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# Subchondral $Po_2$ and $Pco_2$ are unaffected in experimental arthrosis

We have made comparative measurements of oxygen and carbon dioxide tensions in normal and osteoarthritic subchondral bone tissue of rabbits in the 4-month stage of unilateral experimental arthrosis of the knee. The gas tensions were measured by a mass spectrometer via a special catheter inlet system.

The mean values of the oxygen tensions on the normal and the osteoarthritic side were 39.8 and 46.2 mmHg, respectively. The carbon dioxide tensions were 33.3 and 34.2 mmHg. Neither difference was significant.

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The pathogenesis of primary osteoarthritis is largely unknown, but one of several working hypotheses is that the primary insult to the joint causes synovitis, which results in effusion and increased joint pressure with an associated degeneration of the joint cartilage. The pressure increase inhibits the regional blood flow of the subchondral bone due to compression of the intracapsular vein segments draining the epiphysis. The reduction in the blood flow decreases the oxygen supply to the bone and thereby causes tissue hypoxia, which stimulates osteogenesis, hyperaemia and hypervascularisation. Technical difficulties of measuring subchondral $Po_2$ have hampered the experimental evaluation of this hypothesis. The hypothesis is, however, supported by data which show that the bone marrow pressure is positively correlated to the joint pressure (Arnoldi et al. 1979, 1980, Bünger et al. 1981, Lucht et al. 1981). Furthermore, in a recent study (Grønlund et al. 1984), we have shown that an acute increase in the joint pressure can cause a significant fall in both the subchondral $Po_2$ and the regional blood flow.

In the present study we have utilized mass spectrometry to make comparative measurements of the subchondral $Po_2$ and $Pco_2$ of osteoarthritic and normal knee joints of rabbits with unilateral experimental osteoarthritis.

## Material and methods

The subchondral $Po_2$ and $Pco_2$ were measured by a mass spectrometer (Micromass SX 200, VG Gas Analysis, Middlewhich, UK) via a blood gas catheter (Lundsgaard et al. 1980). In essence, this is a stainless steel tube, the lumen of which is connected to the high vacuum chamber of the mass spectrometer. The catheter tip is covered by a polyethylene membrane supported by a sintered bronze plug. When the membrane is in contact with the tissue, oxygen and carbon dioxide diffuse through it and are drawn towards the vacuum chamber and detector. The application of the mass spectrometer and the associated calibration procedures (Lundsgaard et al. 1978) for measurement of subchondral $Po_2$ and $Pco_2$ have been described in detail previously by Kofoed et al. (1983).

Eight adult rabbits with closed epiphyseal lines were subjected to an instability operation a.m. Hulth et al. (1970) on one knee joint to induce unilateral osteoarthritis. Four months after this operation, the rabbits were used for the comparative study of $Po_2$ and $Pco_2$ in subchondral bone tissue. The rabbits were anaesthetized by i.v. infusion of an initial dose of pentobarbitone (20 mg/kg), which was supplemented when necessary, and the periosteum of the lateral aspects of the femoral and tibial condyles of both legs was blocked with a local anaesthetic without adrenaline (0.5 ml lidocaine, 20 mg/ml). The femoral and tibial epiphyses were each penetrated percutaneously with one cannula inserted under image intensification into the subchondral bone of the medial femoral and tibial condyles, respectively. An

open-ended catheter was inserted into the right carotid artery to allow blood sampling and measurement of the arterial blood pressure.

The tip of the blood gas catheter was inserted into the subchondral tissue through the tibial cannula. When the mass spectrometer signals of oxygen and carbon dioxide had reached steady levels, a blood sample was taken from the catheter in the carotid artery and the arterial blood pressure was measured by connecting this catheter to a pressure transducer (Bentley Trantec, UK). The blood sample was analyzed with respect to $P_{O_2}$, $P_{CO_2}$ and pH by a conventional blood gas and acid/base analyzer (ABL 1, Radiometer Copenhagen). After the blood gas sampling, the blood catheter was moved to the femoral condyle of the same leg. When the mass spectrometer signals had stabilized, the procedure was repeated on the opposite leg. To avoid bias we alternated between the osteoarthritic and the normal side as the first side in the measuring procedure. At the conclusion of the experiment, the animals were killed with an overdose of pentobarbitone, and the knee joints were radiographed and opened for macroscopic examination.

## Results

The means of $P_{O_2}$ and $P_{CO_2}$ measured in the osteoarthritic and normal bone are shown in Table 1, together with the simultaneously measured arterial values. The mean arterial values of $P_{O_2}$, $P_{CO_2}$ and pH were constant for each animal during the experiments. The mean arterial blood pressure was 100.1 ± 4.4 mmHg (SEM). The differences between the measured oxygen and carbon dioxide tensions on the normal and the arthritic side were not significant (paired *t*-test, $p > 0.05$).

The macroscopic examination of the joint showed no effusion and the synovial membranes were neither hyperaemic nor fibrotic, but there were signs of cartilage degeneration in the medial joint chamber with loss of glossiness. The radiographic examination of the joints showed marginal osteophytes on both the tibial and femoral bones. The osteophytes were most pronounced on the medial tibial condyle. There was no sign of subchondral osteosclerosis in any of the rabbits. The control knees were all judged normal.

## Discussion

The changes induced by Hulth's operation on the knee joints of rabbits are very similar to those observed in human osteoarthritis (Telhag & Lindberg 1972, Ehrlich et al. 1975, Bohr 1976, Christensen et al. 1982). Tran et al. (1977) measured $P_{O_2}$ and $P_{CO_2}$ in trochanteric bone tissue of 85 patients with coxarthropathy by analysing blood samples, which were aspirated from the subchondral bone tissue via a bone cannula. Eighteen of these patients suffered from osteoarthritis and the mean $P_{O_2}$ and $P_{CO_2}$ values were 47.9 and 40.9 mmHg. The oxygen tension agrees with the mean value of 46.2 mmHg obtained in the present study, whereas the $P_{CO_2}$ value is 6.7 mmHg higher than ours. This discrepancy can be explained by the difference in the arterial $P_{CO_2}$ value, which was 8.1 mmHg higher in Tran et al.'s study.

The fact that there was no difference between the oxygen tensions in the normal and the osteoarthritic bone in the present study does not exclude hypoxia as a pathogenetic factor in the development of osteoarthritis. The hypoxia might either be an early event in the pathogenesis or an intermittent phenomenon, which stimulates other processes such as osteogenesis (Heppenstall et al. 1975). The occurrence of hyperaemia and hypervascularity in

*Table 1. Subchondral $P_{O_2}$ and $P_{CO_2}$ (expressed as mmHg, mean ± SEM) in normal and arthrotic bone. The data were obtained in the femoral and tibial condyles of eight rabbits with unilateral arthrosis of the knee*

| | Arthrosis | | | Normal | | |
|---|---|---|---|---|---|---|
| | $P_{O_2}$ | $P_{CO_2}$ | | $P_{O_2}$ | $P_{CO_2}$ | pH |
| Subchondral values | 46.2±3.7 | 34.2±1.6 | | 39.8±2.3 | 33.3±2.1 | |
| Arterial values | 79.2±5.2 | 29.5±1.1 | 7.46±0.01 | 79.0±5.4 | 28.4±0.8 | 7.46±0.02 |

the osteoarthritic bone (Bohr 1976, Christensen et al. 1982), might be a reaction to tissue hypoxia.

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