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Brief communication

Surgical hip dislocation through a modified direct lateral approach: real-time perfusion monitoring

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ABSTRACT

This study aimed to measure femoral head perfusion during hip resurfacing arthroplasty through a trochanter-sparing modified direct lateral approach. High-power laser Doppler probes were inserted into the femoral heads of 26 patients (26 hips, age range 35-70 years). Changes in blood flow were recorded (1) pre-capsulectomy (reference), (2) post-capsulectomy, and (3) following femoral head dislocation and reduction. There were no statistically significant changes in perfusion amplitudes post-capsulectomy and following femoral head dislocation and reduction (mean −10%, $P = .134$ and +27%, $P = .166$, respectively). Prolonged dislocation with the hip maximally flexed and externally rotated resulted in significantly decreased perfusion (mean −28%, $P = .002$). This study provides in vivo evidence that surgical hip dislocation is feasible using a modified direct lateral approach.

Introduction

The medial femoral circumflex artery (MFCA) provides the predominant blood supply to the femoral head [1]. Knowledge of the course of the MFCA was key to the development of surgical hip dislocation (SHD). Popularized by Ganz et al [2], this technique involves sagittal osteotomy of the greater trochanter, which is then flipped anteriorly along with its muscular attachments, thereby exposing the anterior capsule. Although several studies demonstrated zero incidence of hip avascular necrosis using the trochanteric flip osteotomy technique [2,3], morbidity related to the osteotomy, such as nonunion, malunion, and hardware complications, have been reported [2,4]. Another important limitation is that it is a relatively long learning curve, making this technique largely limited to specialized surgery centers and is generally not adequately taught in most orthopaedic residency programs.

We have previously described a trochanter-sparing technique for SHD through a modified direct lateral approach in a cadaver model (blinded). This technique is based on the anatomic understanding of the vascular danger zones of the MFCA during anterior hip exposure. In addition to avoiding the need for trochanteric osteotomy, the direct lateral approach is one of the most commonly used approaches by arthroplasty and trauma surgeons [5,6]. The purpose of this study is to objectively and continuously monitor the blood flow to the femoral head in vivo through our trochanter-sparing modified direct lateral approach for SHD.

Material and methods

Patient selection

Institutional review board approval was obtained. Based on previously published data by Notzli et al [1], we estimated that a sample size of 24 patients would provide 80% power to detect a 15% difference in paired mean flux between each procedural step of the surgical approach assuming 25% standard deviation and 0.05 significance level. Sixty-one consecutive patients undergoing Birmingham hip resurfacing (Smith and Nephew, Memphis, TN) by the senior author were screened for the study (Fig. 1). Patients with osteonecrosis, post-traumatic osteoarthritis, large femoral head cysts, and those status post prior open reduction internal fixation of

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the hip were excluded. In addition, 6 patients were excluded due to lack of availability of the Doppler probes at the time of their operations. A total of 30 male patients (30 hips) were enrolled after signing an informed consent. The laser Doppler measurements from the first 4 patients were used to familiarize the study team with the equipment and were therefore not analyzed. The remaining 26 patients were included in the analysis. Only males were included in the study following Smith and Nephew's decision to contraindicate Birmingham hip resurfacing for females prior to the initiation of the study.

Surgical approach

After induction of anesthesia, patients were placed in lateral decubitus position. A longitudinal incision centered over the greater trochanter was made and the underlying fascia lata was split in line with the skin incision. The anterior third of gluteus medius and minimus muscles were then divided in the direction of the muscle fibers just proximal to their insertion on the greater trochanter. Distal dissection was carried through the anterior third of the vastus lateralis leaving the gluteal and vastus musculature in longitudinal continuity. Exposure of the anterior capsule was aided by progressive external rotation of the leg and freeing the capsular attachment of the reflected head of rectus femoris. A pencil-tip incision with a #11 blade was made in the anterosuperior capsule for probe placement. The path of the probe was pre-drilled with a 3.5-mm drill bit and the probe was then inserted into the anterosuperior quadrant of the femoral head as previously published [1,7]. The capsule was then divided along the center of the femoral head starting from the acetabular rim and terminating at the head/neck junction. Next, anterior capsulectomy was performed taking care to stay proximal to the lesser trochanter (aggressive inferoposterior capsular dissection is avoided) to prevent violating the deep (main) branch of the MFCA. The hip was then dislocated anteriorly.

