Perfusion of the femoral head during surgical dislocation of the hip

MONITORING BY LASER DOPPLER FLOWMETRY

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We used laser Doppler flowmetry (LDF) with a high energy (20 mW) laser to measure perfusion of the femoral head intraoperatively in 32 hips. The surgical procedure was joint debridement requiring dislocation or subluxation of the hip. The laser probe was placed within the anterosuperior quadrant of the femoral head. Blood flow was monitored in specific positions of the hip before and after dislocation or subluxation.

With the femoral head reduced, external rotation, both in extension and flexion, caused a reduction of blood flow. During subluxation or dislocation, it was impaired when the posterosuperior femoral neck was allowed to rest on the posterior acetabular rim. A pulsatile signal returned when the hip was reduced, or was taken out of extreme positions when dislocated. After the final reduction, the signal amplitudes were first slightly lower (12%) compared with the initial value but tended to be restored to the initial levels within 30 minutes.

Most of the changes in the signal can be explained by compromise of the extraosseous branches of the medial femoral circumflex artery and are reversible. Our study shows that LDF provides proof for the clinical observation that perfusion of the femoral head is maintained after dislocation if specific surgical precautions are followed.

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Patients and Methods

We performed LDF in 32 patients during and after surgical dislocation (21) or subluxation (11) of the femoral head.1

For the last seven years, we have performed elective surgical dislocation of the adult hip,1 respecting the deep branch of the medial femoral circumflex artery (MFCA) which is the dominant source of blood supply to the anterosuperior quadrant of the femoral head.2,3 This is the area where necrosis most often develops. It has been generally considered that operative dislocation of the hip threatens the blood supply of the femoral head.4 Perfusion was therefore carefully monitored during surgery by visual control of arterial bleeding from a small drill hole. For objective proof, laser Doppler flowmetry (LDF) was used to measure the circulation in the femoral head during the procedure.

LDF has been shown to be a reliable method for measuring intraosseous blood flow.5-7 Alterations in the dynamic signal amplitude, corresponding to changes in the intraosseous blood flow, can be monitored at a defined location during surgery.8 We used a high-power laser Doppler flowmeter to evaluate the influence of the position of the leg on the perfusion of the femoral head, and to confirm that the blood flow to the anterosuperior quadrant of the head can either be preserved during surgical dislocation of the hip, or re-established after relocation according to the technique described by Ganz et al.1

Patients and Methods

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The patient is positioned in the lateral position and a longitudinal or dorsally curved incision centred over the greater trochanter is used. The technique includes a trochanteric flip osteotomy1 and exposure of the hip capsule by release of the capsular attachments of gluteus minimus and vastus intermedius. The external rotator muscles are not disturbed and the intact obturator externus muscle and tendon protect the deep branch of the MFCA from being stretched during dislocation.5 Capsulotomy is performed using a Z-shaped incision. Subluxation of the femoral head is accomplished by flexion and external rotation. For dislocation of the hip, transection of the ligamentum teres is necessary. This approach gives a wide exposure of the acetabulum and femoral head for the debridement of labral tears and osteophytes.

There were 17 women and 15 men with a mean age of
34.2 years (22 to 55). Anaesthesia was regional (spinal or epidural) in 17 patients and general in 15. In those who had general anaesthesia this was held constant during the period of measurement to exclude any potential influence on the signal amplitudes.

In order to increase the volume of bone sampled, a new LDF laser source was designed specifically (Moor Instruments, Axminster, UK) and used in combination with a conventional laser Doppler flowmeter (DRT4; Moor Instruments). The source energy was 20 mW (emitting laser light with a wavelength of 780 nm), and the distance between the emitting and receiving fibres was 2.5 mm (one emitting, three collecting). The probe was inserted into the bone through a 3.5 mm drill hole in the anterior neck and advanced into the anterosuperior quadrant of the femoral head. The position of the probe was verified using an image intensifier (Fig. 1). The data were continuously recorded in real-time mode and stored for later analysis on a DRT4 Windows computer software program. Blood flow was measured in flux units which are arbitrary units relating to the mean red blood cell flow. These are defined by calibration against a standard reference of polystyrene microspheres, as provided by the manufacturer (Moor Instruments). The measured amplitude height is dependent on the specific position of the probe. The relative changes in amplitude will identify manoeuvres which alter perfusion.

