Notching of the femoral neck during resurfacing arthroplasty of the hip
A VASCULAR STUDY

P. E. Beaulé, P. A. Campbell, R. Hoke, F. Dorey

From Joint Replacement Institute at Orthopaedic Hospital, Los Angeles, California, USA

During hip resurfacing arthroplasty, excessive valgus positioning or surgical technique can result in notching of the femoral neck. Although mechanical weakening and subsequent fracture of the femoral neck are well described, the potential damage to the retinacular vessels leading to an ischaemic event is relatively unknown. Using laser Doppler flowmetry, we measured the blood flow in 14 osteoarthritic femoral heads during routine total hip replacement surgery, before and after notching of the femoral neck. In ten hips there was a reduction in blood flow of more than 50% from the baseline value after simulated notching of the femoral neck. Our results suggest that femoral head vascularity in the osteoarthritic state is similar to the non-arthritic state, where damage to the extraosseous vessels can predispose to avascular necrosis. Surgeons who perform resurfacing arthroplasty of the hip should pay careful attention to these vessels by avoiding excessive dissection around the femoral neck and/or notching.

Recent reports on the short-term outcome of metal-on-metal resurfacing arthroplasty of the hip have shown that surgical technique and patient selection can minimise short-term failures.1-3 One aspect of the operative technique is the orientation of the femoral component when preparing the femoral head, where excessive valgus positioning4 or poor technique5 can result in notching of the femoral neck. Although mechanical weakening and subsequent fracture of the femoral neck are well described,4,6 notching might also damage the retinacular vessels and impair the blood supply to the femoral head.7

In adults, most of the blood supply to the head of the femur is derived from retinacular vessels on the posterolateral surface of the femoral neck, which arise from the medial femoral circumflex artery.7,8 Consequently, when performing intra-articular procedures in non-arthritic hips, preservation of this extraosseous blood supply is critical in order to avoid osteonecrosis of the femoral head.9,10 However, in the arthritic femoral head, some have proposed that the blood supply relies predominantly on intraosseous sources,11,12 making the contribution of the retinacular vessels unclear.13 Nevertheless, osteonecrosis of the femoral head after hip resurfacing has been described as a cause of femoral loosening.14,15

The aim of our study was to examine the impact of notching of the femoral neck, with its potential implications on the integrity of the retinacular vessels, on the blood supply to the arthritic femoral head. We used laser Doppler flowmetry in patients undergoing a stem-type total hip replacement.

Patients and Methods
We included 12 patients (14 hips) with degenerative hip disease who were scheduled for a conventional total hip replacement. The patients consented to undergo blood flow measurements of their femoral head during surgery. The institutional review boards of the participating hospitals (Santa Monica/UCLA Medical Center and Orthopaedic Hospital) approved this study. Exclusion criteria were a diagnosis of inflammatory arthritis, avascular necrosis or previous hip surgery. There were eight men and four women with a mean age of 63 years (48 to 77).

Measurements of blood flow (flux) were performed with a DRT laser Doppler flowmeter (Moor Instruments, Axminster, UK) using a 20 mW laser, wavelength 780 nm wavelength fiberoptic probe. This probe measures blood flow within approximately 1 mm³ of the surrounding bone.16 During surgery, the probe is placed within the bone through a 3.5-mm drill hole. Once a strong, regular pulsatile signal is established, the flux signal (defined as the product of concentration and velocity of red blood cells within a defined vol-
The volume is recorded for approximately 20 seconds. The same operator (PAC) performed the measurements in all hips. **Operative technique.** The 14 total hip replacements were performed through a modified lateral approach, leaving both the tendon of obturator externus and the underlying branch of the medial femoral circumflex artery intact.\textsuperscript{8,17} For this approach, the patient is placed in the lateral decubitus position and the incision is centred over the greater trochanter, curving anteriorly and proximal to it. The iliotibial band and fascia of gluteus maximus are divided in the interval between the muscle bellies of tensor fascia lata and gluteus maximus. The next interval is between the anterior third and posterior two-thirds of gluteus medius. Finally, the anterior third of gluteus minimus and the capsule of the hip are elevated anteriorly in one layer. This exposes the anterior and lateral aspects of the femoral neck, as well as the extra-articular portion of the femoral head.

