From the University Department of Orthopaedics in Lund, Sweden

Transient synovitis of the hip in the child

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I Introduction

In 1973 Hans Bohr, using ^{18}F scintigraphy, demonstrated the characteristic pattern of defective isotope uptake in the proximal femoral epiphysis in children with (Legg-Calvé-)Perthes disease. With the introduction of ^{99m}Tc scintigraphy this finding was confirmed (Danigelis et al. 1975, Fasting et al. 1978, Bensahel 1980, Tachdjian 1980, LaMont et al. 1981) and scintigraphy was accepted as a diagnostic tool in early Perthes disease preceeding conventional radiography by several months. However, the possibility of establishing the diagnosis of Perthes disease by scintigraphy in the radiographically silent stage of the condition has been contradicted by reports of cases of transient synovitis of the hip in whom a defective uptake in the proximal femoral epiphysis was not followed by radiographic evidence of necrosis (Sutherland et al. 1980, Kloiber et al. 1983).

The similarities in the clinical history and epidemiology with regard to age and sex distribution and the later radiographic evidence of necrosis among children initially presenting with clinical symptoms of transient synovitis have proposed an etiological connection between the two diagnoses. Further support for this suggestion is provided by histological findings suggesting repeated vascular insults in the development of Perthes disease (Inoue et al. 1976).

The blood supply to the proximal femoral epiphysis in this age group is derived mainly from the lateral capsular branches of the medial circumflex artery and partly from medial capsular branches, with no contribution across the growth plate and a very small contribution via vessels in the ligamentum teres (Trueta et al. 1957, Theron 1980). The arteries and veins are located intracapsularly and are thus exposed to an increase in intracapsular pressure. Interruption of these vessels in animals causes necrosis of the epiphysis (Kemp et al. 1981), and in puppies intracapsular tamponade with increased intracapsular pressure and disturbance of blood flow through the epiphysis causes irreversible avascular damage (Woodhouse 1964, Lucht et al. 1983). This mechanism has also been proposed in the development of necrosis of the epiphysis in intracapsular fractures and in septic arthritis (Minikel et al. 1983) as well as in transient synovitis (Kloiber et al. 1983) and in undisplaced cervical fractures in the adult (Wingstrand et al. 1986).

The diagnosis of transient synovitis of the hip has so far been based on clinical findings. Conventional radiography has offered little information in this condition (Brown 1975); mainly the so called capsular shadow, said to reflect capsular swelling

in the affected hip, or an increase in the medial joint space. Recently sonography has been found to be diagnostic of intracapsular effusion in children (Jäppinen et al. 1984, Wingstrand et al. 1984).

Synovitis, induced in animals or spontaneous in childen, may cause cartilage overgrowth, reflecting a secondary metabolic disturbance (Gershuni & Axer 1974, Gershuni et al. 1978).

In this monograph I have correlated the findings in 83 children admitted to the Department of Orthopaedics, University Hospital, Lund, Sweden from May 1983 through July 1985 with regard to the following aspects of transient synovitis:

1) To evaluate the diagnostic capacity of conventional radiography and to identify late radiographic sequelae.
2) To evaluate computed tomography and sonography for diagnosis of transient synovitis of the hip.
3) To describe the ^{99m}Tc-MDP scintimetry pattern in these children and to follow the natural history of cases with evidence of defective isotope uptake in the epiphysis.
4) To identify and quantify the intracapsular effusion and to measure the intracapsular pressure in relation to the position of the hip and to the effect of the aspiration.
5) To analyze biochemically proteoglycan fragments in the joint fluid indicating imbalance in cartilage metabolism.

II Patients

The material consisted of 83 children admitted to our department with acute onset of hip pain and with the clinical diagnosis of transient synovitis of the hip from May, 1983 through July, 1985. The children were studied in 5 subsets (A-E) with considerable overlap (Figure 1).

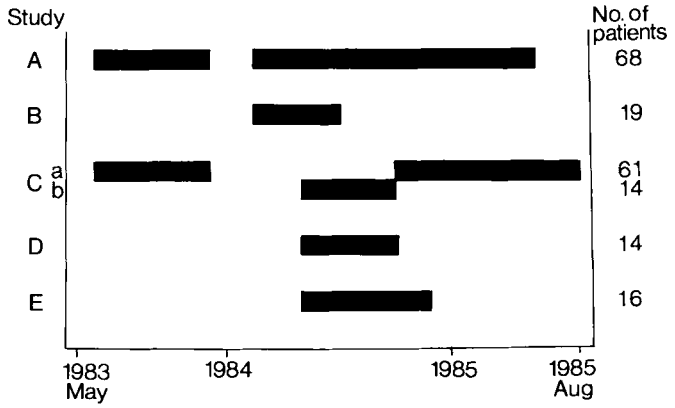


Figure 1. Total material of transient synovitis of the hip divided in subsets A–E demonstrating the period of the studies and the degree of overlapping.
A=Conventional radiography.
B=Computed tomography and sonography.
C=^{99m}Tc-MDP-scintimetry; Pin-hole collimator series (a); Parallel-hole collimator series (b).
D=Intracapsular pressure measurement.
E=Biochemical analysis.

A. Conventional radiography

This study was undertaken to evaluate cartilage reaction, the development of coxa magna and acetabular skeletal reaction following transient synovitis as well as to evaluate the lateral capsular shadow and medial iliopsoas shadow in the diagnosis of the disease.

The study comprised 70 children in two consecutive series initially examined with conventional radiography. Fifty-one were boys, 19 were girls; the mean age was 6 (1–12) years. Two children were excluded due to bilateral symptoms leaving 68 children in the initial radiographic examination. Seventeen children were subjected to hip joint aspiration, 14 of those in a consecutive series (Figure 1; Group D), leaving 51 children who were called for a follow-up radiographic examination. Forty-nine attended this follow-up at 7 (5–9) months following the episode of synovitis.

The diagnosis of transient synovitis was established with sonography at the time of the initial radiographic examination in all except the initial 27 children when sonography was not available. In those children the diagnosis was based on their history and clinical findings, i.e. onset of hip pain with limitation of active and passive movements, no or moderate increase in erytrocyte sedimentation rate and visually normal radiographs in AP and Lauenstein views.

At follow-up all children were free of symptoms except one child who had developed radiographically diagnosed Perthes disease. This child was excluded from the other aspects of the radiographic study.

B. Computed tomography and sonography

This study was undertaken to evaluate computed tomography (CT) and sonography in the diagnosis of hip joint effusion in the child and to describe the normal capsular anatomy.

Nineteen cases of transient synovitis were examined as were 14 asymptomatic children. There were 15 boys and 4 girls with transient synovitis; mean age was 7 (3–12) years. (Table 1 and 2.)

C. ^{99m}Tc-MDP scintimetry

The radionuclide scintimetry studies were undertaken in order to assess the metabolic pattern in children with transient synovitis of the hip, to follow the natural history of cases with evidence of impaired isotope uptake in the epiphysis and to study the effect of aspiration in these cases.

1. Pin-hole collimator series

Twenty-seven consecutive one to 11 year old children presenting with the clinical symptoms of transient synovitis of the hip were included in a first series analyzed numerically with a region of interest method described below. Nineteen were boys,

8 were girls. The mean age was 7 (1–11) years. One patient was excluded due to lack of co-operation leaving 26 children in this study. For further clinical data see Table 3.

