The anterolateral approach leads to less disruption of the femoral head-neck blood supply than the posterior approach during hip resurfacing

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In 12 patients, we measured the oxygen concentration in the femoral head-neck junction during hip resurfacing through the anterolateral approach. This was compared with previous measurements made for the posterior approach. For the anterolateral approach, the oxygen concentration was found to be highly dependent upon the position of the leg, which was adjusted during surgery to provide exposure to the acetabulum and femoral head. Gross external rotation of the hip gave a significant decrease in oxygenation of the femoral head. Straigntening the limb led to recovery in oxygen concentration, indicating that the blood supply was maintained. The oxygen concentration at the end of the procedure was not significantly different from that at the start.

The anterolateral approach appears to produce less disruption to the blood flow in the femoral head-neck junction than the posterior approach for patients undergoing hip resurfacing. This may be reflected subsequently in a lower incidence of fracture of the femoral neck and avascular necrosis.

Despite excellent results overall for primary total hip replacement (THR), there is a markedly higher rate of failure in young patients in both the short- and the long-term. This observation has resulted in renewed interest in hip resurfacing, which conserves more femoral bone and offers more options for future surgery. The short- to mid-term results of hip resurfacing using modern metal-on-metal designs are encouraging. The main causes of early failure include fracture of the femoral neck, with a reported incidence of up to 2%, loosening of the implant and avascular necrosis (AVN).

The pathophysiology of fractures of the femoral neck after hip resurfacing is not well understood, and is probably multifactorial. Alignment of the implant and surgical error have been implicated. However, some other interesting observations have been reported. In a histopathological analysis of the retrieved bone from eight metal-on-metal resurfacings in which a fracture had occurred at the femoral neck, Little et al showed that there was a high incidence of established AVN in the femoral neck and head. Since AVN was not the original pre-operative diagnosis in these cases, it was concluded that disruption to the blood supply of the femoral head and neck had occurred during the procedure. For each of the reported cases, the extended posterior approach had been used.

Steffen et al studied the oxygenation of the femoral head in a series of ten hip resurfacings implanted through an extended posterior approach and found a substantial reduction in oxygenation in the femoral head. It was thought that this was the result of damage to the medial femoral circumflex artery during the division of the short external rotators. This artery provides the main blood supply to the femoral head as previously described by Trueta and Harrison. Since the reported incidence of fracture in different series has been variable, any reduction in blood supply must act in combination with other factors to cause a fracture. In addition, modifications to the posterior approach may affect the blood supply. For example, in the event of disruption of the medial circumflex femoral artery, there are many anastomoses around the proximal femur which could possibly be preserved by modifications to the posterior approach.

The anterolateral approach provides adequate exposure for hip resurfacing while leaving the short external rotators intact. It potentially preserves the blood supply to the femoral head if the medial circumflex femoral artery is not transected. Clearly, it is important to be aware of the location of the artery in order to prevent damage to it.

Our aim was to examine the intra-operative effect of using the anterolateral approach on...
oxygenation of the femoral head and to compare this with previous findings using the posterior approach. In order to check that the measurement system was functioning correctly, the oxygen concentration in the iliac crest was also measured.

Patients and Methods
We recruited 12 patients who were undergoing routine Birmingham metal-on-metal hip resurfacing (Smith & Nephew-Midland Medical Technology, Birmingham, United Kingdom) for primary osteoarthritis (OA) and obtained informed consent from each. The study had the approval of the local ethical committee. All the procedures were performed by two surgeons (DWM, KOR) using the anterolateral approach. There were six men and six women with a mean age of 58 years (39 to 73).

Principle of measurement. We assessed the blood flow on the basis of the concentrations of oxygen (O2) and nitrous oxide (N2O). The principle of measurement has been described in detail previously. Briefly, a silver (Ag) gas-sensitive measurement electrode is inserted into the bone and a silver-silver chloride (Ag-AgCl) reference electrode into surrounding muscle tissue. The measurement electrode, when polarised with a specific voltage, is used to measure a value of current, relative to the reference reading from the Ag-AgCl reference electrode. A single reference electrode can provide a reference reading for several measurement electrodes. The measured current is proportional to the concentration of the target gas present. Switching of the polarising voltages between the appropriate values for O2 and N2O allows the concentrations of these two gases to be measured by a single electrode. Each electrode is custom-made and individually calibrated against known gas concentrations, allowing the relationships between the measured current and gas concentration to be established.

