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THE RELATIONSHIP BETWEEN INCREASING INTRAARTICULAR PRESSURES AND INTRAOSSEOUS PRESSURES IN THE JUXTAARTICULAR BONES

An Experimental Investigation in Dogs

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The present experimental investigation of the relationship between intraarticular and intraosseous pressures was carried out in mongrel dogs. Under general anaesthesia simultaneous pressure measurements were performed in the femoral artery, the knee joint and the tibia and femur adjacent to the knee joint. The intraarticular pressure was increased by infusion of saline. Increase in the knee joint pressure caused an increase in the femoral intraosseous pressure, while the tibial intraosseous pressure remained unchanged. The pressure increase in the femur was most pronounced in dogs with intact epiphyseal plates. It is suggested that the rise in the femoral pressure was caused by compression of the venous drainage from the bone. Further evidence to support this suggestion was obtained from anatomical studies, intraosseous phlebography and experiments with selective venous compression.

Key words: arthropathy; bone marrow pressure; intraarticular pressure; knee joint; venous drainage

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The pathophysiological mechanisms of chronic arthropathies are still unclear. In osteoarthritis, intraosseous stasis and hypertension seem to be important factors (Mériel et al. 1955, Hulth 1959, Philips 1966, Arlet et al. 1968, Arnoldi et al. 1972, Lynch 1974). Furthermore osteoarthritis is often preceded by or associated with synovitis with an increased volume of synovial fluid (Arnoldi & Reimann 1979), which increases the intraarticular pressure (Eyring & Murray 1964). Recent experimental studies have shown that increased intraarticular pressure can increase the femoral marrow pressure in rabbits, presumably by inhibition of the intraarticular venous drainage from the bone (Arnoldi et al. 1979). In the pathogenetic sequence leading to chronic arthropathy it is thus likely that synovitis is followed by venous stasis and intraosseous hypertension. However, more evidence is necessary to elucidate the causal relationship between increased intraarticular pressure, intraosseous hypertension and arthropathies.

The aim of this paper is to present an experimental method which allows such studies. As a first step the present investigation concerns the relationship between intraarticular and intraosseous pressures of the knee and the venous drainage of the juxtaarticular bones. The dog was chosen as the experimental model because the magnitude of the structures, even in postnatal life, allows application of the measuring equipment. Thus it is possible to study the joint-bone pressure relationship at all ages.

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MATERIAL AND METHODS

The experiments were performed on 18 mongrel dogs under general anaesthesia. The anaesthesia was initiated by intravenous injection of pentobarbital and maintained by ventilation with 0.5 per cent halothane.

Six young dogs with epiphyseal plates and 6 adult dogs with closed epiphyseal plates were used for the pressure measurements. Both knees were examined, thus the total number of these experiments was 24. The blood pressure, the intraarticular pressures of the knee joint and the intraosseous pressures were recorded simultaneously. The intraosseous pressure was measured using a 4.5 cm bone cannula (Radner®) with an outer diameter of 2 mm and an inner diameter of 1.5 mm. A little skin incision was made and the cannula with trocar was inserted extraarticularly into the femur and the tibia from the medial side of the knee. The cannulae were placed close to the articular surfaces and the positions were checked using an image intensifier. In young dogs with epiphyseal plates the cannulae were placed between the epiphyseal plates and the articular bone surface. The arterial blood pressure was measured via a 1.2 mm Venflon® catheter placed in the femoral artery and the intraarticular pressure recorded via an intravenous 1 mm cannula. Before connection to the measuring system the cannulae were flushed with heparin-saline.

The cannulae and the catheter were connected by means of 200 cm manometer lines (Portex®), inner diameter 1.5 mm, to a pressure recording system (Siemens), consisting of a strain gauge transducer 746, a pressure amplifier and a Mingograf 805. A constant saline perfusion at a rate of 5 ml/h was used on all channels, to establish a permanent water column between the measuring point and the transducers to avoid coagulation and obstruction (Figure 1). The pressures were recorded with a paper speed of 2.5 mm/s.

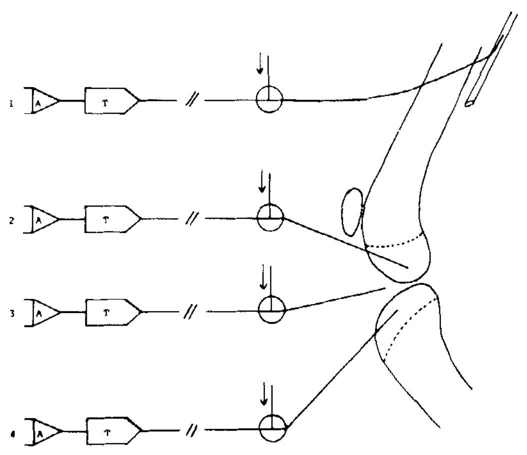

Figure 1. Diagram showing the location of the cannulae and their connection to the measuring system. T – transducer, A – amplifier.