In a second study 56 children were examined. One child who developed Perthes disease on radiographic follow-up was excluded leaving a total of 55 children. Thirty-nine were boys and 16 were girls; mean age was 7 (3–13) years. (Table 4.) Follow-up scintimetry was performed in 10 children; in one twice, thus a pair of 66 pin-hole images were obtained. Two children were excluded due to movement during the examination leaving 53 children in this study. These examinations were numerically analyzed with a profile of interest method described below.

2. Parallel-hole collimator series

Fourteen consecutive children were included in a third study where scintimetric findings were analyzed numerically as described below and were correlated with sonographic data and intracapsular pressure and volume recordings. Twelve were boys and two were girls. The mean age was 6 (3–12) years. for further clinical data see Table 5.

D. Intracapsular pressure measurement

The purpose of this study was to identify and quantify intracapsular effusion as well as to study the intracapsular pressure in relation to the position of the hip, to scintimetric findings and to the effect of aspiration of the effusion.

Fourteen consecutive children presenting with the clinical and sonographic findings of unilateral transient synovitis were included in this study. Twelve were boys, two were girls. The mean age was 6 (3–12) years. The mean duration of symptoms at time of aspiration was 41 (23–144) hours. For further clinical and laboratory data see Table 5.

One patient (Case 9) had Perthes disease in the right hip. This diagnosis had been radiographically and scintimetrically established 5 months prior to this episode of acute onset of pain in the left hip, which was radiographically normal. Case 7 had a non-ossifying fibroma in the neck of femur in the left non-symptomatic hip. In the other children there were no symptoms or pathological radiographic or sonographic findings in the control hip.

E. Biochemical analysis

1. Proteoglycan fragments in joint fluid

This study was undertaken in order to evaluate a possible metabolic response of the articular cartilage to an acute episode of synovitis as reflected by an increase in the

concentration of proteoglycan fragments in joint fluid. Experimentally induced hip joint synovitis in the immature rabbit (Gershuni et al. 1981) has indicated that joint cartilage responds rapidly to synovitis with increased thickness due to increased hydration and, at a later stage, due to increased metabolism and synthesis.

The material consisted of hip joint fluid specimens collected following aspiration of 16 hips with a clinical and sonographic diagnosis of transient synovitis of the hip. Twelve were boys, 4 were girls. The mean age was 6 (3–14) years. The mean duration of symptoms at time of aspiration was 2.4 (1–10) days.

Four patients with radiographically manifest Perthes disease, two children with congenital dislocation of the hip and one child with traumatic dislocation of the hip without fracture served as controls. Two of the children with manifest Perthes disease were aspirated during an episode of acute onset of pain and limitation of movements whereas two were aspirated in connection with preoperative or diagnostic arthrographic examination as were the 3 children with dislocation of the hip. (Table 7.)

III Methods

A. Conventional radiography

Conventional radiographs were obtained in AP and Lauenstein views at time of presentation and at follow-up. The following parameters were studied on the AP views (Figure 2):

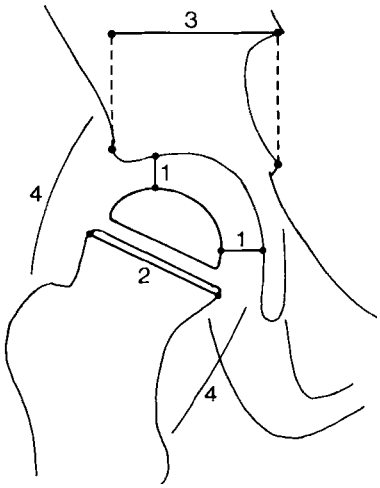


Figure 2. Measurements of medial and cranial joint space (1), the metaphyseal width (2) and the acetabular roof distance (3) as defined in the text on the AP projections on the conventional radiographs. The fat planes lateral and medial to the hip were evaluated (4).

1. Joint space

Medial joint space; defined as the distance from the medial osseous part of the epiphysis to the lateral margin of the tear-drop formation. Cranial joint space; defined as the cranial perpendicular distance between the osseous part of the epiphysis and the acetabulum.

2. Metaphyseal width

Metaphyseal width; defined as the maximum diameter of the metaphysis.

3. Acetabulum

Width of the acetabulum; as measured from the lateral margin of the acetabular roof to the medial margin of the y-cartilage in the horizontal plane.

The measurements were compared with the corresponding measurements in the contralateral non-symptomatic hip. Measurements were obtained with the aid of a digitizer (Hi-Pad®)connected to a microcomputer. The equipment had a resolution of 0.1 mm.

4. Capsular shadow and iliopsoas shadow

To evaluate the radiographs with regard to the lateral capsular shadow and medial iliopsoas shadow the radiographs were independently reviewed by two radiologists well experienced in pediatric orthopedic radiology. (Egund, N and Pettersson, H). The radiographs were not identified with names of the patients, nor did the examiners have knowledge of which hip was symptomatic at the time of the examination. The examiners were asked to note the presence of a bulging capsular shadow laterally or iliopsoas shadow medially in the right and/or left hip respectively. In a second review by one of the observers the radiographs were also studied with regard to asymmetry of abduction at the hips. A difference of more than 5° was considered relevant.

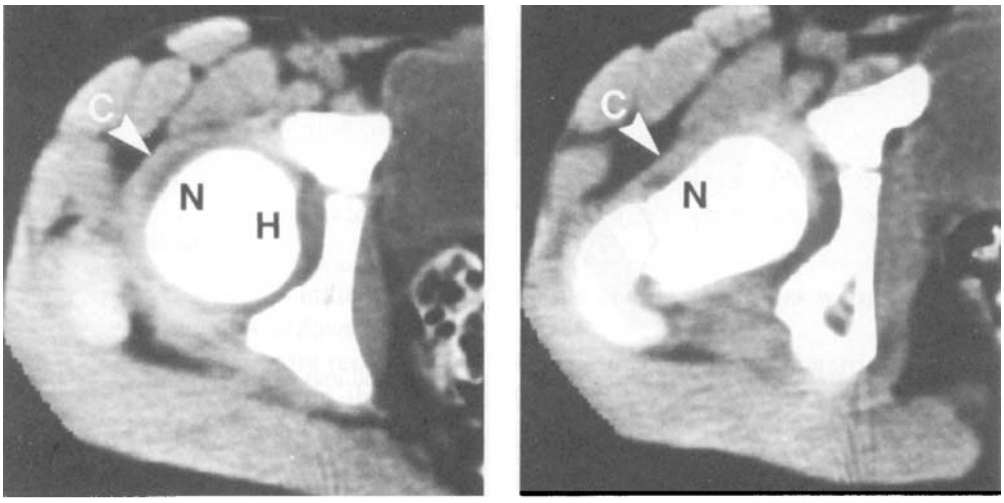
In 19 patients computed tomography and conventional AP radiographs of the pelvis and hip joints were compared with regard to the fat planes surrounding the hip. The geometrical relations between focus, patient and film plane were reconstructed so that the skeletal structures and fat planes could be identified in the same plane in both modalities.

B. Computed tomography and sonography

1. Technique

The CT examinations were performed with Philips Tomoscan 300 or Toschiba TCT 80 A with a slice thickness of 6 mm and 5 mm, respectively. Guided by palpation the first scan was obtained at the proximal level of the greater trochanter and a maximum of 3 scans through the femoral neck and head were obtained.

