence are firmly established.

Conflict of interest None.

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