CAPSULAR DISTENSION AND INTRACAPSULAR PRESSURE
IN SUBCAPITAL FRACTURES OF THE FEMUR

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It has been shown that raised intracapsular pressure causes avascular necrosis of the femoral head in experimental animals, but the relevance of this to clinical fractures of the femoral neck is controversial. We have studied 19 patients with intracapsular fractures of the femoral neck by pressure measurement and by ultrasonography to demonstrate capsular distension.

The intra-articular pressure in Garden Grade I and II fractures averaged 66.4 mmHg with a maximum of 145 mmHg. In 10 Garden Grade III and IV fractures the average pressure was 28 mmHg with a maximum of 65 mmHg. Most of the recorded intracapsular pressures were high enough to have caused possible vascular embarrassment, and it is suggested that early decompression of the haemarthrosis should be considered.

A haemarthrosis under pressure after an intracapsular fracture of the femoral neck has been cited as a possible cause of post-traumatic avascular necrosis (Soto-Hall, Johnson and Johnson 1964; Drake and Meyers 1984), but published results have been inconclusive because of small numbers, inaccurate measuring devices, and uncertainty as to the pressure required to reduce significantly the blood supply of the femoral head.

The vascular supply of the head of the femur has been studied in detail (Trueta and Harrison 1953), and it has been shown that the retinacular vessels on the surface of the neck and those in the ligamentum teres are all influenced by changes in intracapsular pressure (Boyd, Zilversmit and Calandrucchio 1955; Woodhouse 1964).

Normal pressure within the hip is no more than at atmospheric pressure but, once initial laxity has been taken up, the relatively inelastic nature of the capsule ensures that the introduction of a small amount of fluid causes a marked increase in pressure. The capsule is even less elastic in the elderly, especially when arthritis has caused capsular fibrosis. All the older manometric methods of measuring pressure partially decompress the joint and the inelastic nature of the capsule means that any loss of volume causes an immediate drop in pressure, and a falsely low measurement.

Other factors may influence the intracapsular pressure. The psas tendon crosses the anterior capsule and is said to exert compression (Soto-Hall et al. 1964); this is especially important when the leg is in medial rotation because the tendon is then wrapped around the capsule. For this and other reasons different results may be obtained when the patient is under general anaesthesia. The position of the limb is also important because the capsule itself becomes tight in extension and in medial rotation (Walmsley 1928). Lloyd-Roberts (1953) confirmed this and also noted that the capacity of the joint was greatest in lateral rotation of a hip with an effusion due to Perthes' disease.

The pressure required to impair blood supply to the femoral head is not known. It has been estimated to be 40 mmHg by Soto-Hall et al. (1964), and to be that of the diastolic pressure by Drake and Meyers (1984). More recently Swiontkowski et al. (1986) have shown that, in the rabbit, blood flow to the femoral head began to decline significantly at pressures as low as 40 cm H₂O.

In our series we have estimated the distension of the capsule by ultrasonography, comparing this with the normal side, and have also made intracapsular pressure recordings.

METHOD

A consecutive series of patients with subcapital fractures of the femoral neck were examined on admission by ultrasonography of both hips in the supine position. Examination was made anteriorly along the axis of the femoral neck and the iliofemoral ligament. Demonstr-
tion of the femoral head and acetabular labrum allowed identification of the femoral neck and the joint capsule (Figs 1a and 1b).

The separation between the femoral neck and the joint capsule was measured on the screen with calipers and the maximum distance in both hips was recorded as hard copy (Fig. 2). In those cases where the capsule had ruptured there was clear evidence of an extracapsular haematoma (Fig. 3); this is seen as displacement of the soft tissues away from the capsule with mildly echogenic material separating them. There is a marked difference on ultrasound between clear synovial fluid, which is not echogenic, and haematoma (either intra-articular or extra-articular) which is slightly echogenic. In three cases, ultrasound examination could not be performed in the time available and a fourth case was unsuitable because of a total hip replacement on the uninjured side.

In the first five cases pressure measurements and aspiration were performed under ultrasound control. Measurements were made with the patient supine and the leg as near to the neutral position as was comfortable. An 18 gauge needle was attached to a Kontron 108 pressure monitor using a Gould P23 transducer. The system was closed but a three-way tap allowed calibration.

For each case the system was calibrated against a mercury manometer and zero was set at the height of the anterior border of the greater trochanter. Under local anaesthesia the needle was introduced anteriorly; its passage through the thick anterior capsule could be clearly felt, followed by free travel within the joint until bone was reached. When the needle was felt to be within the joint the tap was opened and a measurement taken. A syringe was then applied, and the joint aspirated. If there was immediate aspirate it was assumed that the needle had not penetrated the joint and the procedure was repeated. In cases with high pressure there was a gush of blood as soon as the pressure recorder was detached. Measurements were then made in the uninjured hip.

RESULTS

Of the 19 patients studied, 15 were women. The mean age of the patients was 72.5 years (range 50 to 89 years) and the mean interval between injury and measurement

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**Fig. 1a**

Ultrasound scan and diagram to show the normal appearance of the femoral head and neck and the joint capsule.