The distance from the ventral aspect of the neck of the femur to the ventral aspect of the ilio-femoral capsular ligament was measured directly on the CT display (Figure 3). The measurements were performed at a window level and width of 150 and 400, respectively, the figures being obtained from a series of measurements on a phantom simulating the anatomical conditions (Egund et al. 1986 a). As the spatial orientation of the femoral neck within the scan plane may distort the true distance a geometrical correction of the measurements were made as described by Egund et al. (1986 a).



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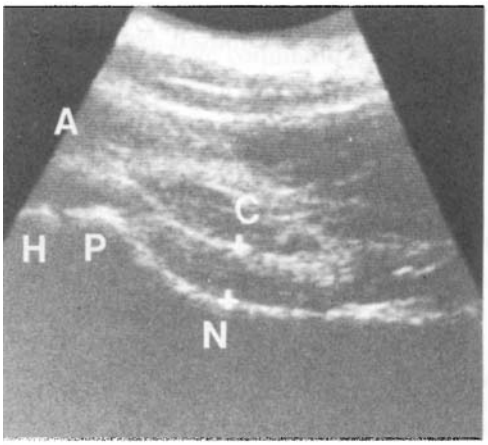


C

Figure 3. CT in a proximal (A) and more distal (B) level of the neck of the femur and sonography (C) of a normal hip. The following anatomical structures are identified: acetabular labrum (A), head of femur (H), growth plate (P), neck of femur (N) and joint capsule (C). The distance from the anterior aspect of the joint capsule to the neck of the femur is recorded. The capsule follows the neck equidistantly.

Sonography was performed with a scanner using a 7.5 or 10 MHz real-time sector transducer (Technicare Autosector or Diasonics DRF 12). The hips were scanned from the anterior aspect of the hip in the plane of the axis of the femoral neck (Figure 4) whereby the femoral neck, metaphysis, physis, epiphysis, acetabular rim and joint capsule were identified (Figure 3). The distance from the anterior aspect of the neck of the femur to the anterior aspect of the ilio-femoral capsular ligament on the sonographic image was measured directly on the display. The sonographic examinations were performed by two skilled radiologists only.

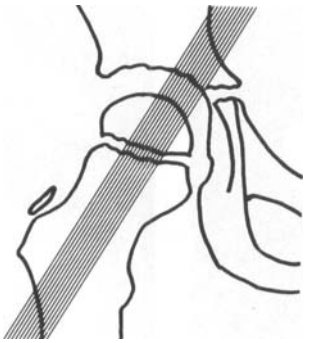


Figure 4. Sonographic sectioning in a sagittal plane along the axis of the neck of femur.

During both CT and sonographic examinations the children were placed in the supine position with the hips in a few degrees of flexion obtained with a pillow under the knees. This position was comfortable and could be reproduced in most children. No sedatives were used.

2. Normal anatomy

In order to evaluate the normal inter- and intra-individual variation of the hip joint capsule anatomy in a group of children with similar age and sex distribution 14 children without any history of hip joint disease and examined with sonography. Eleven were boys, 3 were girls. The mean age was 7 (3–11) years. The children were examined with a 7.5 or 10 MHz transducer as described above.

C. ^{99m}Tc-MDP scintimetry

1. Imaging

^{99m}Technetium methylene diphosphonate (^{99m}Tc-MDP) was administered intravenously in an age related dose from about 100 MBq in the youngest to 200 MBq in the oldest children. Delayed anterior images of the pelvis and both hips were obtained 3–4 hours after injection using an ultrahigh resolution parallel-hole collimator and/or anterior images of each hip in extension and neutral position using a pin-hole collimator with a 4 mm aperture. The tip of the collimator was located on the anterior surface of the patient, the imaging field centered over the mid-part of the growth plate activity in the central part of the hip region.

The data were stored on floppy discs for further numerical analysis.

In the first series of 27 children images were obtained with both types of collimators for correlation of visual parallel-hole collimator evaluation and numerical analysis of the pin-hole collimator data as described below.

2. Evaluation

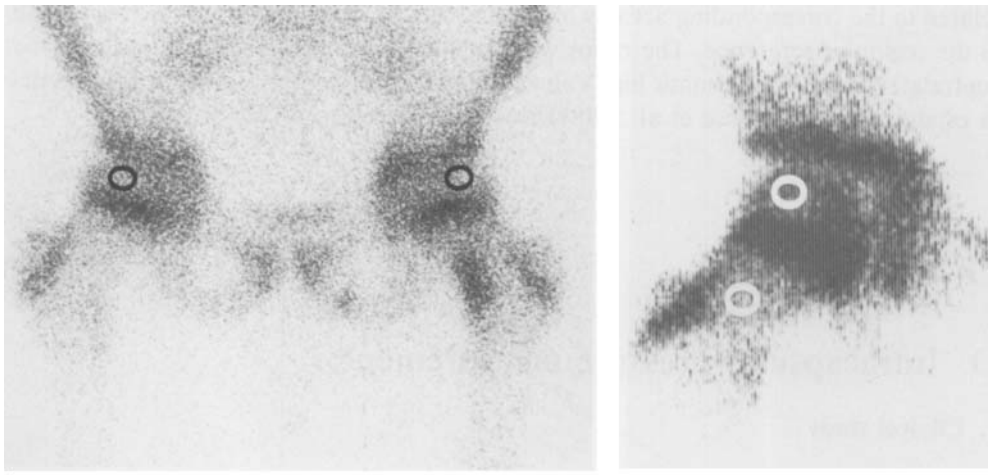
a. Visual evaluation

In the first series of 27 children the parallel-hole collimator images were evaluated visually and graded as follows:
0 = absent, 1 = markedly reduced, 2 = slightly reduced, 3 = symmetric and, 4 = increased isotope uptake in the proximal femoral epiphysis in the affected hip as compared to the control contralateral hip.

b. Region of interest

In the parallel hole collimator images the isotope activity in a region of interest (ROI) in the lateral part of the proximal femoral epiphysis in the affected hip was related to the corresponding activity in the contralateral non-symptomatic hip (Figure 5).

In the pin-hole collimator images a corresponding ROI in the lateral part of the epiphysis was related to a region of reference in the centre of the neck of femur. This ratio was in turn correlated with the corresponding ratio in the control hip (Figure 5).



A B

Figure 5. Position of the region of interest (ROI) in the lateral part of the epiphyses in the parallel collimator examination (A) and of the ROI and region of reference in the lateral part of the epiphysis and the midpart of the neck of femur respectively in the right hip in a pin-hole collimator examination (B).

