

Blood perfusion uneven in femoral head osteonecrosis

Doppler flowmetry and intraosseous pressure in 12 cases

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We measured the microvascular regional perfusion in 12 hips with non-traumatic osteonecrosis of the femoral head, using laser Doppler flowmetry (LDF). Simultaneously, the intraosseous pressure (IOP) was measured in the femoral head. For comparison, the same 2 parameters were measured in 6 normal femoral heads during surgery of the contralateral hip. In osteonecrosis, the regional blood cell flux in the intertrochanteric area was 165 mV, at the rim of the

lesion 430 mV, and in the necrotic lesion 35 mV. In the same areas, the IOP was 38 mmHg, 61 mmHg and 55 mmHg. In the normal hips, the LDF signal was 221 mV and 224 mV, and the IOP was 21 mmHg and 19 mmHg intertrochanterically and in the femoral head, respectively.

We conclude that the microvascular blood perfusion is uneven in an osteonecrotic head.

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Laser Doppler flowmetry (LDF) is based on the Doppler shift of a monochromatic beam of light from a 2mW He-Ne laser source that is reflected from moving blood cells in the tissue. This shift of wavelength is converted into an electronic signal and is presented digitally in millivolts (mV). Thus LDF provides a continuous, real-time monitoring of changes in the local perfusion, and an estimate of the relative blood flow in different regions of a tissue can be given.

We measured the IOP and the LDF output signal simultaneously in the femoral head in patients with non-traumatic osteonecrosis, and in normal hips.

Patients and methods

12 patients with necrosis of the femoral head were included in this study (Table 1). The median age of the patients was 44 (34-66) years. The diagnosis of osteonecrosis was confirmed by a history of pain in the hip, radiograms and 99-Tc methyldiphosphonate scintigraphy. Subsequently, staging of the disease was done according to Ficat (1985).

For comparison, 6 hips without clinical, radiographic or scintigraphic evidence of disease, in patients undergoing surgery of the contralateral hip, were investigated. The median age in these controls was 50 (28-63) years.

All patients had given their informed consent to the examination.

Surgery

The patients were anesthetized, placed in the supine position and prepared for surgery. The systemic blood pressure was kept at a constant level throughout the examination. Through a small longitudinal incision over the trochanter, a slightly conical 3 mm cannula with a trochar was inserted in the intertrochanteric area under biplanar image intensifier control. The trochar was removed, and the cannula was flushed with heparinized saline to prevent clotting.

Through the same skin incision, a second cannula of the same size as the first was inserted in the intertrochanteric area. The tips of the 2 cannulas were thus about 1 cm apart from each other.

Measurement of IOP

The first cannula was connected to a pressure transducer (Trantec 60-800, American Edwards Lab., Santa Ana, CA, U.S.A.) via a tight-fitting polyethylene tube filled with saline. The transducer was positioned at heart level, but as we were only studying the relative IOP in different regions of the femoral head, measurement of the pressure in the extraosseous veins

Table 1. Clinical details, intraosseous pressure (IOP, mmHg) and laser Doppler flow values (LDF, mV) at various sites of the femoral head in 12 patients with osteonecrosis of the femoral head

Case	Age	Sex	Associated finding	Stage	Intertroch.		At border		In lesion							
					IOP	LDF	IOP	LDF	IOP	LDF						
1	47	m	Alcohol	2	12	170	18	70	7	50						
2	36	m	R	4	40	130	40	650	73	10						
3	43	m	R	4	35	120	-	-	45	0						
4	34	f	Idiopathic	2	25	170	52	330	45	60						
5	66	f	R	1	33	130	-	-	40	10						
6	46	m	Steroids	4	95	250	78	650	90	40						
7	47	m	R	4	55	140	-	-	60	80						
8	44	f	R	3	72	290	100	550	93	25						
9	44	f	Idiopathic	3	10	170	63	450	-	30						
10	28	f	Idiopathic	2	9	180	-	350	23	20						
11	39	m	Alcohol	2	35	140	63	700	-	20						
12	63	f	R	3	38	100	70	120	72	80						
Mean SEM					38	7	165	16	61	9	430	77	55	9	35	8

R renal allotransplantation.

was not considered necessary. The IOP was recorded on a strip chart recorder (BBC SE 460, Goerz, Austria), and a pulsatile wave form of the IOP tracing was deemed to be an acceptable recording.