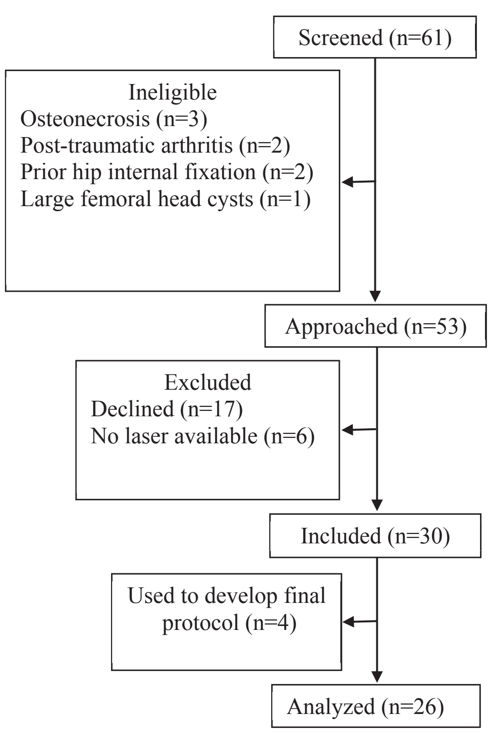

Figure 1. Flowchart showing the sample size available for analysis.

Doppler flowmetry measurements

Blood flow to the femoral head was measured using a high-power laser Doppler monitor (moorVMS-LDF1-HP; Moor Instruments, Wilmington, DE) connected to a 3.3-mm diameter blunt stainless steel probe (VP7BS-HP; Moor Instruments) inserted into the anterosuperior quadrant of the femoral head in accordance with previous reports. [1,7] The probe features separate transmitting and receiving fibers, enabling a larger volume to be monitored. The laser source energy was 20 mW (wavelength 785 ± 10 nm). Due to signal interference from soft tissue retractors, all deep retractors were removed to allow the signal to stabilize, which was then recorded for a minimum of 10 seconds. Measurements were made (1) pre-capsulectomy (baseline), (2) post-capsulectomy, (3) following femoral head dislocation and reduction, and (4) during the resurfacing arthroplasty. The data were calibrated against a standard reference provided by the manufacturer and analyzed using the moorVMS-PC V3.0 software (Moor Instruments). Confirmation of appropriate probe placement was made by observing a pulsatile signal that is synchronous with the patient's heart rate.

Statistical analysis

Results for continuous patient variables were summarized using medians and ranges. Categorical variables were described using counts and percentages. The mean flux and proportional changes in blood flow were calculated at each stage of the approach using each patient's baseline mean flux as a reference. Comparisons were made using the Wilcoxon's rank-sum test. All analyses were performed using R software (R version 3.5.0, Vienna, Austria) assuming a 5% level of significance.

Results

Twenty-six male patients undergoing hip resurfacing were analyzed. The median age was 56 years (range 35-70). Table 1 summarizes the baseline characteristics of the study group. No surgical complications related to the insertion of the probes were encountered. As is typical of laser Doppler measurements, the baseline signal amplitude varied widely between different patients (mean 130, range 6-421), but was synchronous with each patient's heart rate. The absolute change in signal amplitude after anterior capsulectomy was mean −45 flux (range −315 to +83) corresponding to a relative change of −10% (range −77% to +136%; P=.134). The absolute change in signal amplitude after femoral head dislocation and reduction was mean −45 flux (range −380 to +381) corresponding to a relative change of +27% (−93% to +626%; P = .166). Retractor placement around the posterior femoral neck resulted in reversible reduction in the perfusion signal (Fig. 2). However, prolonged dislocation with the hip maximally flexed and externally rotated (corresponding to maximal anterior hip dislocation) resulted in a mean signal decrease of −90 flux (−400 to +240)

Table 1
Baseline characteristics of the study group.