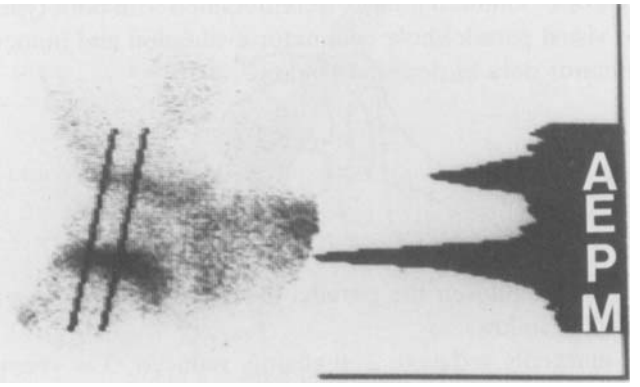


Figure 6. Position of the profile of interest from the neck of femur and metaphysis (M) across the growth plate (P), lateral part of the epiphysis (E) and joint into the acetabulum (A) in a pin-hole examination of the right hip.

c. Profile of interest

In the pin-hole collimator images a profile of interest (POI) was selected from the metaphyseal region, perpendicular to the growth plate, across the lateral part of the epiphysis, across the joint space and into the acetabulum (Figure 6). The activity along this profile was displayed graphically to relate the isotope uptake to anatomic details and facilitate direct visual comparison with the contralateral nonsymptomatic hip. Furthermore the peak activity in the growth plate, epiphysis and acetabulum was related to the corresponding activity in the midpart of the metaphysis which was used as the region of reference. The ratios were related to the corresponding ratios in the contralateral non-symptomatic hip. Values beyond the normal criteria (+/–20 per cent) as established by Deutsch et al. (1981) were considered to be abnormal.

D. Intracapsular pressure measurement

1. Clinical study

On admission to hospital the children were placed supine in bed and were allowed free movement in the affected hip, thus enabling them to adopt the least painful position.

All children were examined with conventional radiographs in AP and Lauenstein views.

Sonography was performed prior to hip joint aspiration using the technique

described in Chapter III.B and the children were followed with serial sonography after aspiration. Sonography verified the clinical diagnosis in all patients.

Intracapsular pressure was recorded using a 1.2 mm epidural needle connected with unelastic tubing via a 3-way stop-cock to a 2 ml syringe and a piezoelectric pressure transducer (HewlettPackard®) The system was filled with saline and calibrated before and after the procedure. Readings were obtained graphically and digitally on an oscilloscope.

All patients had general anaesthesia and were placed supine with the hips freely moveable. With the hip in extension and neutral position with regard to rotation the saline filled needle was introduced antero-laterally under image intensifier control aiming at the midpart of the anterior aspect of the neck of femur where sonography shows capsular distension to have its maximum. The needle was introduced only once. The intracapsular and unobstructed position of the needle was obvious from the observation of a sudden rise in pressure on the oscilloscope as the capsule was penetrated and was further verified when aspirating at the end of the procedure.

Pressure was recorded with the hip in the following positions:
1) Extension and neutral position; 2) extension and maximum inward rotation; 3) extension and maximum outward rotation and 4) with the hip in 45° of flexion. Aspiration was then performed stepwise with the hip in extension-neutral position and with simultaneous registration of pressure and volume. A pressure/volume-reduction graph could thus be drawn describing the capsular compliance in the individual case (Figure 7). Pressures were given in kPa (1 kPa = 7.5 mm Hg).

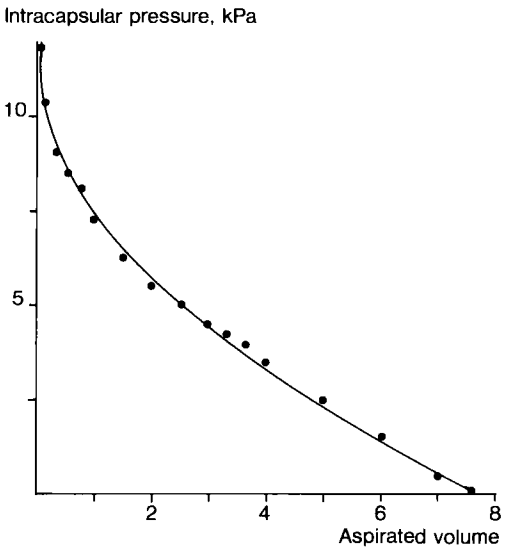


Figure 7. Volume/Pressure-reduction-graph in a patient with an aspirated volume of 7.5 ml. (Table 5, Case 7).

^{99m}Tc-MDP scintimetry with the parallel-hole collimator technique described in Chapter III C was performed prior to aspiration in 8 children and after aspiration in 6 children. In two children with a decrease in isotope uptake in the proximal femoral epiphysis scintimetry was repeated within one to 3 days of aspiration.

The children were kept in bed for 4 days following aspiration and were then discharged with restricted physical activity for another week. Serial clinical and sonographical follow-up was continued for a further two weeks postoperatively.

2. Cadaver study

The purpose of this study was to measure the intracapsular pressure in the hip joint within the normal range of rotation around the axis of the neck of femur, the effect of an increase in intracapsular volume and the role of atmospheric pressure in stabilizing the joint.

a. Material and methods

One of the hip joints from 3 individuals killed accidently were dissected at the Department of Forensic Medicine, University Hospital, Lund. There was no history of hip joint disease nor any evidence of trauma to the joints under examination. The muscles around the joint were excised and the femur was divided 15 cm below the greater trochanter. The os ileum was divided from the major ischiadic incisure to a point just below the superior anterior iliac spine. The inferior and superior rami of the os pubis were also divided. Care was exercised not to damage the capsular structure. The hip joints were taken from two 19-year-old males and from one 52-year-old female.

The specimens were mounted in a test apparatus in the following way: A 2 mm steel pin was drilled 3 cm into the trochanteric region just below the major trochanter and in the direction of the axis of the neck of femur. The pelvis was firmly attached to a fixed steel plate. The rotation of the head of femur in relation to the pelvis around the axis of the femoral neck was controlled and measured with accuracy on a scale with a 20 cm radius.

The moment about the axis of the neck of femur (given in Nm) was measured with two strain-gauge meters mounted to register the traction force when rotating the femur in the direction of extension and in flexion respectively around the axis of the neck of femur. The strain-gauge meters were calibrated before and after each investigation.

Intracapsular pressure was recorded via a 1.2 mm diameter cannula inserted anteriorly through the hip joint capsule aiming at the midpart of the femoral neck. The cannula was connected via an unelastic plastic tube to a piezoelectric pressure transducer where a 3-way stop-cock connected to a syringe controlled intracapsular volume. The system was filled with saline. Intracapsular pressure was given digitally on a display (Mitab®M2). The system was calibrated before and after the procedure. Thus, with this mounting the intracapsular volume (ml), the intracapsular pressure (kPa), the rotation around the axis of the neck of femur (°) as well as the moment needed to perform this rotation (Nm) could be accurately controlled.

Following the stepwise intracapsular infusion of 0,4,8,12 $\rightarrow$ 40 ml of saline the pressure and the moment was recorded when rotating the femur into extension and flexion around the femoral neck axis. The pressure was not allowed to exceed 80 kPa (600 mm Hg).

E. Biochemical analysis

1. Proteoglycan fragments in joint fluid

Intracapsular pressure was recorded prior to aspiration of the hip joint effusion with the technique described in Chapter III.D.

The concentration of proteoglycan fragments in the joint fluid specimens was determined with an enzyme linked immunosorbent assay technique according to Heinegård et al. (1985) and Saxne et al. (1985).

