

The effect of surgical approach on blood flow to the femoral head during resurfacing

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We determined the effect of the surgical approach on perfusion of the femoral head during hip resurfacing arthroplasty by measuring the concentration of cefuroxime in bone samples from the femoral head. A total of 20 operations were performed through either a transgluteal or an extended posterolateral approach.

The concentration of cefuroxime in bone was significantly greater when using the transgluteal approach (mean 15.7 mg/kg; 95% confidence interval 12.3 to 19.1) compared with that using the posterolateral approach (mean 5.6 mg/kg; 95% confidence interval 3.5 to 7.8; $p < 0.001$). In one patient, who had the operation through a posterolateral approach, cefuroxime was undetectable.

Using cefuroxime as an indirect measure of blood flow, the posterolateral approach was found to be associated with a significant reduction in the blood supply to the femoral head during resurfacing arthroplasty compared with the transgluteal approach.

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In young active patients cemented total hip replacement may fail prematurely.¹⁻⁴ Hence, metal-on-metal hip resurfacing is increasingly being used with promising short- and medium-term results.⁵⁻⁹ Metal-on-metal resurfacing may fail because of fracture of the femoral neck^{10,11} or loosening of the femoral component, which may result from poor technique with notching of the femoral neck, varus alignment or inadequate seating of the femoral component.^{10,11} Analysis of retrieved femoral heads has suggested that early failure may also result from avascular necrosis of the head.¹²

Detailed descriptions of the vascular anatomy of the femoral head have indicated that the posterolateral approach destroys most of the normal blood supply,¹³⁻¹⁵ although the relative importance of the extra- and endosteal sources has been debated.¹⁶ In theory, the posterior capsular vessels which perfuse the femoral head should be protected in the transgluteal and modified transtrochanteric approaches.^{15,17}

There is a close correlation between the concentrations of cephalosporins in blood and in bone.¹⁸ Therefore we used cefuroxime, a second-generation cephalosporin, routinely for prophylaxis during hip surgery, as an indicator of the blood supply to the femoral head.

There has been no prospective study which has compared perfusion of the femoral head during hip resurfacing through different surgical approaches and no study has adequately

described the blood flow to the head with the hip reduced after dislocation. Our aim therefore was to compare the effect of a transgluteal with that of an extended posterolateral approach on the blood supply to the femoral head during hip resurfacing.

Patients and Methods

Between September 2005 and April 2006, 14 men and five women underwent 20 routine metal-on-metal resurfacing arthroplasties for primary osteoarthritis of the hip. One woman had staged bilateral procedures. All the patients gave informed consent and the study was approved by the Local Research Ethics Committee. Nine (six men and three women) had their operation performed through a transgluteal approach most closely resembling that described by Bauer et al.¹⁹ Their mean age and weight were 53.2 years (45 to 60) and 75 kg (45 to 105), respectively. The remaining eight men and two women with a mean age and weight of 46.8 years (18 to 62) and 83.1 kg (61 to 109), respectively had their procedure through the extended posterolateral approach.

The overall mean age for the men was 51 years (18 to 62) and the women 47 years (35 to 59). The groups were of similar age and weight and had similar grades of osteoarthritis according to the classification of Kellgren and Lawrence²⁰ (Table I).

Table 1. Clinical details of the 20 cases and the surgical approach used

Case	Age (yrs)	Gender	Weight (kg)	Grade of osteoarthritis according to Kellgren and Lawrence ²⁰
Transgluteal approach				
1*	45	F	60	4
2	60	M	95	4
3	60	M	80	4
4	48	M	75	4
5	59	F	51	4
6	53	M	85	4
7	53	F	45	4
8	55	M	105	4
9	46	M	79	4
10*	45	F	60	4
Posterolateral approach				
11	45	M	85	3
12	57	M	61	3
13	41	F	71	3
14	62	M	90	1
15	18	M	109	4
16	46	M	80	4
17	35	F	75	4
18	61	M	79	3
19	57	M	97	4
20	46	M	84	4

* cases 1 and 10 are the same patient

The patients operated on through the transgluteal approach received a Cormet 2000 (Corin Medical Ltd, Cirencester, United Kingdom) and those with a posterolateral approach a Birmingham resurfacing arthroplasty (Smith and Nephew - MMT, Birmingham, United Kingdom). These were performed by the senior surgeons (RFS, GCB, respectively). All patients had general and spinal anaesthesia.

Operative technique

Transgluteal approach. The patients were positioned in the lateral decubitus position and an incision made centred on the greater trochanter. Once the fascia lata and gluteus maximus had been divided, gluteus medius was split between the anterior and middle thirds with the incision extended into vastus lateralis. This exposed gluteus minimus which was elevated anteriorly exposing the anterior capsule. The capsule was divided, partially excised and the hip dislocated anteriorly by external rotation and adduction. The acetabulum was then cleared from within and a medial release of the femur carried out as necessary to give adequate exposure.