Characteristic	Value
Age (y)	56 (35-70)
Laterality	
Right	14 (47%)
Left	16 (53%)
Acetabular component size (mm)	56 (54-64)
Femoral component size (mm)	50 (48-58)
Baseline signal amplitude (flux)	92 (6-463)

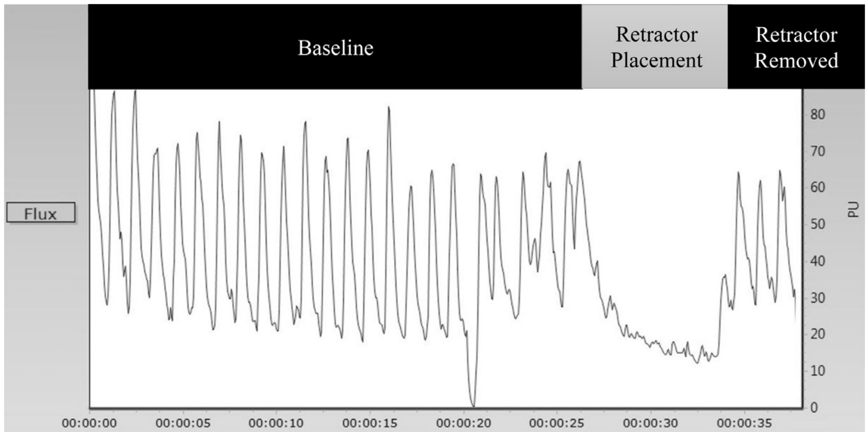

Figure 2. Effect of retractor placement around the posterior femoral neck demonstrating a reversible decrease in signal amplitude.

corresponding to a relative change of −28% (−98% to +560%; $P = .002$). Table 2 and Figure 3 summarize the changes in femoral perfusion at different stages of the surgical approach compared to baseline (pre-capsulectomy).

Discussion

The trochanteric flip osteotomy popularized by Ganz et al [2] is currently the most widely used technique for SHD. Limited training in orthopaedic residency programs combined with osteotomy-related complications [2,4], however, has renewed interest in alternative techniques for SHD without trochanteric osteotomy. We have previously demonstrated the feasibility of SHD using a trochanter-sparing modified direct lateral approach in a cadaver model [8]. In this study, we provided in vivo laser Doppler flowmetry evidence that the perfusion of the femoral head is maintained during this approach.

Our results are consistent with Notzli et al [1] who reported on perfusion of the femoral head during the trochanteric flip osteotomy approach. The group used laser Doppler flowmetry to monitor the femoral head blood flow in 32 patients undergoing joint debridement with either subluxation (11 patients) or dislocation (21 patients) of the hip. Similar to Notzli et al [1], no significant changes in the blood flow signal were observed following capsulectomy, femoral head dislocation, and hip reduction compared to pre-capsulectomy (baseline). There was transient loss in blood flow with retractor placement against the posterior femoral neck, corresponding to compression of the retinacular vessels. This is because the deep (main) branch of the MFCA and its terminal retinacular vessels run along the posterosuperior aspect of the femoral neck as shown by Gautier et al [9].

A significant reduction (28%) in blood flow was observed with the hip maximally flexed and externally rotated, corresponding to the end position of dislocation required to gain full exposure of the femoral head. This finding is consistent with Notzli et al [1] who reported 40% reduction in blood flow in the same position during SHD with the trochanteric flip osteotomy. Maximal external rotation with the hip fully flexed not only increases the torque on the vessels due to axial twisting, but it also brings those posterior vessels into the surgical field, further increasing the risk of injury from instrumentation. Severe torsional forces may lead to buckling and kinking of the blood vessels resulting in diminished or absent flow [10].

The blood vessels on the anterior aspect of the femoral head (capsular branches of the ascending branch of the lateral femoral circumflex artery) did not seem to contribute significantly to the blood flow as complete anterior capsulectomy did not impair perfusion. This is consistent with Gautier et al [9] who described the blood flow to the femoral head based on cadaveric dissections of 24 hips. Using neoprene latex injections, the group found that the lateral femoral circumflex artery contributed very little to the femoral head blood supply, with the predominant source being the deep branch of the MFCA. Similar findings were reported by Trueta and Harrison [11].

