FEMORAL HEAD BLOOD FLOW IN
FEMORAL NECK FRACTURES

AN ANALYSIS USING INTRA-OSSEOUS PRESSURE MEASUREMENT

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We studied 50 patients with fractures of the femoral neck, 33 intracapsular and 17 extracapsular. Intracapsular pressure was measured by a transducer within the bone to quantify blood flow, and intracapsular pressure by a needle introduced into the joint space.

The mean intracapsular pressure was lower in the extracapsular fractures. In these, the mean intracapsular pressure in the femoral head was unchanged by aspiration of the joint. However in the intracapsular fractures aspiration produced a significant decrease in intracapsular pressure and an increase in pulse pressure within the femoral head.

The results suggest that aspiration of intracapsular haematoma produced an increase in femoral head blood flow by relieving tamponade.

The major complications of intracapsular fractures of the femoral neck are failure of fixation, nonunion and avascular necrosis. Avascular necrosis may be caused by damage to the retinacular vessels at the time of fracture or, possibly, by the tamponade effect of an intracapsular haematoma (Soto-Hall, Johnson and Johnson 1964; Kristensen, Kjaer and Pedersen 1989). We have investigated the vascularity of the femoral head following proximal femoral fractures, using intracapsular pressure as an indicator of bone blood flow.

Intra-osseous pressure is not a measurement of arterial or venous pressure alone, but a combination of the two; it can be shown to parallel bone blood flow. The relationship between bone blood flow and intra-osseous pressure has been demonstrated in animals (Azuma 1964; Shim, Hawk and Yu 1972); direct flow measures cannot be made in this way but changes in flow are reflected by changes in pressure.

PATIENTS AND METHODS

We studied 50 patients with proximal femoral fractures: 17 were extracapsular and 33 intracapsular (nine impacted or minimally displaced and 24 displaced). All measurements were made under anaesthesia and before the fracture was fixed, either by a sliding screw or multiple cannulated screws.

Intracapsular pressure was measured with a 125 mm, 18 G spinal needle and three-way tap attached to a 150 cm manometer tube. This was connected to a Gould P50 pressure transducer and then to an amplifier and chart recorder. The system was flushed with saline before insertion of the needle. Pressures were measured with reference to a zero level with the tap open to atmosphere and placed at the level of insertion of the needle. The joint space was approached anterolaterally, guided by image intensification. After all readings had been taken, the intracapsular placement of the needle was confirmed by injection of 1 ml of radio-opaque dye (Niopam). For displaced fractures, pressures were measured after the fracture had been reduced, which often required the leg to be internally rotated, whilst in the remainder the pressures were measured with the hip in neutral position. The hip was not moved during the pressure recordings.

Intra-osseous pressure was measured with a purpose-built stainless steel probe (Gaeltec Ltd) 120 mm in length and 2 mm in diameter. The pressure sensor was 2 mm from...
the tip; it faced sideways. This catheter-tip transducer records the pressure at the site of interest with no intermediate manometer tubing and taps. The transducer can be zeroed before insertion; all measurements are then correct with respect to atmospheric pressure. A standard transducer/catheter system would have made it very difficult to establish an accurate zero reference, because of uncertainty as to the position of the end of the catheter inside the femoral head. Another advantage of the method is that the size, shape and rigidity of the probe makes it easy to introduce through a guide wire hole, while its radio-opacity makes it possible to achieve precise placement. The transducer is connected to an amplifier and chart recorder to provide permanent recordings.

In each hip, the probe was inserted through the central guide wire channel and its placement was confirmed by image intensification. Readings were taken from the trochanteric region and from the head before and after aspiration of the hip. From the readings the pulse pressure was taken as the amplitude between the maximum and minimum of the waveform, and the mean pressure as the mid-point between them (Fig. 1). Intracapsular and intra-osseous pressures were measured simultaneously.

Statistical testing used paired t-tests.

RESULTS

The mean intracapsular pressure before aspiration was 23.07 mmHg (SD 39.1) in extracapsular fractures, and 30.03 mmHg (SD 47.48) in intracapsular fractures. The hip was aspirated with a 20 ml syringe until the intracapsular pressure fell to zero. The exact amount of blood aspirated was difficult to quantify because once the lateral cortex had been perforated there was a slow leak of fluid from the joint.