F. Statistical analysis

The Chi-square test, Student's T-test and Fisher's exact test were used in the statistical evaluation. The following levels of significance were used:

$p < 0.001$	highly significant
$0.001 < p < 0.01$	significant
$0.01 < p < 0.05$	almost significant
$0{,}05 < p$	not significant

Mean values $\pm$ Standarddeviation (SD)

IV. Observations

A Conventional radiography

Patients and methods are described in Chapters II.A and III.A

1. Joint space (Figure 8a+b)

At the time of the initial examination there was a significant (p=0.009) increase in medial joint space distance as compared to the control non-symptomatic hip. The mean difference was 0.33 (SD 1.01) mm. At follow-up this increase persisted; the mean difference was 0.41 (SD 0.84) mm (p=0.001). The cranial joint space was not significantly increased in the initial examinations (the mean difference was 0.1 (SD 0.67) mm) but at follow-up there was a highly significant increase (mean difference was 0.46 (SD 0.63)(p=0.00001)).

2. Metaphyseal width (Figure 8c)

The metaphyseal width was not increased in the initial examinations (mean difference was 0.17 (SD 0.94)) whereas at follow-up there was significant coxa magna (mean difference being 0.42 (SD 0.95)(p=0.003)).

3. Acetabulum (Figure 8d)

There was no asymmetry in the acetabular roof distance in the initial examination, mean difference was 0.17 (SD 1.35). At follow-up there was significant overgrowth of the acetabular roof; mean difference was 0.47 (SD 1.06) (p=0.003).

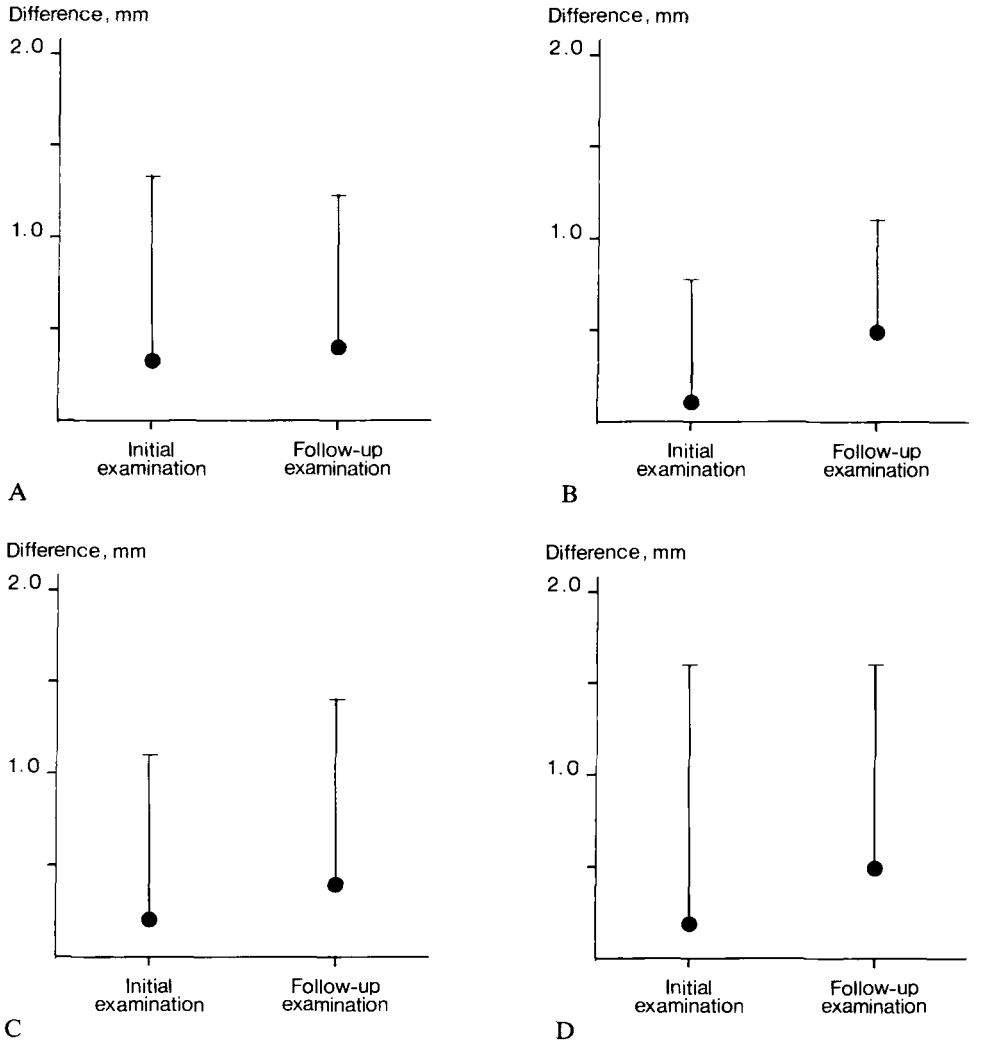


Figure 8. The difference symptomatic – non-symptomatic hip in the initial and follow-up radiographic examinations in 68 children with transient synovitis of the hip with regard to the medial joint space (A), cranial joint space (B), metaphyseal width (C) and acetabular roof (D).

4. Capsular shadow and iliopsoas shadow

The observations on the initial radiographic examinations of 68 children by the two independent radiologists with regard to a bulging lateral capsular shadow and/or medial iliopsoas shadow are illustrated in Figure 9. A lateral capsular shadow was observed as an isolated phenomenon in the symptomatic hips in 17 and 27 examinations respectively by the two observers but in the non-symptomatic hip in only 4 and 4 examinations respectively. An isolated medial iliopsoas shadow was observed in the

