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PRIMARY OSTEOARTHRITIS OF THE HIP

Interrelationship between Intraosseous Pressure, X-ray Changes, Clinical Severity and Bone Density

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The intraosseous pressure of the femoral head and greater trochanter was measured during 146 Charnley hip replacement operations. In 108 hips with primary osteoarthritis the pressure in the femoral head averaged 49.6 and in the greater trochanter 31.6 mmHg. The pressures in the greater trochanter were significantly lower than those in the femoral head. There was no sex difference, and the pressures were independent of age. The intraosseous pressure in the femoral head varied appreciably with a dispersion which did not significantly differ from the normal distribution. There was a faintly positive correlation between the mean blood pressure and the intraosseous pressure. No relationship was found between the pressure in the femoral head and the radiological severity of the osteoarthritis or between the intraosseous pressure and the duration of symptoms, severity of rest pain, walking ability, range of motion or degree of bone density at the site of measurement.

The haemodynamic conditions in bone depend upon blood flow and resistance. Variations in these two factors determine the actual intraosseous pressure. As a consequence intraosseous pressure measurement as the only evaluation of the haemodynamic conditions is of limited value. The vascular factor in osteoarthritis needs further clarification.

Key words: femoral head; hip joint; intraosseous pressure; osteoarthritis

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An elevated intraosseous pressure has been suggested as a possible pathogenetic factor in primary osteoarthritis (Arnoldi et al. 1972a). In osteoarthritis of the hip phlebography has shown signs of intraosseous venous engorgement, compatible with a high pressure and with a tendency to increased osteogenesis (Mériel et al. 1955, Hulth 1958, Phillips 1966, Brookes & Helal 1968, Arnoldi et al. 1972b). The object of the present study was to record the intraosseous pressure in the femoral head and greater trochanter of patients with primary osteoarthritis of the hip and to compare the findings with the radiological and clinical severity of the disease and with the relative bone density at the site of measurement. In addition, pressure measurements were made in a small series of patients with secondary osteoarthritis and rheumatoid arthritis.

MATERIAL AND METHODS

The pressure measurements were performed from March 1975 to March 1976 in all patients subjected to total hip replacement by the method of Charnley. The operations were carried out in a sterile enclosure. The patients were under general anaesthesia and in a controlled horizontal position. The reference level was the mid-axillary plane. After incision of the ilio-tibial tract,

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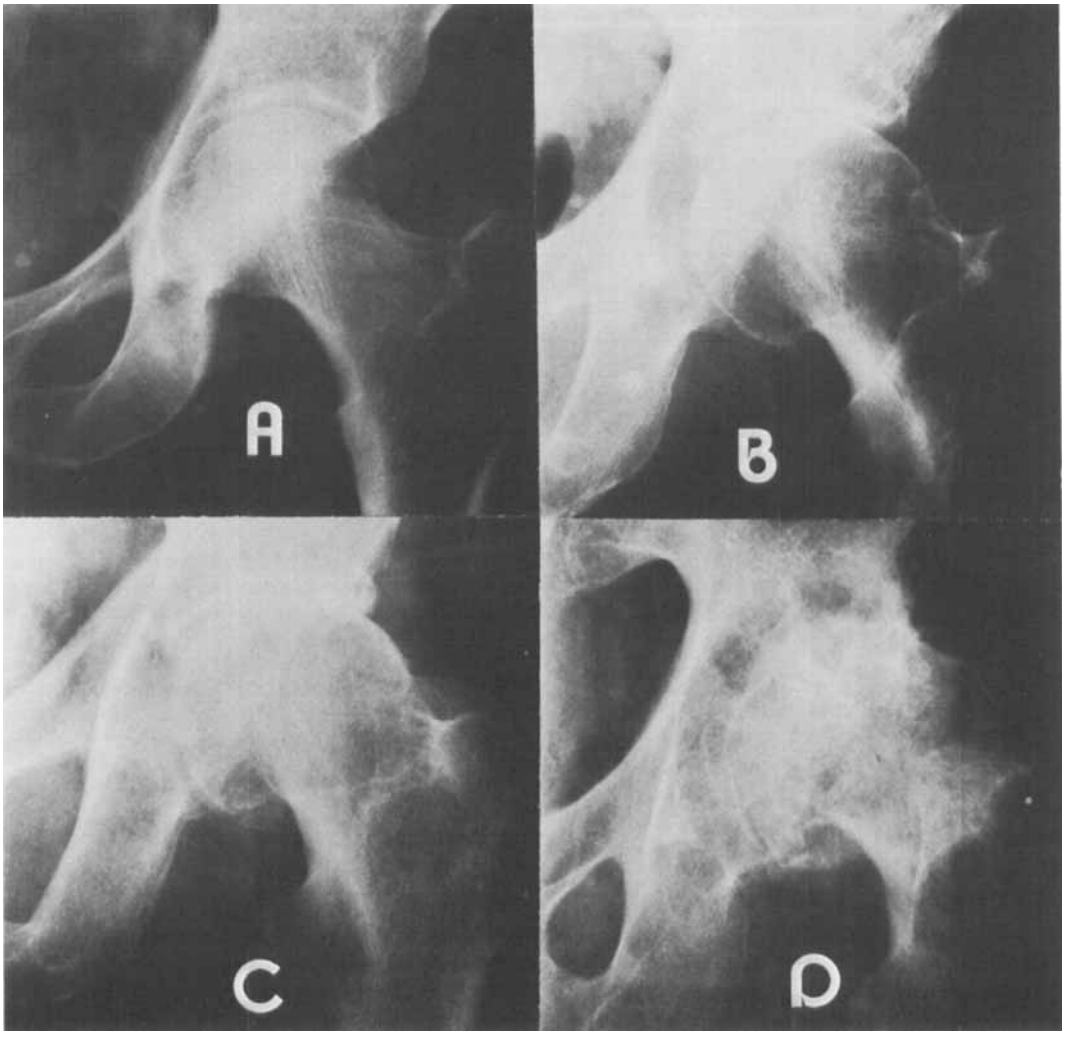