Protocol of measurement. All patients received a 40% O2/air mix through a face mask (open circuit anaesthetic system) and spinal anaesthesia was used. Additional N2O was not given, except during two-minute intervals at the beginning and end of the operation, to ensure that the measurement electrodes were functioning correctly. This technique of anaesthesia was different from that used in the previous study on the posterior approach, in which all the patients were intubated under general anaesthesia.

After the spinal anaesthesia had been induced, the patient was positioned laterally and the pelvis stabilised by a padded support. A small incision was made over the iliac crest, the wound was explored and a channel into the iliac crest drilled using a 2.3 mm diameter Kirschner (K)-wire. A size 14 Ag gas-sensitive electrode was introduced. After placing of the electrode in the iliac crest, a standard anterolateral incision was made. Once the fascia lata had been divided, a similar K-wire was introduced into the femoral neck below the greater trochanter. It was advanced up the femoral neck under fluoroscopic guidance until its end lay superolaterally in the femoral head (Fig. 1), near the head-neck junction. The K-wire was then removed. The mouth of the resulting tunnel in the cortical bone was widened slightly using a drill and a size 14 Ag electrode was inserted into the femur. Correct placement of the electrode was confirmed fluoroscopically. An Ag-AgCl1 reference electrode was then placed within gluteus medius and all three sets of electrodes were connected to a potentiostat (potentiostat control box Model MEC V1; opto-electronic head stage Model MHS V1; power supply unit Model MPS V1; EMS, Newbury, United Kingdom) which generated the correct polarising voltages for the electrodes and the data collection system using signal wires 2 m long to reach beyond the sterile field. The data collection system consisted of an analogue-to-digital converter (PowerLab; AD Instruments Ltd, Chalgrove, United Kingdom) which sampled the output current from both electrodes at 10 Hz, connected to a personal computer.

Baseline measurements were established for O2 in the iliac crest and femoral head. The anaesthetist (not an author) then increased the N2O concentration in the anaesthetic gas from 0% to 40% for an interval of two minutes.

After cessation of this N2O pulse, the surgeon (DWM, KOR) continued the operation. The anterior third of gluteus medius was detached from the greater trochanter with an osteoperiosteal flap in continuity with the anterior part of vastus lateralis. Having mobilised the detached portion of gluteus medius anterosuperiorly, the attachment of gluteus minimus was exposed and elevated with the anterior capsule of the joint. Gluteus minimus and the capsule were

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Fig. 1
Fluoroscopic guidance of the insertion of the Kirschner-wire into the femoral head.
split superiorly to the acetabular margin. The capsule was then released from the acetabular margin anteriorly and posteriorly as far as could be visualised. The hip was dislocated by flexion and external rotation. The circumferential capsular division was completed under direct vision.

Hip resurfacing surgery was then performed in the standard manner, with the acetabular component implanted first. During the procedure, the leg was positioned in various configurations to facilitate exposure of both the acetabulum and the femoral head in the following sequence:

Position 1. Straight during incision, with both hip and knee in full extension;
Position 2. Hip flexed to 60° and externally rotated 135°, and knee slightly flexed (Fig. 2a) during acetabular preparation and implantation;
Position 3. Straight during insertion of the lateral femoral cortical pin for the alignment jig;
Position 4. Hip flexed to 90° and 180° externally rotated, and knee flexed (Fig. 2b) during femoral preparation and implantation;
Position 5. Straight during closure.

A second two-minute N₂O pulse was given by the anaesthetist (not an author) after the final reduction of the resurfaced joint and the electrodes were removed after reattachment of the gluteal muscles. In one case, conversion to general anaesthesia was required. Further validation measurements of the electrodes were made immediately after their removal. A recalibration with known gas concentrations was undertaken in the laboratory at a later stage.

Electrode calibration and validation. The calibration procedure for each electrode used four known concentrations of each gas, O₂ and N₂O. The electrodes were placed in the known solutions (gases dissolved in water), given the appropriate polarising voltage and the current generated recorded. For O₂, the concentrations used were 0%, 5%, 21%, 40% and 60% and for N₂O they were 0%, 25%, 40%, 60% and 79%. Linear regression was then used to obtain the individual calibration equations relating output current to gas concentration.