With part of the extra-articular femoral head exposed and with the leg in a neutral position, a 3.5-mm drill hole was made through the neck into the anterolateral quadrant of the femoral head and a measurement was taken to document its viability. The anterolateral region was chosen as this site had been used in earlier studies of femoral head vascularity.\textsuperscript{18,19} The hip was then dislocated anteriorly and two additional 3.5-mm drill holes were made on the articular surface of the femoral head, penetrating approximately 1 to 2 cm, one anterolateral and one centromedial. These areas represent bone which will subsequently be loaded and used for fixation of the femoral component in hip resurfacing.\textsuperscript{20}

Measurements were taken at these two sites before and immediately after simulated notching of the femoral neck, with the hip dislocated and held in neutral rotation for both readings. Notching of the lateral femoral neck was performed using a three-quarter inch osteotome directed at the retinacular vessels, with flowmeter measurements being taken immediately after the simulated notch was made.

Recent anatomical studies have confirmed that the majority of the retinacular vessels are located in the posterolateral aspect of the femoral neck.\textsuperscript{8,21} The position of the probe was verified on radiographs of the removed femoral heads (Fig. 1). One probe was used moving between the two holes.

**Statistical analysis.** Measurements were recorded in real time, and later analysed with DRT statistical software (Moorsoft for Windows, version 1.2; Moor Instruments) so that the mean flux levels for the various sites were recorded and tabulated. Changes of flux were compared before and after dislocation and before and after simulated notching, using the percentage change for analysis. The results were then statistically analysed using a non-parameter paired sign rank test. A power analysis was performed assuming a paired $t$-test for comparing the change in values at the 5% significance level. Assuming effect sizes of 0.72 to 0.9, between 12 and 18 hips were required to obtain 80% power. Because the precise decrease in blood flow which is necessary to cause a significant avascular event is unknown, we chose a change of $\geq 50\%$ between pre- and post-notch values as clinically relevant.

**Results**

The mean baseline blood flow to the femoral head before notching of the femoral neck was 60.4 flux units (18 to 133.6; 95% confidence interval (CI) 40.3 to 80.5), and 82.4 flux units (15 to 194; 95% CI 55.2 to 112.6) for the anterolateral and centromedial sites, respectively (Table I). After simulated notching, the percentage change varied from less than 5% to nearly 90%, and mean blood flow values decreased to 21.4 flux units (8.5 to 71.2; 95% CI 11.9 to 30.8) and 39.6 flux units (9.2 to 134.5; 95% CI 17.3 to 60.7) for the anterolateral and centromedial sites, respectively. Figure 2 shows a typical pulsatile baseline flux measurement with a marked decrease in signal height after notching. For the anterolateral and centromedial sites the mean percentage change was 54.9% (SD 30.2; 95% CI 42 to 77), and 47.8% (SD 25.1; 95% CI 33 to 62), respectively. This decrease was significant from the baseline ($p = 0.001$). The difference in reduction between the two sites was greater anterolaterally than centromedially although this was not significant ($p = 0.09$). Only four hips (28.6%) had a decrease of less than 50% in both hips. The blood flow...
measurement in the anterolateral region after surgical dissection, but before dislocation, was a mean of 108.5 flux units (24.4 to 229.9; SD 64.6).

**Discussion**

Notching of the femoral neck has been described as a cause of femoral neck fracture. However, the actual incidence of fracture after resurfacing arthroplasty of the hip is less than 2% and does not represent the main mechanism of failure on the femoral side which in our experience is loosening of the femoral component. Notching of the femoral neck during hip resurfacing is most likely to occur as the cylindrical reamer moves across the femoral head/neck junction, most commonly engaging the lateral aspect of the neck. Damage to the retinacular vessels in this area may sufficiently impair the blood supply to the femoral head so as to increase the risk of an avascular event and lead to subsequent femoral failure.