Figure 1 – A, B, C, D. Radiological classification of osteoarthritis of the hip joint according to the degree of joint space narrowing.

but before further exposure, two pressure needles (lumen 1.2 mm) were placed in the greater trochanter and in the femoral head from the anterior aspect of the femoral neck after palpating the edge of the head. Via a 2 m long polyethylene catheter (lumen 1.2 mm) the needles were connected to a pressure transducer (Siemens-Elema) which was calibrated by water columns. The curves were traced on a writer (mingograph). Prior to the measurements the needles and catheters were filled with heparinized saline (Termansen & Okholm 1976). To assess the reproducibility the pressure was measured, during a great part of the period, elsewhere in the greater trochanter and femoral head, the stylet being introduced anew into the needle which was hammered 0.5–2.75 cm deeper into the bone. The pressures were measured directly. At the same time, the systolic and diastolic blood pressure was measured, and the mean blood pressure was calculated as the diastolic pressure plus one-third of the difference between the systolic and diastolic pressure.

The radiological severity was evaluated by the degree of joint space narrowing when comparing an ordinary anteroposterior view of the hip with four standard photos (Figure 1 A, B, C, D). Moreover, the number and size of bone cysts were assessed on an X-ray film of the removed femoral head (Figure 2): Grade I: 0 cyst, grade II: 0–5 cysts, less than 10 mm, grade III: more than 5, less than 10 mm, and grade IV: cysts over 10 mm in diameter.

The *clinical severity of osteoarthritis* was assessed by

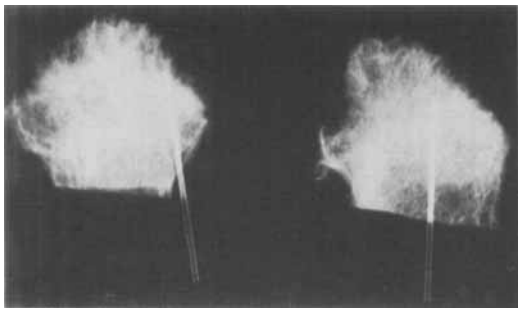

Figure 2. Femoral head from a patient with osteoarthritis of the hip joint in a-p and lateral views showing the position of the needle for pressure measurement.

the duration of symptoms, the nature of pain on weight-bearing and at rest (none, periodical, constant), the duration of constant rest pain, and by a numerical score for pain, walking function, and range of motion (Merle d'Aubigné & Postel 1954).