Measurement of LDF

The LDF probe, which was metal-shafted, 1 mm in diameter and 15 cm long, was inserted into the second cannula, and the tip of the probe was placed gently against the bone tissue. The probe was tightly sealed in the cannula and held in place in the cannula by a specially designed probe-holder, which allowed a steady location of the LDF probe against the bone in 4 reproducible positions. The probe was connected to the laser Doppler flowmeter (Periflux PF 3, Perimed, Stockholm, Sweden). The output signal was displayed digitally and recorded on the strip chart recorder. The recordings were performed with the unit in the wide band mode, i.e., the upper Doppler frequency limit was 12 KHz. The time constant selector was initially set to 0.02 sec to ensure a pulsatile nature of the signal, then switched to 0.2 sec for averaging and more comparable readings.

After achievement of a steady state, usually after about 5 minutes, the IOP and the LDF values were recorded simultaneously in 2 or 3 different places in the femoral head: 1) in the intertrochanteric region, 2) at the rim of the necrotic segment, if this region could be outlined on the image intensifier, and 3) in the necrotic segment or in the anterolateral part of the femoral head. The results are in most cases given as an average of 4 measurements in each region.

Wilcoxon's signed rank test for paired data was used to test the significance of the differences, and the Spearman test for correlation was used to examine the correlation between the measured LDF and IOP values. A probability value < 0.05 was considered significant. Values are given as mean (SEM).

Results

In all cases, pulsatility that was synchronous with the patient's electrocardiogram was noted in the tracings of the IOP and of the LDF values. In 8 cases, measurements from all 3 regions were obtained, but this was not possible in 4 cases due to technical problems or inability to outline the rim of the necrotic lesion on the image intensifier.

The mean IOP intertrochanterically was 38 (7) mmHg compared to 61 (9) mmHg at the rim and 55 (9) mmHg in the necrotic lesion (Table 1). The difference between the IOP intertrochanterically and at the rim of the lesion was significant, as also was the difference in the IOP intertrochanterically and in the lesion, while there was no difference between the IOP at the rim and in the necrotic lesion.

The mean LDF values in the intertrochanteric region was 165 (16) mV. At the rim of the lesion the mean LDF output signal was 430 (77) mV and in the necrotic lesion 35 (8) mV. All these differences were significant.

In most cases, the IOP in the necrotic lesion and at the rim of the lesion were higher than intertrochanterically. Correspondingly, the LDF values were lower in

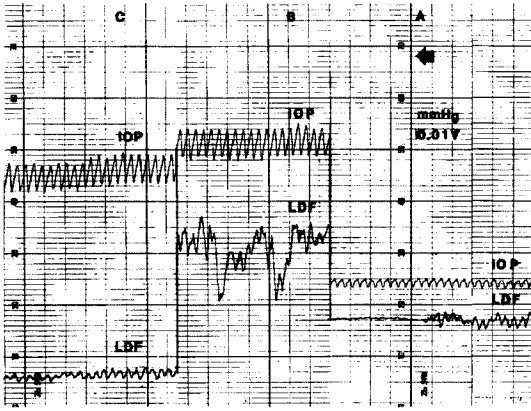


Figure 1. Strip chart tracing of IOP (mmHg) and LDF output signal (mV) from: A) intertrochanteric region, B) at the rim of the lesion, and C) in the lesion of an osteonecrotic femoral head. Sampling time 0.02 and 0.2 sec

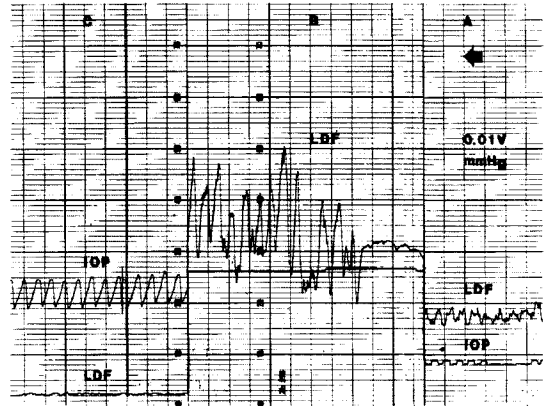


Figure 2. Strip chart tracing of IOP (mmHg) and LDF output signal (mV) from the 3 different regions (A, B, C as in Figure 1) of an osteonecrotic femoral head.

the lesion than intertrochanterically. However, this apparent inverse correlation between the values of IOP and LDF did not reach the level of significance ($r = -0.31$, $P > 0.05$).