**Table I. Laser Doppler flow measurements before and after notching of the femoral neck**

<table>
<thead>
<tr>
<th>Case</th>
<th>Anterolateral site</th>
<th>Centromedial site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline flux</td>
<td>After notching</td>
</tr>
<tr>
<td>1</td>
<td>29.6</td>
<td>16.9</td>
</tr>
<tr>
<td>2</td>
<td>97.5</td>
<td>18.3</td>
</tr>
<tr>
<td>3</td>
<td>63.5</td>
<td>8.5</td>
</tr>
<tr>
<td>4</td>
<td>133.6</td>
<td>12.8</td>
</tr>
<tr>
<td>5</td>
<td>45.5</td>
<td>37.6</td>
</tr>
<tr>
<td>6</td>
<td>37.7</td>
<td>8.9</td>
</tr>
<tr>
<td>7</td>
<td>74.5</td>
<td>71.2</td>
</tr>
<tr>
<td>8</td>
<td>21.0</td>
<td>15.4</td>
</tr>
<tr>
<td>9</td>
<td>36.1</td>
<td>13.95</td>
</tr>
<tr>
<td>10</td>
<td>18.0</td>
<td>14.0</td>
</tr>
<tr>
<td>11</td>
<td>86.4</td>
<td>11.1</td>
</tr>
<tr>
<td>12</td>
<td>105.7</td>
<td>21.9</td>
</tr>
<tr>
<td>13</td>
<td>39.7</td>
<td>28.8</td>
</tr>
<tr>
<td>14</td>
<td>57.2</td>
<td>20.2</td>
</tr>
<tr>
<td>Mean (sd)</td>
<td>60.4 (34.8)</td>
<td>21.4 (16.4)</td>
</tr>
</tbody>
</table>
Our data provide evidence to support this mechanism as the majority of the arthritic femoral heads (ten of 14) demonstrated a significant decrease (≥ 50%) in blood flow after simulated notching. The incidence of avascular necrosis in the early experience of resurfacing of the hip was relatively low,14,15 the primary mechanism of failure being polyethylene wear-induced osteolysis and aseptic loosening.27,28 In addition, most retrieval analyses did not find a high incidence of avascular necrosis.29,30 However, one of the difficulties in analysing these failed femoral components is that, after the prosthesis has loosened, subsequent micromotion can lead to bone resorption and replacement by fibrous tissue,31 often leaving only a small remnant of the original bone. This, in addition to the osteolytic reaction to the polyethylene wear debris27,28 can make the identification of necrotic bone very difficult.30 Although the decrease in blood flow which is necessary to induce avascular necrosis is unknown, it is reasonable to assume that a change of > 50% could have a significant clinical impact, as recently reported by Little et al.24 In addition, de Waal Malefijt and Huiskes12 found that hips which had notching of the femoral neck during hip resurfacing had a higher rate of femoral loosening than those without notching, 28.6% vs 6.8%, respectively. There were no cases of femoral neck fracture reported in their series.

Compromising blood flow to the proximal femur as a result of surgical technique or operative exposure has been reported using laser Doppler flow measurements.33 El Maraghy et al33 reported a decrease of between 51% and 55% in trochanteric perfusion after detachment of quadratus femoris during total hip replacement surgery. Our measurements were similar after femoral neck notching with a mean percentage decrease of 55% and 48% in the anterolateral and centromedial aspects of the femoral head, respectively. Because of the smaller fixation area in resurfacing of the hip compared with a stem-type total hip replacement, an ischaemic event within the femoral head could be more significant. Osteolytic death, with the ensuing reparative phase and creeping substitution, could result in debonding at the bone-cement interface and allow micromotion with the subsequent formation of a fibrous membrane, leading to eventual loosening of the femoral component.15,28 It is important to note that not all cases of notching lead to a significant decrease in blood flow, which may in part be because of the location of the retinacular vessels at the femoral head/neck junction (Fig. 3). Harty13 described the entrance of the retinacular vessels as being mainly at the posterolateral head/neck junction which, depending on the orientation of any notching may leave some of the retinacular vessels intact. Also, as proposed by Freeman,11 in the arthritic hip some of the vascularity of the femoral head might be intraossseous, leaving the retinacular vessels to play a secondary role. In addition, with cement being the primary mode of fixation, a biological event such as avascular necrosis may be less problematic than if cementless fixation is used. Cementless femoral fixation with metal-on-polyethylene has a significantly higher rate of failure compared with cemented fixation.20

Our results show that, in this group of patients, the retinacular vessels provide a blood supply to the arthritic femoral head in the same way as they do in the non-arthritic state,18 contradicting the notion that arthritic femoral heads in humans rely mainly on an intraossseous blood supply.11,12,34 This may also have implications in terms of the choice of surgical approach for resurfacing of the hip.35 In our study, a modified lateral approach was used leaving the main branch of the medial femoral circumflex artery intact. However, with the posterior approach most commonly used for resurfacing of the hip, the tendon of obturator externus is divided and this branch of the medial femoral circumflex artery is sacrificed.36 Consequently, the main blood supply to the retinacular vessels8 is compromised, which could lead to an even more dramatic drop in
blood supply. Reports of avascular necrosis in failed, resurfaced femoral heads inserted through a posterior surgical approach lend support to the importance of preserving the blood supply to the femoral head.\(^5,24\)

With the introduction of a low-wear bearing surface, such as metal-on-metal, avascular necrosis and its subsequent reparative phase may become a more important mechanism of femoral failure. Careful attention should be paid to the blood vessels during preparation of the femoral head when performing resurfacing arthroplasty of the hip and notching of the femoral neck and/or extensive dissection should be avoided.

We would like to acknowledge Moor Instruments for supplying the equipment.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