In five patients the probe was inserted through the site of the trochanteric osteotomy before performing the anterior capsulotomy. Continuous LDF monitoring during capsulotomy showed no significant changes in signal height in these cases. Given this information and the fact that a probe in the trochanter subsequently impinges upon the iliotibial band, insertion through the anterior neck after capsulotomy was used in the other patients.

LDF measurements were made before dislocation of the hip in five positions; neutral rotation and maximal internal and external rotation with the hip either extended or flexed to 90°. The neutral position was in neutral rotation with the leg straight. The signal height was again recorded with the femoral head subluxed or, after transection of the ligamentum teres, dislocated. After reduction of the femoral head, LDF measurements were finally performed in the neutral position and compared with the signal amplitude before surgical dislocation or subluxation. Towards the end of the procedure, the segment of the retinaculum of the femoral neck containing the terminal branches of the deep branch of the MFCA was compressed by finger pressure in five arbitrarily chosen cases.

Statistical analysis. Signal heights were compared in each individual for each of the positions and before and after performing a therapeutic procedure. The measured values did not show a normal distribution and therefore the Wilcoxon rank-sum test was applied for statistical analysis.

Results

There were no surgical complications related to LDF monitoring.

After the probe had been positioned in the anterosuperior quadrant of the femoral head a pulsatile signal, synchronous with the heart rate, was obtained in all 32 patients. The mean blood flow with the leg in the neutral position was 69 flux but as is typical in LDF, varied widely, ranging from 8.8 to 164.9 flux. Significant changes in blood flow, observed as percentage changes in flux, were seen in extreme positions and in subluxation or dislocation (Tables I and II). With the hip reduced the largest decrease in signal height occurred with maximal external rotation of the extended hip. The signal height decreased by a mean of 52% when compared with the value recorded in the neutral position (p<0.0001) (Table I). In 17 hips (53%), the pulsatile pattern disappeared in maximal external rotation (Fig. 2). Statistically significant decreases in the signal amplitudes were observed in other positions: combined flexion and external rotation (-40%), internal rotation in extension (-32%) and combined flexion and internal rotation (-20%). In five hips (16%) loss of a pulsatile signal pattern occurred during maximal internal rotation in extension. Flexion to 90° without rotation did not significantly alter the signal height (Table I). Repetition of the manoeuvres showed high reproducibility of the measured values.

The ligamentum teres was preserved in the 11 subluxed hips and transected in the 21 dislocated hips. The signal heights decreased by a mean of 9% (p = 0.109) with subluxation and 17% (p = 0.073) with dislocation (Table II; Fig. 3), corresponding to the end position of dislocation in...
90° of flexion and 90° of external rotation (Table II). The decrease in signal height was statistically significant when the hips with subluxation and dislocation were analysed together (Table II). When the femoral neck was allowed to rest on the acetabular rim during dislocation, the pulsatile signal disappeared but was restored when it was lifted up slightly. Immediately after reduction, with the hip in the reference position, the mean signal height was 12% less than that initially recorded in the same position. This difference was not statistically significant (Table II). The signal continued to improve as flow was monitored during the subsequent 20 minutes.

The LDF signal disappeared immediately in five patients with digital compression of the retinaculum and promptly returned upon release (Fig. 4).