There were no significant differences in the mean or pulse pressures recorded in either type of fracture in the trochanteric region (Table I), or in the femoral head (Table II).

In extracapsular fractures, there were no significant differences in the mean or pulse pressures in the head before and after aspiration (Table II). However, in intracapsular fractures, the mean pressure in the femoral head fell by 4.56 mmHg and the mean pulse pressure rose by 0.65 mmHg following aspiration (Table II); these changes are statistically significant for both mean pressure (p = 0.037) and for pulse pressure (p = 0.038).

DISCUSSION

Intra-osseous pressure measurement has been used by other authors as a means of measuring bone blood flow (Azuma 1964; Shim et al 1972), but earlier methods were restricted by technical shortcomings. The method we describe, using a catheter-tip pressure transducer, has the advantage that the pressure sensor is in direct contact with the site to be measured. This technique is easier and gave far greater reproducibility in our hands.

An initially surprising finding was the increased intracapsular pressure in some extracapsular fractures. Theoretically there should be no direct bleeding into the joint space, but these fractures are almost always produced by a fall, and local trauma may produce an effusion. It is therefore less surprising that some of these patients may develop an effusion or a haemarthrosis.

The large standard deviations in the results are a
feature of all work involving intra-osseous pressures; this makes direct comparison between individuals difficult. However, in each individual subject the values are reproducible if the pressure is recorded from the same place, as in our study. Therefore if external conditions are altered and cause a change in bone blood flow, this will be reflected by changes in intra-osseous pressure.

In individual cases changes in intra-osseous pressure probably do reflect changes in bone blood flow: venous obstruction will cause an increase in pressure; abolition of arterial flow will be reflected by abolition of the pulse pressure (Azuma 1964).

It has been suggested by various authors (Soto-Hall et al 1964; Crawford et al 1988) that increased pressure in the joint cavity, after an intracapsular fracture, may reach levels sufficiently high to obstruct the flow of blood to the femoral head. Experimental work with juvenile animals (Swiontkowski et al 1986; Vegter and Lubsen 1987; Svalastoga, Kiaer and Jensen 1989) has shown that sustained increases in intracapsular pressure, even to levels no higher than 40 mmHg in the rabbit, can produce hypoxia and ischaemic changes in the femoral head. Intracapsular pressures well above diastolic have been reported in the clinical literature (Crawford et al 1988; Strömqvist et al 1988); in our series intracapsular pressures varied from 0 to 200 mmHg.

There is therefore good evidence that high intracapsular pressures can occur after fractures of the femoral neck, more particularly in relatively undisplaced intracapsular fractures where the capsule is probably intact. However, there has been little direct evidence in man that these intracapsular pressures can stop or decrease the bone blood flow to the femoral head. Strömqvist et al (1988) showed indirectly, using bone scanning techniques, that some femoral heads had an increased uptake following aspiration of the hip. However, other factors may have influenced this result: the hips were scanned 24 hours after aspiration and after osteosynthesis. Kristensen et al (1989) showed increases in PO2 following aspiration of the hip in two of nine patients with intracapsular fractures, but intracapsular pressures were not measured.

The fall in mean intra-osseous pressure that we report after aspiration of intracapsular fractures may be interpreted as being due to relief of an initial venous obstruction by removal of an intracapsular haematoma. Similarly, the associated increase in pulse pressure may be interpreted as showing an increase in bone blood flow. Our results add further evidence that an intracapsular haematoma, in the presence of a damaged intra-osseous circulation after an intracapsular fracture, may cause ischaemia of the femoral head which can be reversed by aspiration of the joint. If this is to prevent osteocyte death, then it should be performed as soon as possible after the fracture.

We acknowledge the assistance of the Smith and Nephew Research Foundation, Richards Medical and Glaxo Laboratories. Although none of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but are directed solely to a research fund, foundation, educational institution, or other non-profit institution with which one or more of the authors is associated.

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