

# Intraosseous pressure, oxygenation, and histology in arthrosis and osteonecrosis of the hip

Niels Wisbech Pedersen<sup>1</sup>, Thomas Kiær<sup>1</sup>, Kristian Damgaard Kristensen<sup>1</sup> and Henrik Starklint<sup>2</sup>

We compared intraosseous pressure, partial pressure of oxygen and carbon dioxide, and histopathology in 10 hips with arthrosis and in seven hips with nontraumatic necrosis of the femoral head. Hypoxia of the subchondral bone was present in both conditions. In arthrosis the intraosseous pressure was normal, whereas intraosseous hypertension was present in necrosis. Partial pressure of carbon dioxide was normal in both conditions. Identical signs of subchondral medullary and trabecular necrosis were found in both conditions.

Localized infarction of the subchondral bone has been found in primary arthrosis (Ficat and Arlet 1979, Ilardi and Sokoloff 1984, Milgram 1983, Wong et al. 1987), as well as in nontraumatic necrosis of the femoral head (Arlet and Durroux 1973, Ficat and Arlet 1979, Inoue and Ono 1979, Jacqueline and Rutishauser 1971). Intraosseous blood circulation has been evaluated indirectly by measuring intraarticular pressure (Goddard and Gosling 1988), intraosseous pressure (Arnoldi et al. 1972, Ficat and Arlet 1979, Termansen et al. 1981), and intraosseous blood gas tensions (Kiær et al. 1986, 1988). These studies indicate that hypoxia due to intramedullary stasis is of pathogenetic importance in both conditions. However, because most studies of the arthrotic bone have been performed in the advanced stages of the disease, the findings could be secondary.

We report blood circulation and histopathology in patients with early arthrosis and nontraumatic necrosis.

## Patients and methods

We studied 6 patients with 10 arthrotic hips, and 4 patients—1 alcoholic, 3 without known predisposing factors—with 7 nontraumatic osteonecrotic femoral heads (Table 1). The severity of arthrosis was graded according to Heripret (Danielsson 1964) and necrosis to Ficat and Arlet (1979). Nine of the 10 arthrotic hips had only slight changes: narrowing of the joint space of less than 2 mm combined with either osteophytosis at one pole or slight sclerosis or cyst formation. One hip showed moderate arthrotic changes. Two of the necrotic femoral heads were Grade 1, one was Grade 2, and four were Grade 3. None of the patients suffered from secondary arthrosis. All the patients complained of hip pain.

The partial pressure of oxygen and carbon dioxide was measured in situ by a mass spectrometer (Balzers QMG 112, Liechtenstein) via a blood-gas catheter (Lundsgaard et al. 1980). The catheter was inserted into the subchondral bone through a cannula. Only intravenous anesthetics were used. The patients were normoventilated with atmospheric air without oxygen enrichment. Intraosseous hydrostatic pressure was measured with a transducer (Siemens-Elema, Stockholm, Sweden). The measurement was accepted only if pulsation was obtained. In three arthrotic hips,  $pO_2$  and  $pCO_2$  could not be measured because of technical failure.

Departments of Orthopedics<sup>1</sup> and Pathology<sup>2</sup>, Odense University Hospital, Denmark

Correspondence: Dr. Niels Wisbech Pedersen, Department of Orthopedics Ø, Odense University Hospital, DK-5000 Odense C, Denmark

Table 1. Hydrostatic pressure, PO<sub>2</sub>, PCO<sub>2</sub> (kPa), and histologic findings in patients with early arthrosis (Cases 1-6) or nontraumatic osteonecrosis (Cases 7-10) of the hip