**Fig. 1b**

**Fig. 2**

Ultrasound scans of both hips to show the capsular distension and intracapsular haematoma on the fractured (left) side.

**Fig. 3**

Ultrasound scan of a fractured hip to show a large extracapsular haematoma (between markers); note its ill-defined edge.
was 12.1 hours (range 3 to 25 hours). Radiographs were graded according to Garden's classification (1961). There were three Grade I, six Grade II, four Grade III, and six Grade IV fractures (Table I), that is nine patients with minimally displaced fractures.

Ultrasound showed that the mean capsular distension of those hips in which the capsule had remained intact was 9.2 mm (5.5 to 12 mm) in the minimally displaced group compared with 11.6 mm (11 to 12 mm) in the displaced group. Four of the displaced group had extracapsular haematomas while only one was revealed in the minimally displaced group.

| Table I. Intracapsular pressure in 19 cases of subcapital fracture of the neck of the femur |
|---------------------------------|------------------|------------------|------------------|
| Garden grade | Number of patients | Mean (mmHg) | Range |
| I | 3 | 103 | 69 to 145 |
| II | 6 | 48 | 37 to 71 |
| III | 4 | 37 | 20 to 65 |
| IV | 6 | 22 | 5 to 48 |

In cases with an intact capsule the separation of neck and capsule was about twice that on the normal side, with values of 9.9 mm and 5.3 mm respectively.

The mean intracapsular pressure in the nine minimally displaced cases was 66.4 mmHg (range 37 to 145 mm), whereas in the displaced group the mean was 28.0 mmHg (range 5 to 65 mm). The mean pressure in the uninjured hip was 6.1 mmHg. The low pressures found in the displaced group were associated with rupture of the capsule on ultrasonography, and in cases where this had been proven, the mean pressure was 19.5 mmHg.

DISCUSSION

The presence of a haematoma under pressure within the joint after an intracapsular fracture has been well documented (Woodhouse 1964; Soto-Hall et al. 1964; Drake and Meyers 1984), but its importance in the aetiology of avascular necrosis of the femoral head is disputed (Drake and Meyers 1984; Nagy et al. 1975).

Earlier studies have generally given lower pressure values than those we recorded and, with the uncertainty as to the pressure required to compromise blood supply, have led to conflicting conclusions. Very high pressures were reported by Strömqvist et al. (1985); they found pressures of 280 and 360 mmHg in two cases examined with the leg in extension and medial rotation. They also demonstrated by bone scans that, in some cases, blood flow to the femoral head was occluded before aspiration but restored after decompression.

Soto-Hall et al. (1964) used a manometric method; this is likely to give artificially low results since the pressure falls rapidly with the release of the haematoma due to the small capacity of the hip and the inelasticity of the capsule.

There is no direct evidence of the pressure required to occlude the blood flow to the human femoral head, but Borgsmiller et al. (1980), using a hydrogen washout technique in immature dogs, found that there was no significant reduction at 50 mmHg but that a pressure of 100 mmHg reduced the flow and 150 mmHg caused complete occlusion of the blood flow to the epiphysis. Woodhouse (1964), using adult dogs, found that avascular necrosis developed when intracapsular pressure was maintained at 50 mmHg for 12 hours after osteotomy of the femoral neck, a situation similar to that in the human adult after a subcapital fracture.

The length of time the human femoral head can survive without a blood supply is unknown, but Henard and Calandruccio (1970) produced avascular necrosis of the capital femoral epiphysis of immature dogs after holding the left hip in abduction, extension and medial rotation for six hours or more.

In our study the capsule was demonstrated by ultrasonography and its distension was measured before aspiration, while it was possible to demonstrate the extracapsular haematoma when the capsule had ruptured, which was the case in four of the 10 displaced fractures and in one of the nine undisplaced fractures. The intracapsular pressure was low in all cases with capsular rupture.

The presence or absence of a high pressure due to haemarthrosis is unimportant in displaced fractures since the retinacular vessels have probably been damaged by the displacement of the fracture. The chance of avascular necrosis is high, and hemiarthroplasty is often advised. However, our series has shown that a high pressure may follow undisplaced and minimally displaced fractures. In this group, the mean pressure was 66.4 mmHg; in the three cases of Garden I fractures it averaged 103 mmHg. Undoubtedly these high pressures (approaching systolic blood pressure) must impair or even occlude the blood supply but it is likely that even a modest increase in pressure may significantly reduce blood flow.

Conclusions. We have confirmed that a haemarthrosis under high pressure may follow an intracapsular fracture of the femoral neck, and have shown by ultrasound that this results in capsular distension. The pressure of the haemarthrosis may exceed the diastolic blood pressure, and must embarrass the blood supply to the femoral head. It may therefore be important to decompress the joint by either a fenestration of the capsule or an aspiration of the haemarthrosis at an early stage, whenever it is possible that the femoral head will be retained.
REFERENCES