Extended posterolateral approach. The patients were placed in the lateral decubitus position and an incision made centred on the greater trochanter. The fascia lata was divided and gluteus maximus was split proximally. The tendon of gluteus maximus was divided at its insertion into the femur. The short external rotator muscles, including piriformis, obturator internus, externus and quadratus femoris were released from the femur, the capsule incised and turned back as a flap, and the hip dislocated posteriorly by internal rotation, flexion and adduction. A total circumferential capsulotomy was then performed. The psoas tendon was not divided routinely.

Measurement protocol

After adequate exposure, a sterile rubber glove was applied over the femoral head in order to prevent contamination with blood and the head was then reduced back into the acetabulum. After reduction, 1.5 g of cefuroxime was given intravenously in all but one patient, a woman who weighed 45 kg who, for reasons pertaining to body-weight, was given 750 mg instead. After five minutes the hip was redislocated, the glove removed and the femoral head prepared as routine for the operation. A guide-wire was passed using a centring jig. This was followed by a cannulated drill, a centring rod and then a crown drill head cutter. The fragments from this provided the first sample of bone. The 'napkin ring' was then applied, the top of the head resected and chamfered, which provided the second sample. The samples were then frozen. The microbiologist (AL) who was blinded to the approach used, assayed the bone samples to determine the concentration of cefuroxime. The mean time to prepare the femur and harvest the first and second samples was seven (5 to 9) and ten (7 to 12) minutes, respectively.

Assaying technique

Samples were assayed for cefuroxime by high-performance liquid chromatography²¹ which was performed on a Hypersil 50DS column (HPLC Technology Ltd, Macclesfield, United Kingdom) using a mobile phase of methanol:water:phosphoric acid (25:74:1) with detection by UV absorbance at 254 nm.

Bone samples, each of approximately 0.5 g, were crushed, a volume of phosphate-buffered saline equal to twice the weight of the bone added (1 g = 1 ml) and the cefuroxime extracted at 4°C for five hours. Any sample with visible evidence of gross contamination with blood was discarded

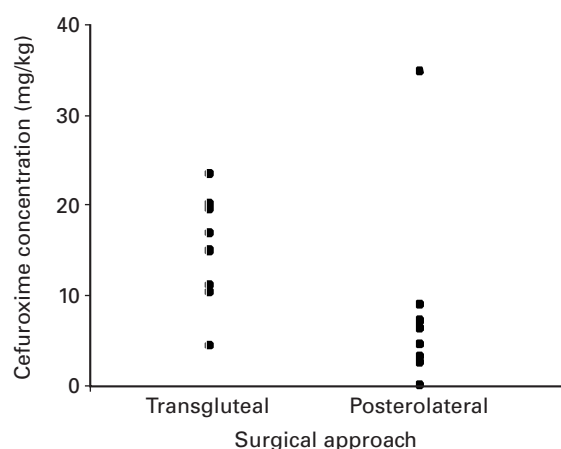


Fig. 1

The concentration of cefuroxime (mg/kg) observed for each procedure.

and all adherent tissues were removed before processing. After extraction the samples were centrifuged at 5000 g, an aliquot of the aqueous layer was treated with acetonitrile, centrifuged and a volume of 10 µl of the supernatant injected into the chromatograph.

Statistical analysis

Based on earlier data which gave a mean concentration of cefuroxime in bone at 10 to 30 minutes after intravenous administration of 36.0 mg/kg (SD 7.42),²¹ a study size of ten procedures in each arm gave 80% power, with an alpha of 0.05, to detect a difference in mean concentration between the two groups of 10 mg/kg when the highest mean concentration was 25 mg/kg. As suggested by Beaulé et al²² we chose a decrease of 50% or more in the mean concentration of cefuroxime between groups to signify a clinically relevant avascular event. We applied the paired *t*-test when comparing samples from the same patient and an unpaired *t*-test when comparing parametric data between groups. The Mann-Whitney U test was used for non-parametric data. Calculations were performed using SPSS software (SPSS UK Ltd, Woking, United Kingdom). A *p*-value < 0.05 was considered to be significant.

Results

No patient developed an infection after delayed intravenous administration of cefuroxime at operation. In all cases the set protocol was adhered to rigidly. There was no discrepancy in administration of the antibiotic or in the time to sampling between the two approaches. The mean time taken to harvest samples after injection of antibiotic was 13.5 minutes (12 to 17). There was a clear difference in the concentration of cefuroxime in the samples between the two groups (Fig. 1).