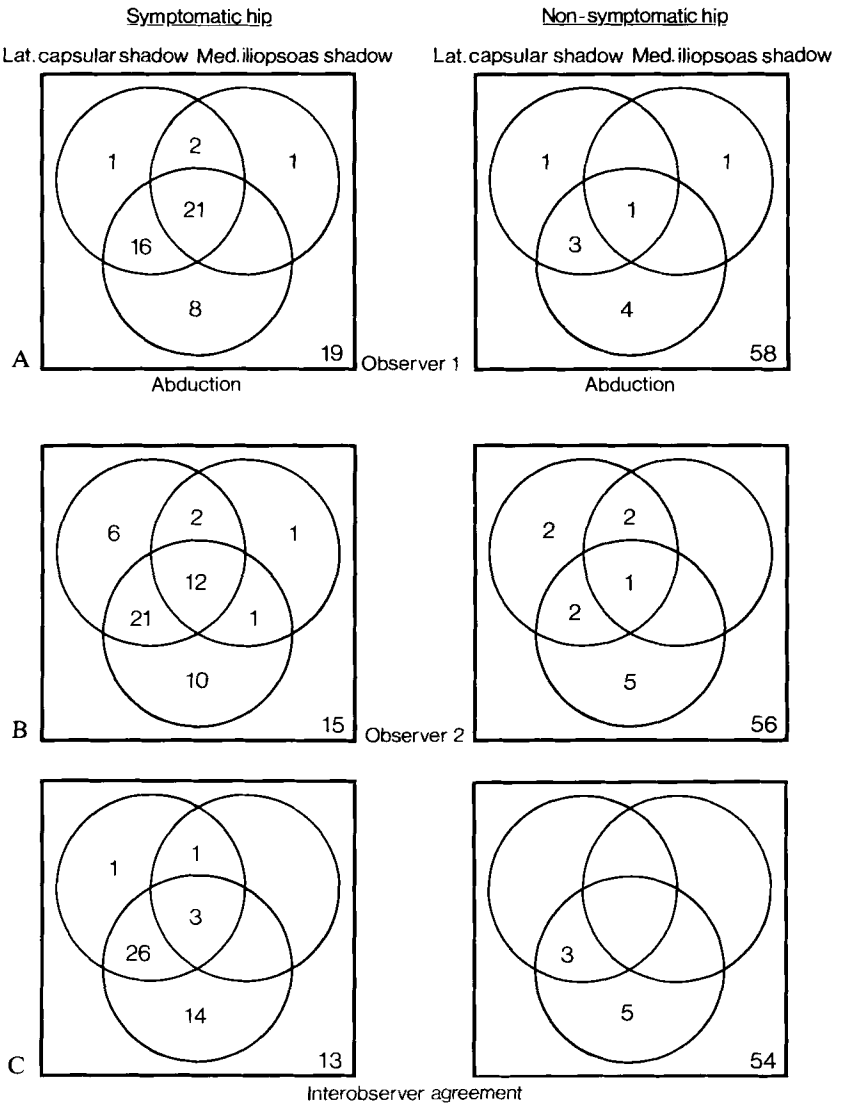


Figure 9. The presence of a bulging lateral capsular shadow and/or medial iliopsoas shadow in the initial radiographs of 68 children with transient synovitis of the hip as judged by two independent radiologists (A) and (B) and the degree of intraobserver agreement on observations (C). Observations are correlated to the position of abduction (>5° as compared to the contralateral hip).

symptomatic hips in only one and two examinations respectively and in the non-symptomatic hip it was noticed by one of the observers in one examination only. Co-existing capsular and iliopsoas shadows in the symptomatic hips were noticed in 23 and 14 examinations respectively, and in the non-symptomatic hips in only one and 3 examinations respectively. There was interobserver agreement about the presence of an isolated lateral capsular shadow in the symptomatic hips of 27 children and about

a co-existing capsular shadow and iliopsoas shadow in another 4 children whereas in none of the examinations did the observers agree about an isolated medial iliopsoas shadow ($p<0.001$). Thus, in only 31 out of 68 examinations (46 per cent) did the observers agree about a lateral capsular shadow in the symptomatic hip and the iliopsoas shadow cannot be said to reliably occur as an isolated phenomenon in these patients.

There was a strong correlation ($p<0,001$) between a lateral capsular shadow and increased abduction in the symptomatic hip (figure 9c). Thus, out of 31 observations of a lateral capsular shadow only 2 occurred without concurrent abduction. In the control hip a lateral capsular shadow was observed in 3 examinations, all in the position of abduction.

From the comparative study of the CT and conventional radiographic examinations in 19 patients the lateral capsular shadow was identified as the fat plane situated anteriorly between the gluteus minimus, tensor fascia lata, rectus femoris and iliopsoas muscles (Figure 10).

The medial iliopsoas shadow could be identified as the fat surrounding the femoral vessels.

A more detailed analysis of the fat planes was presented by Egund et al. (1986 b).

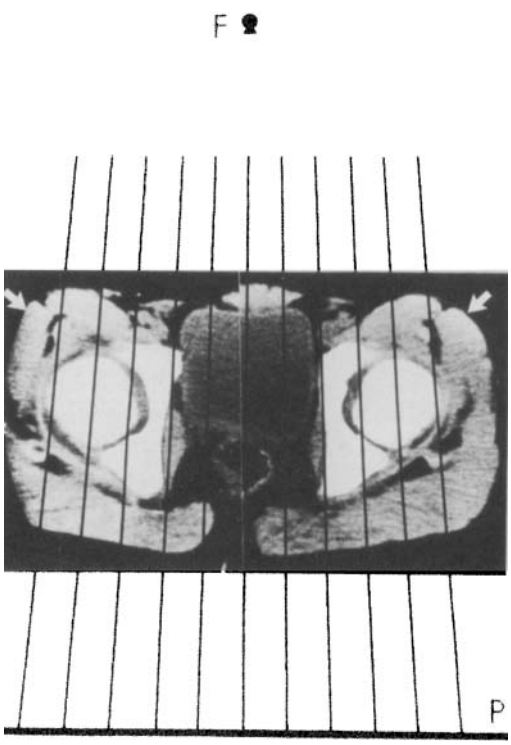


Figure 10 A. The geometrical reconstruction of the beams in conventional radiography from the focus (F) through the hips to the film plane (P). The white arrows indicate the tensor fascia lata muscles behind which the lateral "capsular shadow" fat planes are situated. There was a slight lateral displacement of the fat plane in the right symptomatic hip due to a 1 cm tilt in the pelvis with subsequent abduction in the right symptomatic hip.

Figure 10 B. CT in the same patient but more distally at the level of the neck of femur where capsular distension due to effusion in the right hip has its maximum. In contrast, the capsule is not distended at the level of the femoral head where the lateral capsular shadow is studied (A).

B. Computed tomography and sonography

1. Normal anatomy

In the sonographic images of normal asymptomatic hips, the femoral neck, metaphysis, physis, epiphysis and hip joint capsule are clearly identified. The anterior aspect of the hip joint capsule is also clearly identified on the CT images. The anterior aspect of the neck of the femur and the capsule parallel each other (Figure 3).

In the 14 children without any history of hip joint disorder the distance from the anterior aspect of the neck of femur to the anterior aspect of the hip joint capsule varied between 4.2 and 6.7 mm in the right hip and between 4.3 and 6.8 in the left hip. The mean distance in the right hip was 5.24 (SD 0.76) mm, and in the left hip 5.21 (SD 0.79) mm. The difference in the right and left hip measurements in the 14 children varied between 0.0 and 0.6. The mean difference was 0.2 (SD 0.2). There was no correlation of capsular distance with age within this age group. (Table 1.)

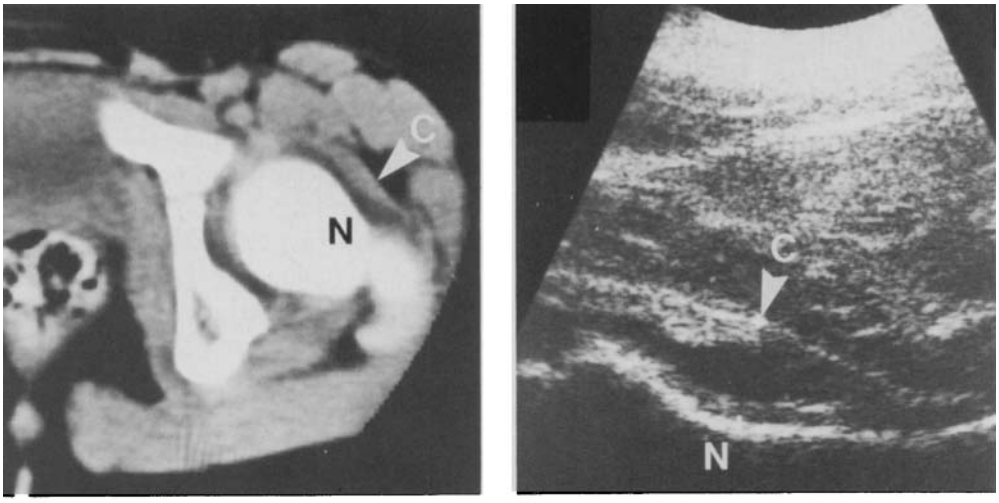
2. Diagnosis of synovitis

An intracapsular effusion distends the capsule anteriorly with the largest displacement along the midpart of the neck of femur. On CT examinations most effusions could also

Table 1. Sonography of the hip joint capsules in 14 asymptomatic children aged 3–11 years.