Variations in the knee joint pressure were obtained by infusion of saline into the knee joint cavity. The measuring cannula in the knee joint was connected via a three-way stop-cock to a bottle with saline. The pressure in the knee joint was increased by elevating the bottle. This was done suddenly or slowly with increments of 5 cm water from 0 to 100 cm. After each infusion the intraarticular pressure was measured by turning the cock.

Intraosseous phlebography was performed in 2 dogs with epiphyseal plates and in 2 dogs with closed epiphyseal plates. The X-ray contrast medium (Biligrafin®) was injected into the bone marrow through the cannulae which had been used for the pressure recording. By means of an X-ray television system (Siemens) the pictures were transferred to a video tape.

In 4 dogs anatomical dissections was carried out to study the venous drainage from the juxtaarticular parts of the femur and tibia. The identification of the veins was facilitated by injection of methylene blue through the intraosseous cannulae prior to the dissection.

At the end of the experiments the animals were sacrificed and the knee joints were examined. Penetration of cannulae into the joint cavities was not observed.

A significance test for linear ranks (Page 1963) was used for the statistical analysis.

RESULTS

Stable resting intraosseous pressures were obtained within a few minutes after application. The pressure tracings were pulsative, relating heart activity as well as respiration. A compression of the femoral vein was followed by an increase in the bone marrow pressure in both the tibia and femur.

Before infusion into the knee joint, the marrow pressures in the femur and tibia were higher in young animals with preserved epiphyseal plates than in older ones without epiphyseal plates (Figures 2 and 3).

The gradual increase in the pressure in the knee joint resulted in a gradual increase in the femoral marrow pressure. The increase was most pronounced in animals with epiphyseal plates, but it was significant ($P<0.001$) in both groups of dogs (Figures 2 and 3). In contrast, the tibial bone marrow pressure did not change.

When the knee joint pressure was increased suddenly to 100 cm water, it was followed by a slightly delayed increase in the femoral marrow pressure and when it suddenly was decreased again, a slightly delayed decrease of the femoral

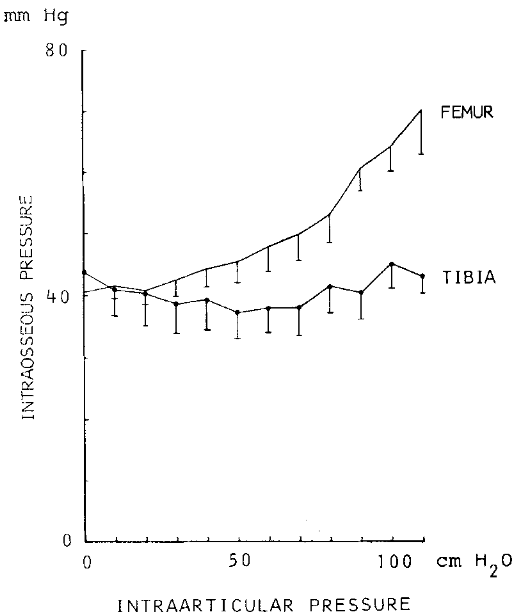

Figure 2. The relationship between intraarticular and intraosseous pressures in dogs with epiphyseal plates.

marrow pressure occurred (Figure 4). Throughout this procedure the tibial marrow pressure remained constant. The increased femoral marrow

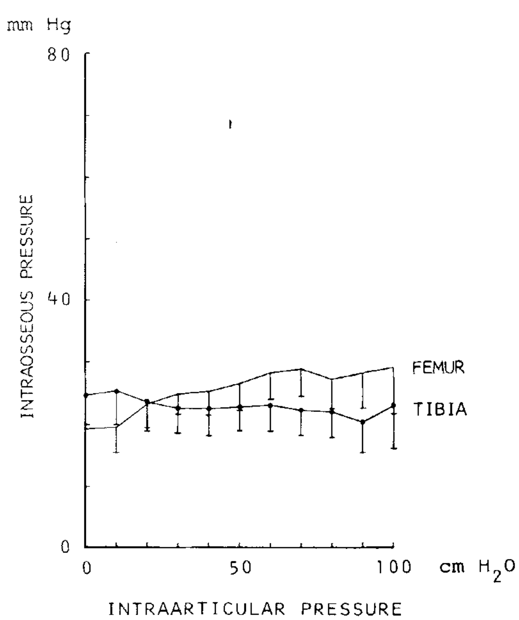

Figure 3. The relationship between intraarticular and intraosseous pressures in dogs without epiphyseal plates.