Case	Sex	Age	Grade of arthrosis or necrosis <sup>b</sup>	Hydrostatic pressure	PO <sub>2</sub>	PCO <sub>2</sub>	Grade of histologic necrosis <sup>c</sup>
1	f	49	s	1.7	—	—	2
—	—	—	s	4.9	—	—	1
2	f	55	s	3.2	6.8	3.6	2
3	m	42	s	3.7	4.9	8.0	3
—	—	—	m	5.1	8.0	7.3	3
4	f	56	s	5.9	8.0	6.5	2
—	—	—	s	4.0	7.3	5.9	2
5	m	66	s	3.5	—	—	3
6	m	55	s	1.1	6.4	5.5	0
—	—	—	s	3.7	10.5	6.0	0
Mean SEM				3.7 0.4	6.9 0.7	6.1 0.5	
7	m	44	2	7.9	7.3	4.5	2
—	—	—	1	6.0	7.5	6.8	0
8	f	56	1	7.6	12.4	5.8	2
9	m	29	3	9.3	8.0	4.9	3
—	—	—	3	7.3	7.9	3.7	3
10	m	53	3	10.7	1.6	10.1	2
—	—	—	3	8.7	1.9	10.0	2
Mean SEM				8.2 0.5	6.7 1.5	6.1 0.9	

<sup>a</sup> m moderate; s slight (Danielsson 1964).

<sup>b</sup> 1-3 (Ficat and Arlet 1979).

<sup>c</sup> 1 disappearance of the hemopoietic marrow. Separation of lipocytes by edema or hemorrhage; 2 necrosis of the fatty marrow; 3 medullary fibrosis and appositional bone formation (Arlet and Durroux 1973).

After the gas measurements, a core biopsy was obtained with a trephine with an outer diameter of 8 mm. Specimens were taken from the femoral neck and head up to a distance of 5 mm from the joint space. The biopsies were all examined by the same pathologist and graded according to Arlet and Durroux (1973).

For statistical analysis the Mann-Whitney rank sum test was used.

## Results

The hydrostatic pressure was increased in hips with necrosis as compared with arthrosis ( $P < 0.001$ ). No difference in pO<sub>2</sub> or pCO<sub>2</sub> could be found between arthrotic and necrotic hips. The degree of histologic necrosis was evenly distributed between the two groups (Table 1).

## Discussion

One hypothesis of the etiology of arthrosis is that initially synovitis causes increased intraarticular pres-

sure (Arnoldi and Reimann 1979, Goddard and Gosling 1988) leading to increased intraosseous pressure, which has been found in advanced arthrosis of the hip (Arnoldi et al. 1972, Termansen et al. 1981, Kiær et al. 1988), but not in early arthrosis of the knee (Arnoldi et al. 1975). However, we found normal pressures in our cases of early coxarthrosis.

Blockage of the intraosseous microcirculation causing elevated intraosseous pressure may incite cell anoxia and death of the osteocytes (Ficat and Arlet 1979, Hungerford and Zizic 1983). In agreement with previous studies (Ficat and Arlet 1979, Solomon 1981, Hungerford and Zizic 1983), we found increased intraosseous pressure in these patients.

Decrease of partial pressure of oxygen and intraosseous hypertension has been found in patients with advanced arthrosis of the hip (Kiær et al. 1988), suggesting that hypoxia is caused by reduced regional blood flow. We now found decreased pO<sub>2</sub> also in early arthrosis, but with normal intraosseous pressure in seven out of 10 hips. Another interpretation of the hypoxia is increased oxygen consumption; but in bone tissue showing histologic signs of necrosis, this seems improbable.

Our findings suggest that the hypoxia in nontraumatic osteonecrosis is caused by decreased blood flow due to increased outflow resistance.

Reduced blood flow, as well as increased oxygen consumption, would be expected to cause an increase in  $p\text{CO}_2$ . This was not observed in our cases of arthrosis or osteonecrosis, probably because of the reversible exchange of  $\text{CO}_2$  between blood and bone matrix (Poyart et al. 1975).

In advanced arthrosis, focal necrosis of the osteocytes in and adjacent to the eburnated bone and cysts has been noted (Ficat and Arlet 1979, Milgram 1983, Ilardi and Sokoloff 1984). In two thirds of patients with advanced arthrosis, widespread bone death was found

by Wong (1987), who suggested that primary arthrosis of the hip frequently could be caused by episodes of osteocyte death. In both early arthrosis and in nontraumatic osteonecrosis, we found varying degrees of marrow necrosis, and in some cases also necrosis of the trabeculae. No characteristics in the histologic pattern of the subchondral bone that could differentiate between arthrosis and nontraumatic osteonecrosis could be demonstrated. The hypoxia in the early stages of both conditions could explain the osteocyte death, but final evidence is lacking.