At the rim of the necrotic lesion, the LDF output signal was usually higher than in the other regions of the femoral head. In this area, the LDF signal usually was very unsteady and the amplitude was high (Figures 1 and 2).

The mean IOP intertrochanterically in normal femoral heads was 21 (7) mmHg and in the middle of the femoral head 19 (3) mmHg. The corresponding LDF values were 221 (63) mV and 224 (75) mV (Table 2).

Discussion

The laser Doppler flowmeter produces an output signal that is linear over the entire measured range and

that is proportional to the microvascular blood cell perfusion of the target tissue. The perfusion value is the product of the number of cells moving in the measuring volume and the mean velocity of these cells, but is independent of the direction of the movement of the blood cells. The measured area is about 1.5–2 mm², and the maximum penetration depth is 3.5 (0.2) mm in trabecular bone, and 2.9 (0.2) mm in cortical bone (Nötzli et al. 1989). The reproducibility error of the perfusion recorded with this method is 7–15 percent (Hellem et al. 1983a, Swiontkowski et al. 1986, Lausten et al. 1993).

The LDF output signal is relative in nature. A calibration standard to convert the signal into an absolute quantitative index of blood flow in various organs and different individuals has not been possible due to the variation in the optical properties of various tissues and to spatial variation in the vascular bed. Thus, LDF is primarily useful for monitoring dynamic responses

Table 2. Age and sex, intraosseous pressure (IOP, mmHg) and laser Doppler flow values (LDF, mV) in the intertrochanteric region and in the femoral head in 6 control patients

Case	Age	Sex	Intertrochanteric		Femoral head	
			IOP	LDF	IOP	LDF
1	28	f	15	185	30	175
2	63	f	50	125	18	110
3	58	f	15	190	17	190
4	60	m	—	530	—	590
5	44	f	10	135	10	170
6	47	m	13	160	20	110
Mean SEM			21 7	221 63	19 3	224 75

of the microvascular perfusion to various physiological stimuli at a single site, or for demonstrating regional distribution of the perfusion in a specific organ (Smits et al. 1986, Swiontkowski et al. 1986, Obeid et al. 1990).

In pigs, LDF has proven useful in measuring the perfusion in cancellous bone following regulation of the systemic blood pressure (Hellem et al. 1983b). More recently, the blood perfusion of the femoral head was monitored by LDF following selective occlusion of the blood supply to the femoral head (Bassett et al. 1991) and after induction of intracapsular hyperpressure in the hip joint (Vegter and Klopper 1991). The LDF signal was obtained either through the cartilage of the femoral head (Bassett et al. 1991) or through a drill hole in the femoral bone (Vegter and Klopper 1991). However, in a clinical study, Swiontkowski et al. (1987) has found a close correlation between measurements through the articular cartilage and those obtained intraosseously through a drill hole, and animal experiments have shown undisturbed blood flow after bone cannulation for pressure measurements (Wilkes and Visscher 1975, Bouteiller et al. 1984).

In our study, the LDF probe was introduced into the cancellous bone of the femoral head through a drill hole. As bleeding during insertion of the cannula might cause a disturbing artefact, it is important to fit the LDF probe into a tight-fitting cannula to minimize oozing of blood into the illuminated area. It is important to fix the probe firmly to the bone (Obeid et al. 1990).

Our findings are in accordance with Swiontkowski et al. (1987), who reported the LDF values of 5 patients with femoral head necrosis, and who also found a pronounced variability in the LDF output signals in the same regions in different patients and in the different regions of the femoral head in the individual patient.

In our study, IOP was measured simultaneously with the blood cell flux, and a trend for inverse correlation between a high IOP and a low cell flux in the necrotic lesion was noticed. A pronounced variability in both IOP and LDF was noticed in the osteonecrotic femoral heads, whereas the values of these parameters were much higher, even in different regions of the normal femoral heads.

In conclusion, we have found, as previously observed histologically and by ⁹⁹Tc-MDP scintigraphy (Lausten and Christensen 1989), that the perfusion is relatively high in the transitional zone between the necrotic lesion and the normal cancellous bone in non-traumatic osteonecrosis of the femoral head. In the

necrotic lesion, the IOP was high and the perfusion was low. It remains to be elucidated whether the increased IOP in the necrotic femoral head is the cause or the consequence of the decreased perfusion.

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