In order to evaluate *bone density* 98 femoral heads from patients with primary osteoarthritis of the hip were examined histologically. The pressure needle was left in the femoral head after the latter had been removed, or a mark was later placed at the site of the tip of the needle (Figure 2). In two cases the site could not be identified, and in one case the tip of the needle was found in a cyst 13 mm in diameter. These three specimens were excluded from the study. The remaining 95 bone specimens were fixed in 4 per cent neutral, buffered formalin, and a block of bone, about 10 × 10 × 3 mm was removed from around the needle tip. Without being decalcified, the bone specimen was embedded in methacrylate, cut into 4–6 μ sections, and stained with Goldner's trichrome. The relative bone area (per cent trabecular bone area) was determined by point counting using a No. 2 100-point Zeiss integration filter at a 100 × magnification. Sixteen randomly selected fields, corresponding to a total of 1600 points, were counted on each specimen. The counting was done only on cancellous bone. The relative trabecular bone area was expressed as the percentage of the points on trabecular bone in relation to the total number of points. The reliability of the method was assessed by 20 blind double counts. There was no systematic error. The dispersion of the difference between the first and second count was 1.7, corresponding to a counting error of 8.8 per cent.

Pressure measurements were done during a total of 146 operations. Seven pressure curves were discarded as technically poor, while 139 were stable.

The age distribution and sex ratio of 101 patients (pts.) with 108 operated hips affected with primary osteoarthritis are shown in Figure 3 (seven operations were bilateral). The mean age at operation was 63 years. Only three patients were under 50, and the sex ratio was approximately equal.

RESULTS

Figure 4 illustrates the distribution of the pressures in the femoral head in primary osteoarthritis. The mean pressure was 49.6 mmHg, with a wide range. The distribution does not differ significantly from a normal distribution. (Chi^2, $0.90<P<0.95$). Figure 5 presents the distribution of the pressures in the greater

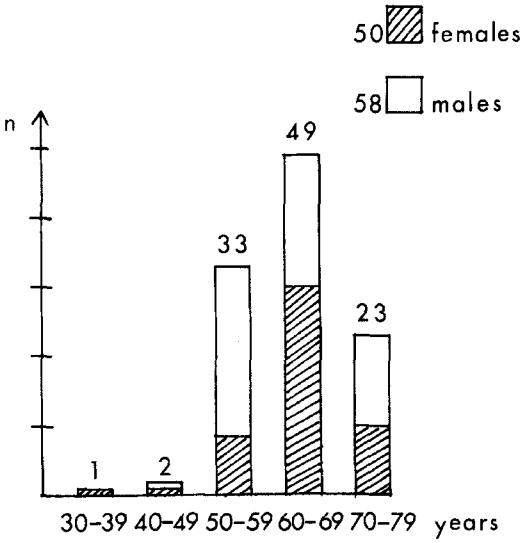

Figure 3. Sex and age distribution of 108 cases of osteoarthritis of the hip joint (101 patients). Mean age 63 years. Range 35–75.

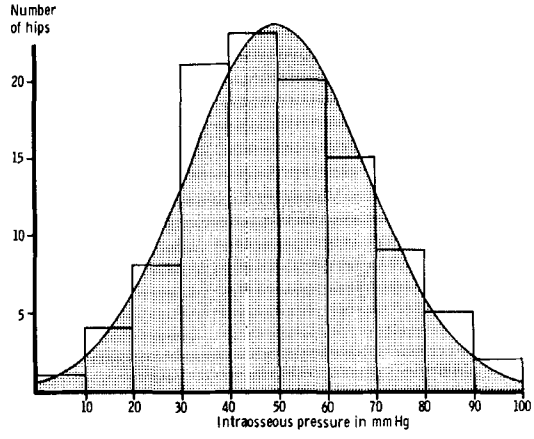

Figure 4. Intraosseous pressure in the femoral head in 108 cases of osteoarthritis of the hip joint. Mean 49.6. SD 18.3. Range 8.3–92.5.

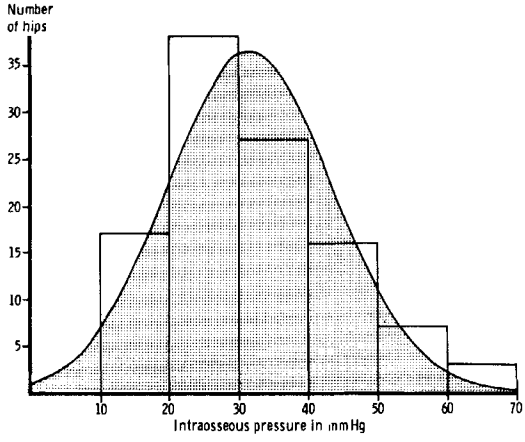

Figure 5. Intraosseous pressure in the greater trochanter in 108 cases of osteoarthritis of the hip joint. Mean 31.6. SD 11.9. Range 10.1–65.0.