After use, the electrodes were placed in a saline solution containing 20% O₂ and the concentration value measured by the electrodes was recorded. This validation procedure established that the accuracy of the measurement of the gas concentration was within acceptable limits. If not, the measurements were excluded. Electrode damage was also noted.

Analysis. This was undertaken in an identical manner to the previous study of the posterior approach to facilitate a direct comparison.

The intra-operative current measurements in the femoral head were converted into O₂ and N₂O concentrations, on the basis of each individual electrode calibration. Baseline concentrations were considered to be those values measured immediately after insertion of the electrodes. The subsequent measurements of gas concentration were represented as a percentage of the baseline gas concentration. The surgical steps were grouped in the following manner, and were used as a standardised event-based timeline to facilitate comparison between patients:

1. START. Measurements were taken immediately after the placement of the electrodes;
2. APPROACH. This step included the muscle and soft-tissue divisions, dislocation and capsulotomy. The measurement was made at the end of circumferential capsulotomy;
3. INSERTION OF THE IMPLANT. This included the preparation of the femur and the acetabulum as well as the insertion and fixation of the components. The measurement was made after the insertion of the second component;

4. RELOCATION. In this step, the replaced joint was reduced and the capsule repaired. The measurement was made during closure of the fascia lata.

**Statistical analysis.** This was performed using the Wilcoxon signed-rank test for matched pair analysis and SPSS software version 14.0 (SPSS Inc., Chicago, Illinois). Statistical significance was set at a p-value < 0.05. Concentrations of O₂ at the following pairs of surgical time points were tested as matched pairs: START and APPROACH, APPROACH and IMPLANT INSERTION and finally, IMPLANT INSERTION and RELOCATION.

Two further analyses, which had not been previously performed with the posterior approach, were undertaken. First, the intra-operative measurements in the iliac crest were analysed in the same manner as for those of the femoral head. Secondly, a further subanalysis of intra-operative changes in oxygenation was performed to investigate the effects of the different leg positions used during surgery. The O₂ concentration values recorded at the end of each period spent with the leg in positions 1 to 5 were analysed in the following pair groups using the Wilcoxon signed-rank test for matched pair analysis: position 1 (straight) and position 2 (hip hyper-rotated), position 2 and position 3 (straight), position 3 and position 4 (hip hyper-rotated), and, finally, position 4 and position 5 (straight).

**Results**

There were no surgical complications related to the measurement of the blood-gas concentrations in the iliac crest or the femoral head. Successful collection of data was achieved in all patients with the electrodes registering both N₂O pulses given at the start and end of the procedure. The pattern of changes in gas concentration was variable across the series. An illustrative case is given as an example of the general response to the surgical procedure, before the summarised data for the entire cohort are presented (Fig. 3). The baseline O₂ concentration at the START in the femoral head was 13%. This decreased to approximately 5% at the time of dislocation and rose by the end of the APPROACH to around 20%. During acetabular preparation, for which period the leg was in position 2 (hip hyper-rotated), the O₂ concentration decreased to approximately 15%. While the leg was in position 3 (straight) and the femoral alignment pin inserted, there was an increase in the O₂ concentration of the femoral head to approximately 30%. While the femoral preparation was performed, with the leg in position 4 (hip hyper-rotated), it dropped to 5% and then recovered when the leg was straightened again. By the time of RELOCATION, the O₂ concentration was approximately 35%.

Generally, the same pattern was observed for the entire series, with some variation between individual patients (Fig. 4). The overall pattern was of some increase in oxygenation of the femoral head from the baseline level by the end of APPROACH, with the mean of the series increasing to 141% (31% to 228%) of the value at the start of the procedure (Fig. 5). This change was statistically significant (Wilcoxon signed-rank test, p < 0.03). In all but one case, there was a decrease in the relative oxygenation concentration during the preparation and component implantation phase (Fig. 4), the mean of the series dropping to 32% (-54% to 116%) relative O₂ concentration (Fig. 5). This reduction was highly significant compared with the values...
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In direct contrast to the observations made using the posterior approach, with the anterolateral approach all the patients except one showed recovery in oxygenation of the femoral head by the end of the procedure. In the exception, the patient had a suboptimally positioned femoral electrode which was close to the central axis of the femoral neck and may have been damaged at the time of the insertion of the femoral component. We suspect that the measurement after relocation of the hip was unreliable even although the N₂O pulse was detected after relocation implying that there must have been some blood supply to the femoral head. The tip of this electrode showed signs of damage on removal and it was not possible to perform validation for this particular electrode.