Transgluteal approach. The mean concentrations of cefuroxime found in samples from the top of the femoral head and the sides were 17.7 mg/kg (5.0 to 26.9; 95% confidence interval (CI) 13.2 to 22.1) and 13.5 mg/kg (4.0 to 28.0; 95% CI 8.9 to 18.1), respectively (*p* = 0.075, Table II). One

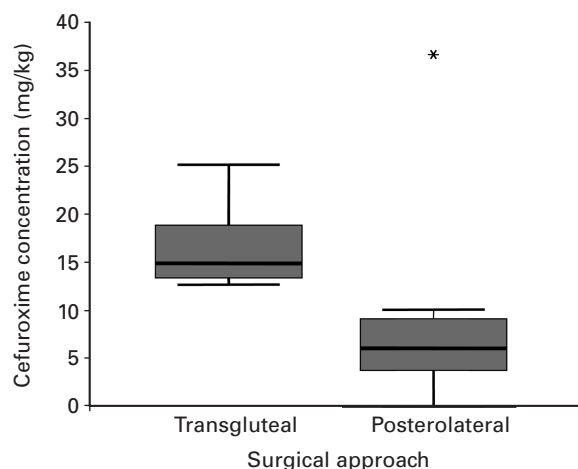


Fig. 2

The median concentration of cefuroxime (mg/kg) and interquartile ranges observed with the transgluteal and posterolateral approaches in bone samples taken at a mean of 13.5 minutes (12 to 17) after administration. All data were normalised to a dose of 20 mg/kg.

man, weighing 80 kg, had concentrations of cefuroxime of 5 mg/kg and 4 mg/kg for samples taken from the top and sides, respectively. Despite the reduced levels of antibiotic in his samples there was no evidence of pre-existing avascular necrosis of the femoral head at operation.

Extended posterolateral approach. The mean concentrations of cefuroxime in samples from the top and sides of the femoral head were 4.1 mg/kg (0 to 7.9; 95% CI 2.3 to 5.8) and 6.3 mg/kg (0 to 10.2; 95% CI 4.2 to 8.4), respectively (*p* = 0.007). In one man, weighing 90 kg, cefuroxime was undetectable.

The highest level of cefuroxime seen in the study was detected in a man weighing 79 kg (case 18) who had a posterolateral approach. Concentrations of cefuroxime were 38.0 mg/kg and 31.2 mg/kg for the top and side samples, respectively. There was no clear reason as to why this patient had concentrations so much higher than the rest of the group. Since this represented a skew in the data he was excluded from all primary analyses, but included in secondary assessments to establish whether his inclusion affected our overall findings.

Standardised comparisons. In order to eliminate the effect of body-weight on the concentration of cefuroxime all comparisons between the groups were standardised for dose and body-weight. The mean concentrations were normalised to a dose of cefuroxime of 20 mg/kg. The normalised mean concentrations of cefuroxime were 15.7 mg/kg (4.8 to 25.0; 95% CI 12.3 to 19.1) and 5.6 mg/kg (0.0 to 10.1; 95% CI 3.5 to 7.8) for the transgluteal and posterolateral approaches, respectively (*p* < 0.001). There was no overlap of the groups when their interquartile ranges were plotted (Fig. 2). Even when the normalised data from case 18 were included there was a significant difference between the groups (Mann-Whitney U test, *p* = 0.008).

Table II. The concentrations of cefuroxime (mg/kg) found in samples of bone collected from the top and side of the head of the femur, at a mean of 13.5 minutes (12 to 17) after administration, using the transgluteal and posterolateral approaches, along with mean concentrations normalised to a dose of cefuroxime of 20 mg/kg

Case	Top	Side	Normalised for dose and weight of patient
Transgluteal approach			
1*	22.3	11.7	13.6
2	25.7	13.9	25.0
3	5.0	4.0	4.8
4	22.0	8.2	15.1
5	26.9	12.1	13.3
6	9.3	13.1	12.7
7	11.9	17.9	17.9
8	15.8	4.9	14.5
9	19.0	21.3	21.3
10*	18.9	28.0	18.8
Mean (range; 95% CI)	17.7 (5.0 to 26.9; 13.2 to 22.1)	13.5 (4.0 to 28.0; 8.9 to 18.1)	15.7 (4.8 to 25.0; 12.3 to 19.1)
Posterolateral approach			
11	7.9	9.9	10.1
12	5.1	7.5	5.1
13	3.6	5.4	4.3
14	0.0	0.0	0.0
15	0.9	4.2	3.7
16	6.6	7.6	7.6
17	2.2	4.0	3.1
18	38.0†	31.2†	36.4†
19	6.5	7.6	9.1
20	3.9	10.2	7.1
SD	7.15	7.37	3.2
Mean (range; 95% CI)	4.1 (0 to 38.0; 2.3 to 5.8)	6.3 (0 to 31.2; 4.2 to 8.4)	5.6 (0 to 36.4; 3.5 to 7.8)

* cases 1 and 10 for the transgluteal approach are the same patient but different sides