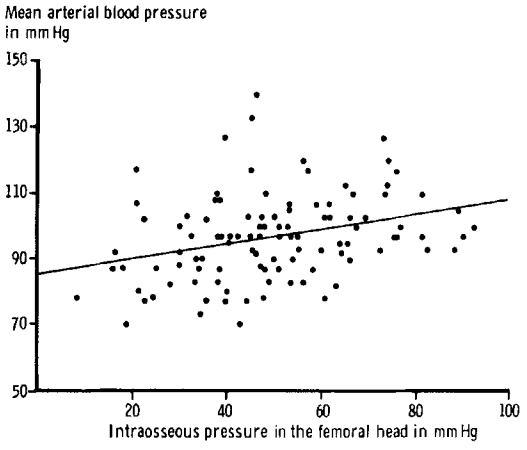

Figure 7. Correlation between intraosseous pressure in the femoral head and the mean arterial blood pressure in 108 cases of osteoarthritis of the hip joint. r = 0.32. P<0.001.

trochanter. This distribution differs from the normal distribution (Chi^2, $P<0.01$). The mean pressure was 31.6 mmHg. This is significantly lower than in the femoral head (Wilcoxon signed rank test, $P<0.001$). There was a significantly positive correlation between the pressures in the greater trochanter and the femoral head (Figure 6).

Pressure measurement at two depths was performed in 86 cases in the femoral head and in 78 in the greater trochanter. In both series the mean of the pressures measured last – that is nearest to the hip joint – was significantly higher than the mean of those measured first, and there was the same positive correlation between them (r = 0.85).

There was no sex difference between the pressures in the femoral head, and the intraosseous pressure was independent of age. There was a faintly positive, but significant, correlation between the mean blood pressure and the mean pressure in the femoral head (Figure 7).

In 23 patients with *secondary osteoarthritis* the mean intraosseous pressure in the femoral head was 42.3 mmHg (SD: 18.2, range 14.7–74.5). In 7 patients with *rheumatoid arthritis* the pressure in the femoral head averaged 44.8 mmHg (SD: 19.2, range 26.0–78.8). One patient with a *necrotic femoral head* without osteoarthritis had an intraosseous pressure in the femoral head of 79.2 mmHg.

Radiologically nearly all the hips were assigned, according to the degree of joint space narrowing, to groups C and D (Figure 1: A:0, B:2, C:48, D:58). On classification according to the size and severity of the cysts group I consisted of 0, group II of 23, group III of 65, and group IV of 20 hips. There was no relationship between the pressure in the femoral head and the degree of joint space narrowing or between the pressure and the number of cysts. The intraosseous pressure assessed by mean value and range was the

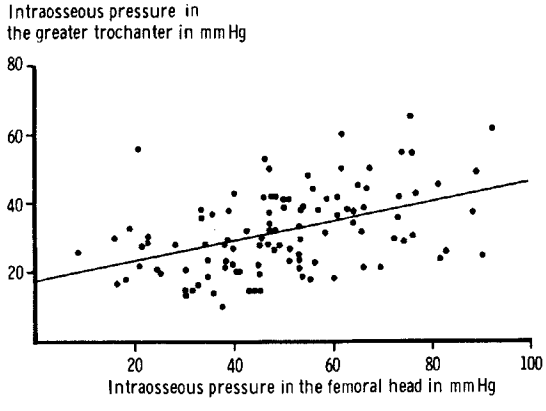

Figure 6. Correlation between intraosseous pressure in the femoral head and greater trochanter in 108 cases of osteoarthritis of the hip joint. r = 0.44. P<0.001.