This study should be interpreted in the context of some limitations. First, the study was limited to skeletally mature adult males undergoing hip resurfacing arthroplasty for osteoarthritis. However, patients with post-traumatic osteoarthritis, avascular necrosis, large femoral head cysts, and prior internal fixation of the hip were excluded. Patent blood flow to the femoral head was confirmed in all patients by identifying a perfusion signal that was synchronous with each patient's pulse oximeter. In addition, we are not aware of gender differences in perfusion patterns. Second, while laser Doppler flowmetry detects changes in perfusion, it does not measure absolute blood flow. Accordingly, a critically low level for developing avascular necrosis cannot be defined. Third, due to the wide fluctuations in signal amplitude following dislocation and reduction in the femoral head, the sample became underpowered to detect the significance of this wide variation. We believe that the high variability in signal amplitude was related to vessels kinking

Table 2
Changes in femoral perfusion at different stages of the surgical approach compared to baseline (pre-capsulectomy).

Surgical step	Mean change in signal amplitude (flux)	Relative change in signal amplitude (%)	*P* value
Capsulectomy	−48 (−315 to +83)	−10 (−77 to +136)	.134
Femoral head dislocation and reduction	−45 (−380 to +381)	+27 (−93 to +626)	.166
Continued dislocation with hip maximally extended and externally rotated (just before cementing the final head)	−90 (−400 to +240)	−28 (−98 to +560)	.002

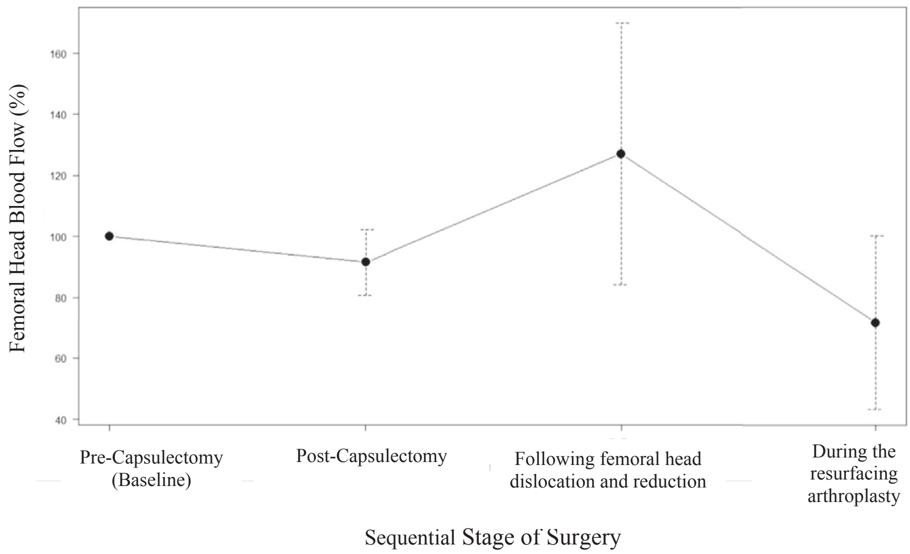

Figure 3. Variation in mean femoral head blood flow as a percentage of the baseline Doppler flux, with 95% confidence intervals, during sequential stages of surgical hip dislocation.

and recovery as well as the high sensitivity of the laser probes. A large increase in sample size (>1000) would be needed in order to power for such a large standard deviation. Fourth, the long-term clinical outcomes of the patients' native femoral heads are not available as they all underwent implantation of a cemented resurfacing femoral component. Although we cannot comment on the long-term osteonecrosis rate, we previously published a series of 541 patients who underwent this approach for hip resurfacing at minimum 5-year follow-up [12]. The rate of femoral head collapse was 0.2% and the rate of heterotopic ossification requiring excision was 0.7%. Schweitzer et al [13] recently reported on their experience with SHD using a modified direct lateral approach without trochanteric osteotomy in 4 patients (6 hips) at a mean follow-up of 2.5 years (range 2-4). The indications were tumor resection (5 hips) and extraction of a retained bullet (1 hip). At final follow-up, there were no clinical or radiographic evidence of avascular necrosis of the hip.

Conclusions

In summary, we have shown the feasibility of SHD preserving the blood supply to the femoral head through a modified direct lateral approach. The primary advantages of this approach are the avoidance of trochanteric osteotomy and increased familiarity among orthopaedic surgeons. Because the main branch of the MFCA enters the femoral head along the posteromedial aspect of the femoral neck, the surgeon should minimize prolonged and aggressive retraction against the posterior neck especially during maximal external rotation of the hip. Extended capsular release at or below the level of the lesser trochanter should also be avoided.

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