† data excluded from mean, SD and 95% CI calculations

Discussion

Several methods have been used to assess blood flow in the femoral head including laser Doppler flowmetry and gas electrode-based systems.^{13,17,23} However, these methods are invasive, can be technically difficult to use and produce indirect measurements of vascularity.^{13,17} We used a simpler, non-invasive technique to measure blood flow, incorporating established technologies without major changes to routine surgical practice.^{18,21}

The posterolateral approach was associated with a significant reduction in blood flow to the femoral head. In one patient cefuroxime was undetectable. This can be explained by the anatomy of the blood supply to the femoral head. The vascular anatomy was described more than 50 years ago.²⁴ The main supply is from the deep branch of the medial femoral circumflex artery, the main division of which crosses posterior to the tendon of obturator externus and anterior to the tendons of the gemelli and obturator internus, before perforating the capsule just caudal to the tendon of piriformis. It then divides into two or four terminal branches which course sub-synovially along the posterosuperior surface of the femoral neck before penetrating the head 2 mm to 4 mm lateral to the articular surface.¹⁴

It is important to preserve the medial femoral circumflex artery during hip resurfacing.²⁵ Tenotomies of the short external rotators including quadratus femoris, as performed during

the extended posterolateral approach, and dissection of the capsule distal to piriformis are likely to damage the branches of the medial femoral circumflex artery and potentially render the femoral head avascular.^{14,15,26} This would explain the significantly-reduced levels of cefuroxime found in the samples taken through the posterolateral approach in our study. If the femoral heads failed to reperfuse, this would result in avascular necrosis and eventual failure. Bone death, with the ensuing reparative phase and creeping substitution, may result in debonding at the cement-bone interface and weakening of the femoral neck, increasing the risk of fracture,¹³ or eventually, by allowing micromovement and the subsequent formation of a fibrous membrane, lead to loosening of the femoral component.^{22,27} By contrast, despite the extensive anterior and superior capsulotomy associated with a transgluteal approach, perfusion of the head is preserved. The vessels on the anterior aspect of the hip are not critical to the circulation of the head.¹⁷

A number of authors have suggested that the adult femoral head also has a significant intra-osseous blood supply.^{16,23,24,28} It has been suggested that there is a shift in blood supply from retinacular vessels to endosteal vessels in an increasingly osteoarthritic hip.^{16,23,28} This may explain the good results of the resurfacing procedure in the short and medium term as well as the relative paucity of avascular necrosis in histological studies which have analysed retrieved femoral heads.²⁹⁻³¹ It could also explain why our patient with grade-3 osteoarthritis

had the highest levels of cefuroxime in bone despite having his operation through a posterolateral approach. However, this was not found in other patients from the same group with more severe grades of osteoarthritis. Evidence of reduced perfusion of the femoral head in arthritic hips after retinacular stripping and reaming, and notching of the femoral neck point to a more tenuous medullary supply.^{22,23} An alternate explanation is that in this patient the retinacular supply may have run an aberrant course or have further ramifications which were not jeopardised by the posterolateral approach. There is a considerable anastomosis between the medial femoral circumflex artery and a branch of the inferior gluteal artery along piriformis which may be capable of compensating after injury to the deep branch of the medial femoral circumflex artery.¹⁴ It is unlikely that the raised levels of cefuroxime were a result of contamination or a difference in operative technique since these remained constant throughout the study.

The difference in concentration between the top and side samples reached significance for the posterolateral approach only. Since most of the retinacular vessels are located in the posterolateral aspect of the neck^{14,17,22,25,32,33} and most vascular foramina are found at the posterosuperior aspect of the junction of the head and neck,^{14,33} samples taken from the side of the head would incorporate these vessels in contrast to those taken from a relatively avascular crest. A transgluteal approach, by sparing this retinacular blood supply, would result in time-dependent increased concentrations in samples, with the highest concentrations in the top of the head.

We consider that measuring concentrations of cefuroxime in reamings of the femoral head is an accurate method of determining perfusion. The reamings incorporated the anterolateral quadrant of the head which has been used before in studies of vascularity of the head.^{17,22} This region receives its blood supply almost exclusively from the deep branch of the medial femoral circumflex artery and is the area where necrosis most often develops.^{14,32}

Our results suggest that the extended posterolateral approach to the hip during resurfacing is associated with a significantly greater ischaemia of the femoral head than with the transgluteal approach. We describe a static reading of perfusion of the femoral head with the hip reduced in the acetabulum when the vessels are less likely to be twisted or kinked. In the light of reports of avascular necrosis in retrieved femoral heads^{10,12} and the reduced perfusion with the posterolateral approach,¹³ we believe that a transgluteal approach is less detrimental to the viability of the femoral head. Evaluation of whether this translates into a reduced incidence of femoral loosening or fracture of the neck requires further studies.

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