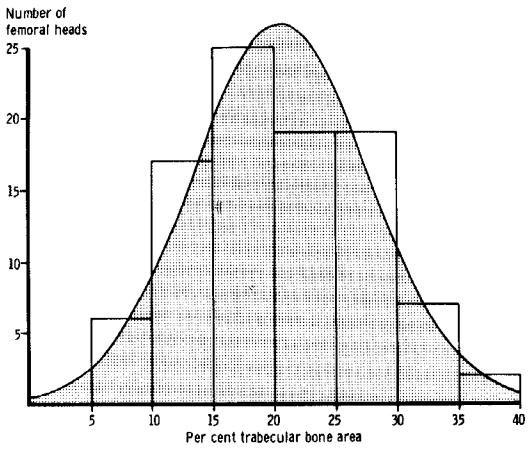

Figure 8. Per cent trabecular bone area measured by point counting in 95 femoral heads from patients with osteoarthritis of the hip joint.
Mean 20.5. SD 7.1. Range 7.1–35.6.

same in the various groups. The intraosseous pressure in the femoral head also proved to be independent of the duration of symptoms and of the severity of pain on weight-bearing and at rest (none, periodical, or constant).Nor did grading of pain, range of motion, and walking ability (grades 1–6) disclose any association between the severity of osteoarthritis and the intraosseous pressure. In fact, analysis of the material divided into four groups according to the magnitude of the intraosseous pressure in the femoral head showed a completely uniform distribution of the various radiological and clinical degrees of osteoarthritis within the four pressure groups and without significant differences (Chi^2, 5 per cent level).

Bone density is shown in Figure 8. The relative area of bone averaged 20.5 per cent with a standard deviation of 7.1.

In Figure 9 the intraosseous pressure in the femoral head is plotted against the relative area of bone. There is no correlation between these two values.

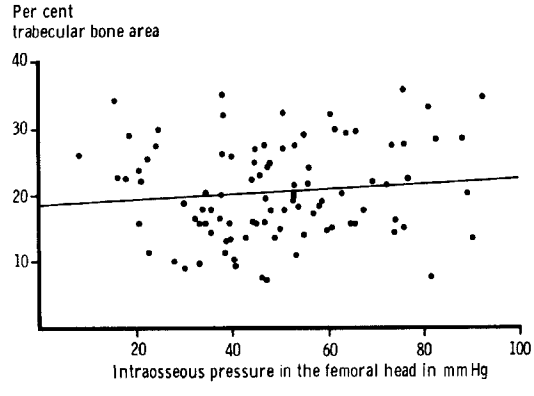

Figure 9. Intraosseous pressure plotted against relative trabecular bone area of the femoral head in 95 cases of osteoarthritis of the hip joint. r = 0.10. P>0.1.

DISCUSSION

Pressure conditions in the proximal part of the femur of normal subjects have been studied in only a few and small series. In 11 healthy persons Arnoldi et al. (1971) found a mean pressure in the femoral neck of 18.7 mmHg (range 12.9–23.5), and the same mean pressure was found in the femoral neck on the contralateral side in 15 pts. with unilateral osteoarthritis of the hip (Arnoldi et al. 1972a). In 9 pts. with radiological and phlebographically normal hips Arlet et al. (1968) found a mean pressure in the greater trochanter of 17.2 mmHg (range 12–26). Lastly, Arlet et al. (1972), in 4 pts. with unilateral osteoarthritis of the hip, found a pressure of 20–30 mmHg in the femoral head on the contralateral side. All the measurements were made under general anaesthesia.

Arnoldi et al. (1972a) have found the pressure in the femoral vein to be between 6.5 and 15.6 mmHg under conditions similar to ours. We did not measure the pressure in the femoral vein for fear of causing thrombosis. All our patients had a normal cardiac condition, which means that the pressure in the central veins must have been low, varying within very narrow limits.

Signs of intraosseous venous engorgement with retention of contrast medium and altered drainage conditions through the cortex have been found in primary osteoarthritis of the hip (Mériel et al. 1955, Hulth 1958, Phillips 1966, Brookes & Helal 1968, Arnoldi et al. 1972a). The intraosseous pressure in the proximal part of the femur has often been reported to be elevated in osteoarthritis of the hip, increasing from the trochanter towards the femoral head, whereas the

extraosseous, venous pressure has proved to be normal (Arlet et al. 1972, Arnoldi et al. 1972a, Termansen & Okholm 1976, Hiétala & Åström 1977). Ficat & Arlet (1972) stated that the upper limit for normal pressure in the femoral head is 30 mmHg. Arnoldi et al. (1972a) consider the elevated intraosseous pressure to be the cause of rest pain in osteoarthritis of the hip. On penetration of the corticalis and drainage of the cancellous bone it has been claimed that the pressure decreases (Arnoldi et al. 1973), the pain disappears, and after a certain time the venous drainage may return to normal (Phillips et al. 1967). Hiétala & Åström (1977), however, were unable to confirm this.