A similar loss of signal height and pulsatile pattern was observed with traction on the posterior capsule and with tight capsular closure. In five of the 21 patients in whom perfusion of the femoral head could be measured during capsular closure the signal decreased in extension and neutral rotation by a mean of 69% with loss of pulsatility. Release of tight capsular sutures led to prompt restoration of the signal amplitude. Loose approximation of the capsular flaps did not compromise the signal.
Discussion

The treatment of certain conditions such as fixation of fractures of the femoral head, reduction and casting in developmental dysplasia of the hip or reduction of a slipped capital femoral epiphysis is known to threaten the blood supply to the femoral head. A reliable method for monitoring bone blood flow during such procedures is therefore desirable and despite recognised limitations, LDF has been shown to be suitable. It has provided important information regarding the safety of surgical dislocation of the hip and added support to the belief that the terminal branches of the MFCA are a critical source of vascularisation in the adult femoral head.

The main disadvantage of LDF is that it cannot measure absolute blood flow and cannot be used to identify a critically low level for developing avascular necrosis. It will, however, identify significant changes of blood flow at a given position in the femoral head in any individual.

We introduced a higher energy laser system of 20 mW because the signal-to-noise ratio in human subjects is unsatisfactory with lower energy systems. Also the volume of bone sampled can be increased by using separate emitting and receiving fibres and increasing the distance between them at the tip of the probe. Contrary to current trends in LDF this requires a larger probe and drill hole, but for the assessment of blood flow in the human hip both modifications are beneficial.

For LDF no additional surgical exposure is needed in order to position the probe and to generate a signal which can be easily detected.

Because LDF does not measure oxygen tension or absolute blood flow, we could not ascertain that the bone was not ischaemic during dislocation. The fact that blood flow was always restored after relocation of the hip, explains the clinical observation that surgical dislocation does not lead to avascular necrosis. Furthermore, the observation that direct compression of Weitbrecht's retinaculum significantly reduced blood flow to the head demonstrates the contribution of the extraosseous vessels and the importance of protecting this circulation during the procedure.

The value of LDF monitoring is illustrated by the unexpected discovery that capsular suture can adversely affect the circulation in the head indicating the need to avoid tight capsular closure.

The main blood supply to the superior area of the femoral head is provided by the deep branch of the MFCA usually terminating in two to four superior retinacular vessels. Trueta and Harrison showed, however, that intraosseous vessels cross the physeal scar in adults and theoretically could reduce dependence on the retinacular vessels. Such an anastomosis could explain the relatively low incidence of segmental collapse after simple traumatic dislocation of the hip, but our LDF findings do not support such a general conclusion. It is more likely that traumatic dislocation usually does not tear the posterior vessels as long as the obturator externus muscle remains intact.

Experimental studies have shown that the blood supply of the femoral head after traumatic dislocation is interrupted by kinking or compression of the extracapsular vessels. This explains why the incidence of avascular necrosis (AVN) after such dislocation is, in most series, related to the length of time which the joint remains dislocated and the vessels could be stretched or compressed against the posterior acetabular rim. In our study, resting the posterior neck against the acetabular rim during dislocation diminished blood flow in the head although we did not extend the hip during that phase of the operation and thus did not fully recreate the position of a traumatic posterior dislocation. Distraction of the dislocated hip also consistently caused loss of signal. Dislocation itself clearly impaired blood flow, presumably because of traction on the retinacular vessels and not as a result of section of the ligamentum teres or other irreversible cause, since the decrease in the signal was promptly reversed on relocation. Vessels on the anterior aspect of the hip seem not to be critical to the circulation of the femoral head. These findings are endorsed by our LDF measurements of its vascularity. No change in the amplitude of the blood flow could be detected before and after an extended anterior and superior capsulotomy in the five patients investigated, despite the fact that this would disrupt the anterior intra- and extracapsular anastomoses and capsular branches of the lateral femoral circumflex artery.

Collectively, our data suggest that operative dislocation of the hip is safe and support the value of intraoperative demonstration of bleeding from drill holes into the head. Follow-up of 213 hips for two to seven years has shown no signs of AVN in any hip. This is consistent with other
reports of surgical dislocation of the hip\textsuperscript{24-28} and contradict the contention that surgical dislocation of the femoral head is hazardous and should not be recommended,\textsuperscript{2} especially in combination with a trochanteric osteotomy.

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References