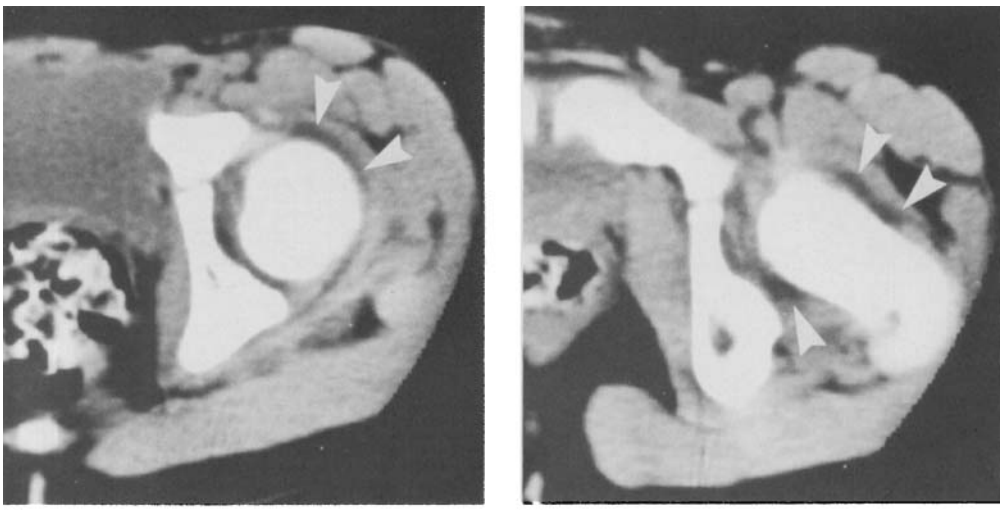
A	B	C	D	E	F
1	5.5	M	4.2	4.8	0.6
2	9.5	M	4.7	5.0	0.3
3	10.0	M	5.3	4.7	0.6
4	9.5	M	4.5	4.0	0.5
5	7.0	F	4.6	4.6	0.0
6	4.5	F	4.6	4.3	0.3
7	8.0	F	5.2	5.2	0.0
8	7.0	M	6.0	6.0	0.0
9	10.0	M	6.2	6.2	0.0
10	3.0	M	5.7	5.4	0.3
11	11.0	M	4.7	4.7	0.0
12	8.0	M	5.0	5.2	0.2
13	8.0	M	6.7	6.8	0.1
14	8.0	M	6.0	6.0	0.0

A = Patient number
B = Age (years)
C = Sex
D = Sonographic distance between the anterior aspect of the neck of femur to the anterior aspect of the hip joint capsule in the *right* hip (mm)
E = As in D in the *left* hip (mm)
F = Difference |D-E| (mm)



A B

Figure 11. CT (A) and sonography (B) of the symptomatic hip in transient synovitis. For legends see Figure 3. The effusion distends the capsule ventrally.



A B

Figure 12. CT of a hip with effusion (arrows), at the level of the head (A) and the distal portion of the neck (B).

be noticed lateral to the head and at the medial and posterior aspect of the neck (Figure 11). Capsular distension was less pronounced at the level of the head and even large effusions were never observed at the lateral aspect of the femoral neck (Figure 12).

Intracapsular effusions were found by both CT and sonography in all 25 examinations of the 19 symptomatic hips.

C. Comparison of computed tomography and sonography for the diagnosis of synovitis

Patients and methods are described in Chapters II.B. and III.B Computed tomography of both hips immediately followed by sonography was performed within 12 hours of admission to hospital. In 5 children the examinations were repeated to give a total of 25 CT and sonographic examinations. Hip joint aspiration was performed in 9 children, preceded by intracapsular pressure recordings with the technique described in Chapter III.D. In 3 patients (Table 2, Cases 13,17,18) aspiration was performed prior to the first CT and sonography measurements.

In the 25 CT and sonography images of the 19 control hips the correlation between CT and sonographic measurements proved to be good ($r=0.77$). Thus the CT measurements varied between 3.8 and 7.3 (mean 5.4, SD 0.8) mm and the corresponding sonography measurements between 4.3 and 6.3 (mean 5.3, SD 0.7) mm. At the level of the femoral head these values were slightly lower. The discrepancy between the CT and sonography measurements of the control hips exceeded 1.0 mm in two examinations only, corresponding to the largest pixel used on the CT display.

Table 2. Observations in 19 children with transient synovitis of the hip.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	8	F	L	30	10	36.4	Yes	6.4	4.6	7.0	4.6	–	–
2	6	M	R	3	–	37.5	No	7.3	4.6	7.6	4.6	–	–
3	3	M	L	3	15	37.8		9.3	6.7	11.5	6.2	–	–
								7.4	5.6	7.9	6.0	–	–
4	5	F	R	½	7	37.6	No	8.7	5.6	8.9	5.7	–	–
5	12	M	L	21	3	–	No	8.9	5.1	8.9	5.6	–	–
								9.6	5.8	9.8	6.0	–	–
6	4	M	R	3	15	37.0	Yes	8.3	4.6	8.6	4.5	–	5.0
								7.3	3.8	7.2	4.5	–	–
7	6	M	L	14	18	36.9	No	11.4	5.1	12.0	4.7	–	5.5
								8.6	5.1	9.1	4.7	–	–
8	6	M	L	7	10	36.8	No	7.6	6.0	7.2	5.0	–	–
9	5	F	R	½	12	37.0	No	6.7	5.1	6.8	5.1	–	–
10	9	M	L	4	44	36.6	No	11.0	5.7	11.7	6.2	–	–
11	3	M	L	1	13	36.9	No	9.4	5.1	9.7	5.1	–	–
12	5	M	L	1	7	36.9	No	10.0	6.0	11.2	6.0	–	–
13	5	M	R	4	26	37.9	No	9.8	5.0	11.0	5.3	–	3.0
14	5	F	L	1	5	37.2	Yes	7.1	5.0	8.0	5.4	15.2	2.5
15	12	M	L	1	5	36.4	No	10.4	7.3	10.0	5.6	11.0	5.5
16	4	M	R	1	4	36.8	No	9.0	4.8	9.1	4.7	12.1	2.8
17	6	M	L	1	15	38.2	No	8.1	6.2	8.2	6.3	14.5	1.6
								7.3	6.4	7.4	6.1	–	–
								6.3	5.6	6.6	6.1	–	–
18	3	M	R	2	3	37.6	No	5.6	4.0	5.8	4.3	10.5	0.5
19	10	M	R	2	7	37.5	Yes	12.2	5.4	12.9	5.0	11.8	7.5

A = Patient number
B = Age (years)
C = Sex (M=male, F=female)
D = Left/right symptomatic hip
E = Duration of symptoms at time of admission (days)
F = ESR (mm/hour)
G = Body temperature (°C)
H = Previous episode of transient synovitis?
I = CT measurement, symptomatic hip (mm)
J = CT measurement, *non*-symptomatic hip (mm)
K = US measurement, symptomatic hip (mm)
L = US measurement, *non*-symptomatic hip (mm)
M = Intracapsular pressure with the hip in extension neutral position (kPa)
N =Aspirated volum (ml)

Intracapsular effusions were found by both CT and sonography in all 25 examinations of the 19 symptomatic hips. The CT measurements of capsular displacement in the symptomatic hips varied between 5.6 and 12,2 (mean 8.5, SD 1.7) mm and the corresponding sonography measurements varied between 5.8 and 12,9 (mean 9.0, SD 1.9) mm. Thus there was a good correlation in the symptomatic hips (r=0.96, k=1.09) the difference being within 1 mm in all except two hips (Figure 13).