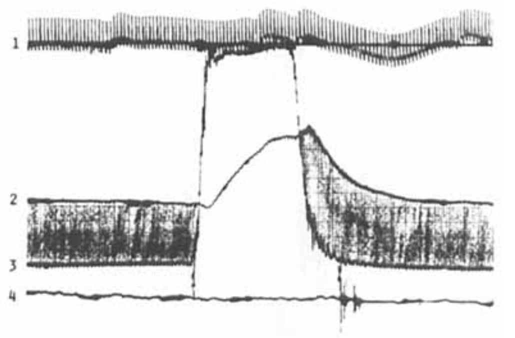

Figure 4. Pressure tracings from simultaneous measurements in the femoral artery (1), the femoral bone marrow (2), the knee joint (3) and the tibial bone marrow (4).

pressure approached but did not reach the level of the mean blood pressure.

Intraosseous phlebography demonstrated the venous drainage from the juxtaarticular bones (Figure 5). A vein from the distal extremity of the femur and another from the proximal end of the tibia appeared behind the knee. The two veins joined before entering the popliteal vein. In adult dogs a substantial venous drainage through the femoral diaphysis was observed but this was not found in young dogs. During phlebography the contrast passed instantaneously into the veins from the juxtaarticular bones.

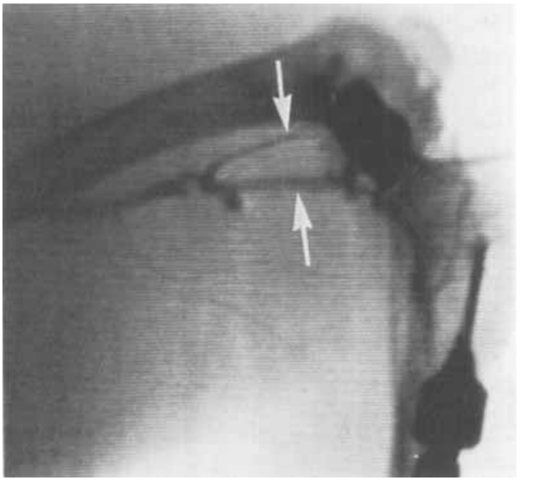

Figure 5. Phlebogram demonstrating the tibial and the femoral drainage veins from the juxtaarticular ends of the bones (arrows).

Figure 6. Diagram showing the anatomy of the drainage veins.

By anatomical dissection the veins could be identified. It appeared that the smaller femoral epiphyseal drainage vein had an intraarticular course and passed through the joint capsule. The larger tibial vein was located extraarticularly but with a close relationship to the joint capsule (Figure 6). A selective compression of the two veins, during simultaneous measurements, resulted in an increase in the femoral and the tibial bone marrow pressure, respectively.

DISCUSSION

The present experimental investigation in dogs has demonstrated that an increase in the knee joint pressure is followed by an increased pressure in the juxtaarticular femoral bone marrow. This observation supports the corresponding results in rabbits (Arnoldi et al. 1979). The additional evidence from intraosseous phlebography, anatomical studies and selective venous compression strongly indicates that the pressure increase is caused by an intraarticular compression of the venous drainage from the distal end of femur.

Selective compression of the tibial drainage vein caused increased tibial marrow pressure. Therefore the absence of an increase in the tibial marrow pressure, during intraarticular pressure increase, may be explained by the extraarticular location of the tibial drainage vein.

The increase in bone marrow pressure after venous compression is in accordance with other studies (Lemperg & Arnoldi 1978).

The higher bone marrow pressure in dogs with epiphyseal plates, during increased intraarticular pressure, may be explained by a more complete blockage of the venous drainage than in older dogs. Thus, phlebography did not reveal any passage of blood via diaphyseal veins in the young dogs, which is in contrast to dogs without epiphyseal plates, where a substantial metaphyseal drainage was observed.

Human anatomical studies of the distal end of the femur indicate that some drainage veins have an intraarticular course (Rogers & Gladstone 1950). This makes it likely that conditions accompanied by increased intraarticular pressures such as rheumatoid arthritis (Jayson & Dixon 1970) and haemarthrosis in haemophilics (Trueta 1968) may cause increased intraosseous pressures as in the experimental model. However, further anatomical studies are necessary to clarify the relationship between the tibial and the femoral drainage veins and the knee joint cavity in humans. In addition, studies of the relationship between the intraarticular pressure and the intraosseous pressures have to be performed on the human knee.

The significance of the present observations in relation to the pathogenesis of chronic arthropathies, or juvenile osteonecrosis of the distal femoral epiphysis (Goff 1954), is still a matter for future investigation. The problem can be further elucidated by longitudinal studies with chronic increased intraarticular pressures and such studies are in progress.

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