A limitation of the measurement technique is that the probe only sampled a relatively small volume of bone. It was difficult to be sure of the exact measurement volume. Also, O₂ concentration was used as a surrogate marker of the blood supply. If the blood supply is interrupted, there is a sudden reduction as O₂ is metabolised, but it cannot be assumed that there is a one-to-one relationship between the O₂ concentration and blood supply. However, for bone-cell viability measurement of the O₂ tension is probably more important than a precise measurement of the blood supply.

There were some surprising results. In all 12 patients, there was a significant increase in the mean oxygenation concentration in the femoral head during the surgical approach. This differed from the finding in the previous study on the posterior approach. 17 In part, this may be explained by differences in the technique of anaesthesia between the two studies. The posterior approach was performed under general anaesthesia and intubation while in the current study spinal anaesthesia and a face mask were used. All the patients who had been intubated had baseline oxygenation at the end of APPROACH (Wilcoxon signed-rank test, p < 0.005). All but one patient showed an increase in relative O₂ concentration by the time of RELOCATION (Fig. 4), the mean of the series rising to 122% (-4% to 300%) (Fig. 5). This was a significant increase from the end of the IMPLANT INSERTION, but not significantly different from the START (Wilcoxon signed-rank test, p < 0.02 and p = 0.46, respectively).

There was no significant change in the O₂ concentration recorded in the iliac crest during the entire procedure (Wilcoxon signed-rank test, p = 0.1) (Fig. 5).

Subanalysis showed that changes in leg position from straight to either of the rotated positions, position 2 or 4, resulted in a significant reduction in the relative O₂ concentration in the femoral head (Wilcoxon signed-rank tests, p < 0.02 for position 2 and p < 0.05 for position 4; Fig. 6). Conversely, straightening the leg from either of the two rotated positions led to a significant increase (Wilcoxon signed-rank test, p < 0.02) in the relative O₂ concentration in the femoral head (Fig. 6).

Discussion

The risk of fracture of the femoral neck after metal-on-metal hip resurfacing is recognised, and is similar to that of dislocation after THR. The aetiology of a fracture is likely to be multifactorial, but AVN of the femoral head has been implicated. 16 It has been suggested that bone resorption at the interface between viable and dead bone will weaken the prosthesis-bone construct and may lead to fracture. Avascular necrosis can also lead to late collapse of the femoral head. Previous work has shown that using the extended posterior approach for metal-on-metal hip resurfacing leads to significant interruption of the blood supply to the femoral head. 17
levels of 40%, corresponding to the anesthetic gas mix, whereas the baseline levels were considerably lower when the face mask was used. We found that the anterolateral approach resulted in a mean increase in oxygenation of the femoral head of 41%. This was of short duration and appeared to follow dislocation and positioning of the leg for acetabular preparation. A possible explanation for this observation is that the arterial supply through the deep branch of the medial femoral circumflex artery persisted while venous flow became occluded because of the position of the leg after dislocation. This could have produced an increase in the proportion of arterial blood in the femoral head until venous occlusion caused an increased pressure within the femoral head which then secondarily obstructed arterial flow. After this temporary increase in O₂ concentration, the oxygenation levels gradually reduced until the leg was straightened which restored blood flow. We also recorded variability in the initial oxygenation of the femoral bone. Some of the patients had a relatively low O₂ concentration recorded at the start of the procedure, suggesting that their bones were poorly perfused.

As previously shown by Notzli et al., our data demonstrated that positioning of the leg had a significant effect upon the oxygen concentration during the anterolateral approach. Blood flow was restricted by hyper-rotation of the hip, and restored once the leg was straightened. External rotation of the leg, which was considerably more than that possible with the joint intact, may have led to obstruction of the medial circumflex femoral artery. Since the oxygenation rapidly recovered, this suggested that the artery remained intact.

The measurements made in the iliac crest showed that there were no changes in the O₂ concentration in this location during the entire procedure. This was expected and demonstrated that the measurement system was functioning correctly.

Complications of hip resurfacing such as fracture of the femoral neck and AVN may be reduced by adopting surgical approaches intended to preserve the blood supply. The anterolateral approach disrupts the blood supply to the femoral head less than the posterior approach in patients undergoing hip resurfacing. The latter is advocated for resurfacing since the hip: experience of the McMinn prosthesis. Clin Orthop 1996;329(Suppl):11-34. 