Although surgical treatment of osteoarthritis by osteotomy and drilling was introduced on an empirical basis, the explanation of the success of this treatment has been based partly on the above-mentioned phenomena, and partly on biomechanical theories. However, the reported pressures in pts. with osteoarthritis of the hip have varied widely (Arlet et al. 1972, Arnoldi et al. 1972a, Termansen & Okholm 1976), and this also applies to measurements on experimental animals (Bloomenthal et al. 1952, Stein et al. 1957, Azuma 1964). Therefore, doubt has been expressed concerning the close correlation claimed to exist between intraosseous pressure and rest pain in osteoarthritis of the hip (Termansen & Okholm 1976).

In the present series we found a marked variation in the intraosseous pressure. The pressures in the femoral head closely approached a normal distribution; they were significantly higher than those in the greater trochanter and above normal values. In secondary osteoarthritis and rheumatoid arthritis we found similar pressures suggesting that the same vascular factors play a part in these conditions. We could not find any relationships between the intraosseous pressure and the clinical or radiological severity of the osteoarthritis. The result of duplicate measurements showed that the wide range cannot have been due to inaccuracy of the measuring method. In our material the mean pressure in the trochanter and in the femoral head was of the same magnitude as found by other authors, also showing an increase from the trochanter towards the femoral head. The intraosseous pressure depends upon the arterial pressure, which has been confirmed by Azuma (1964) and Hawk & Shim (1970) in the experimental animal, and by Arlet et al. (1972) in man. After compressing the femoral artery, these authors demonstrated a fall in the intraosseous pressure in the femur when the pulsation ceased. Arlet et al. (1972) also found an increase in the intraosseous pressure with advancing age in man, possibly in step with increasing arterial blood pressure. Nearly all our patients were over 50 years of age, which might be the reason why we could not demonstrate any correlation between age and intraosseous pressure. The faintly positive correlation between the mean blood pressure and intraosseous pressure in our material and the previously demonstrated lack of correlation (Termansen & Okholm 1976) indicate that there is no simple relationship between them.

Our findings indicate that the momentary intraosseous pressure of the femoral head at the time of performing a hip operation for osteoarthritis bears no relationship to the degree of osteoarthritis. Sufficient information is not obtainable by simple pressure measurement alone. A single pressure measurement does not reflect the haemodynamic conditions. The pressure is affected not only by the blood pressure and venous drainage of the femoral head, but also by the viscosity of the blood and the state of contraction in the afferent vessels (Stein et al. 1957, Hawk & Shim 1970). Arlet et al. (1972) demonstrated that the contraction state in adjacent muscles influenced the pressure contraction of the quadriceps femoris entailing an increased pressure in the greater trochanter. Aichroth et al. (1975) observed rapid changes in pressure in the femur of experimental persons while walking. The intraosseous pressure is proportional to the blood flow and resistance (Brookes 1971). Blood flow measurements in bone have been performed on animals (McPherson et al. 1961, Brookes et al. 1970, Hawk & Shim 1970), but no method is suited for clinical use. Resistance in the veins can be investigated by isotopes (Hernborg 1969), phlebography, or provoked hyperpressure test (pressure measurement after intraosseous injection of a given volume of fluid (Arlet et al. 1968, Ficat & Arlet 1975)).

It is assumed that changes in the biochemical state of the bone can elicit osteogenesis in congestive states (Brookes & Helal 1968, Arnoldi et al. 1972b). Long-lasting venous congestion in the femoral head in advanced osteoarthritis might be imagined to entail increased bone density, but we could not demonstrate any correlation between the relative area of bone and the momentary intraosseous pressure. The relative area of bone did not differ from that which is found in normal cancellous bone (Aaron et al. 1974, Melsen 1978, Reimann et al. 1977). The situation of the bony tissue studied in relation to joint surface and weight-bearing area may have influenced the result of the bone-area study (Reimann et al. 1977).

In conclusion it may be stated that intraosseous pressure measurements as the only evaluation of the intraosseous haemodynamic conditions in osteoarthritis are of only limited value. The vascular factor in primary osteoarthritis needs further clarification. Our measurements have perhaps been done at too late a phase of the osteoarthritis, so that other pathogenetic factors have been veiled. As we found increased pressure in the femoral heads also in secondary osteoarthritis and rheumatoid arthritis, this abnormality must be characteristic of the final stage of the disease.

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