## References

- Arlet J, Durrroux R. Diagnostic histologique précoce de l'ostéonécrose aseptique de la tête fémorale par le forage biopsie. In: Premier Symposium International de Circulation Osseuse, Toulouse, Paris, INSERM 1973.
- Arnoldi C C, Lemperg K, Linderholm H. Intraosseous hypertension and pain in the knee. *J Bone Joint Surg (Br)* 1975;57(3):360-3.
- Arnoldi C C, Linderholm H, Müslichler H. Venous engorgement and intraosseous hypertension in osteoarthritis of the hip. *J Bone Joint Surg (Br)* 1972;54(3):409-21.
- Arnoldi C C, Reimann I. The pathomechanism of human coxarthrosis. *Acta Orthop Scand* 1979;(Suppl 181):1-47.
- Danielsson L G. Incidence and prognosis of coxarthrosis. *Acta Orthop Scand* 1964;(Suppl 66).
- Ficat R P, Arlet J. Ischemia and necroses of bone. Williams & Wilkins, London 1979.
- Goddard N J, Gosling P T. Intra-articular fluid pressure and pain in osteoarthritis of the hip. *J Bone Joint Surg (Br)* 1988;70(1):52-5.
- Hungerford D S, Zizic T M. Pathogenesis of ischemic necrosis of the femoral head. In: *The Hip: Proceedings of the Eleventh Open Scientific Meeting of The Hip Society* (Ed. Hungerford D.S.). C.V. Mosby, St Louis 1983:249-62.
- Ilardi C F, Sokoloff L. Secondary osteonecrosis in osteoarthritis of the femoral head. *Hum Pathol* 1984;15(1):79-83.
- Inoue A, Ono K. A histological study of idiopathic avascular necrosis of the head of the femur. *J Bone Joint Surg (Br)* 1979;61(2):138-43.
- Jacqueline F, Rutishauser E. Idiopathic necrosis of the femoral head. In: *Idiopathic Ischemic Necrosis of the Femoral Head in Adults* (Ed: Zinn W M). Thieme, Stuttgart 1971:34-48.
- Kiær T, Grønlund J, Sørensen K H. Subchondral  $p\text{O}_2$ ,  $p\text{CO}_2$ , pressure, pH, and lactate in human osteoarthritis of the hip. *Clin Orthop* 1988;(229):149-55.
- Kiær T, Sørensen K H, Grønlund J. Intraosseous pressures of oxygen and carbon dioxide in coxarthrosis. *Acta Orthop Scand* 1986;57(2):115-8.
- Lundsgaard J S, Jensen B, Grønlund J. Fast responding flow independent blood gas catheter for oxygen measurement. *J Appl Physiol* 1980;48(2):376-81.
- Milgram J W. Morphologic alterations of the subchondral bone in advanced degenerative arthritis. *Clin Orthop* 1983;(173):293-312.
- Poyart C F, Freminét A, Bursaux E. The exchange of bone  $\text{CO}_2$  in vivo. *Respir Physiol* 1975;26:101-7.
- Solomon L. Idiopathic necrosis of the femoral head: pathogenesis and treatment. *Can J Surg* 1981;24(6):573-8.
- Termansen N B, Teglbjærg P S, Sørensen K H. Primary osteoarthritis of the hip. Interrelationship between intraosseous pressure, X-ray changes, clinical severity and bone density. *Acta Orthop Scand* 1981;52(2):215-22.
- Wong S Y, Evans R A, Needs C, Dunstan C R, Hills E, Garvan J. The pathogenesis of osteoarthritis of the hip. Evidence for primary osteocyte death. *Clin Orthop* 1987;(214) 305-12.