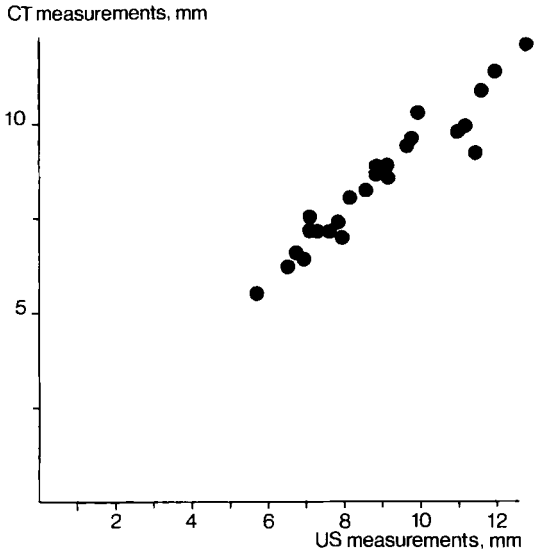


Figure 13. Correlation of 25 CT and sonography measurements of the capsular displacement in 19 children with effusion of the hip joint.

Aspiration was performed in 9 consecutive patients yielding a mean of 3.8 (0.5–7.5) ml of clear fluid. The mean preoperative capsular distension in these patients measured as the difference between the symptomatic and non-symptomatic hip was 5.1 mm. A good correlation was found between capsular distension and volume of aspirated fluid (r=0.80, k=0.74).

D. ^{99m}Tc-MDP Scintimetry

Patients and methods are described in Chapters II.C and III.C 1.

1. Pin-hole collimator series

For clinical and scintimetric data see Table 3. The initial conventional radiographic examinations in AP and Lauenstein views were normal in all 26 children. Follow-up

Table 3. Clinical and scintimetric data in 26 patients with transient synovitis of the hip.

A	B	C	D	E	F	G	H	I	J	K	L	M
1	7	M	R	5	No	8	37.8	0.49	1.30	0.38	1.37	
2	8	M	L	4	No	58	38.3	0.62	1.09	0.57	1.04	
3	4	M	L	4	No	12	36.6	0.51	1.05	0.48	0.58	*1
4	7	M	L	2	No	2	38.0	0.88	1.16	0.77		
5	7	M	L	30	No	21	37.2	1.39	1.25	1.11	1.21	
6	10	M	R	4	No	4	37.3	1.40	1.31	1.02		
7	6	F	L	5	No	17	36.8	1.40	1.24	1.13		
8	8	M	R	7	No	5	37.9	1.47	1.39	1.06		*2
9	9	F	R	3	Yes	5	36.5	1.73	1.78	0.98	0.91	
10	7	M	R	3	No	7	36.2	1.05	0.90	1.17		
11	6	M	L	8	No	–	–	1.51	1.28	1.18		
12	11	F	L	3	Yes	2	36.0	1.45	1.74	0.83		
13	6	M	R	16	No	14	37.3	1.59	1.32	1.20		
14	10	M	L	27	Yes	7	36.5	1.39	1.18	1.18		
15	10	M	R	3	Yes	12	37.8	–	–	–		*3
16	6	M	R	3	No	7	37.3	0.83	0.75	1.10	1.22	
17	5	M	R	67	Yes	–	–	0.88	0.82	1.07		
18	1	F	R	5	No	21	38.4	1.10	1.01	1.09		
19	4	F	L	2	No	3	37.0	0.90	1.60	0.56	1.19	
20	6	F	R	2	No	3	37.4	1.64	1.42	0.87		
21	5	M	R	5	No	16	37.5	1.67	1.50	1.11		
22	9	M	L	10	Yes	26	37.1	1.23	1.44	0.86		
23	3	F	R	6	No	7	37.3	1.69	1.43	1.18		
24	5	M	L	5	No	9	36.1	1.17	1.44	0.81	1.15	
25	8	F	R	15	No	12	37.4	1.38	1.16	1.19		*4
26	10	M	L	1	Yes	9	36.2	1.15	1.23	0.94		

*1 6 weeks later radiographic evidence of LCPD.
*2 Transient recurrence 1 month after initial episode.
*3 Recurrent arthralgias, referred for rheumatological examination.
*4 Transient recurrence 1 month after initial episode.

A = Patient number
B = Age (years)
C = Sex (M=male, F=female)
D = Left/right symptomatic hip
E = Duration of symptoms at time of initial scintimetry (days)
F = Previous episode/episodes of transient synovitis
G = Erythrocyte sedimentation rate (mm/hour)
H = Body temperature at time of admission (°C)
I = Epiphysis/neck ratio in the affected hip
J = Epiphysis/neck ratio in the non-affected hip
K = Ratio I/J
L = As in K in follow-up examination
M = Comments

examinations at 5 to 11 months were all normal except for Case 3 who had developed radiographic evidence of Perthes disease.

In all cases except in Case 3 the clinical symptoms subsided within a week. At follow-up Cases 8 and 25 had each had one additional transient episode of pain within a month of the initial episode. Case 15 had recurrent pain in several other joints after the initial episode and was referred for reumatological examination but with negative results.

a. Visual evaluation

The visual evaluation of the parallel – hole collimator images obtained immediately prior to the pin-hole collimator images was as follows: In 14 children the uptake was considered symmetrical in the epiphyses of both hips. In 7 children there was an increased epiphyseal uptake, in one child uptake was markedly reduced and in 3 uptake was absent. One examination (Case 15) was excluded due to a technical error.

b. Region of interest evaluation

The epiphysis/neck scintimetric ratio was increased (ratio >1.0) in the affected hip when compared to the control hip in 14 initial examinations and decreased (ratio <1.0)

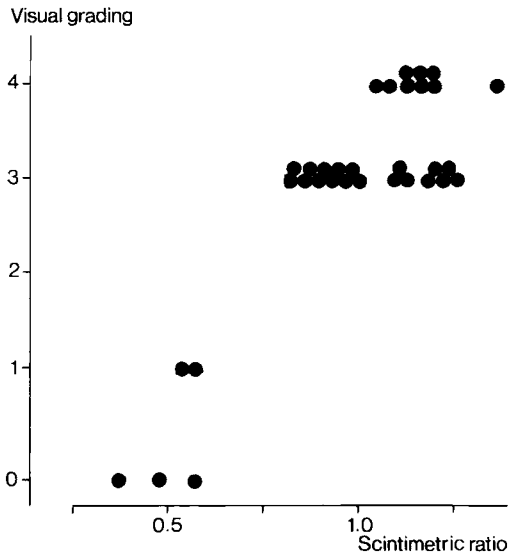


Figure 14. Comparison of visual and scintimetric evaluation of the activity in the proximal-femoral epiphysis in the symptomatic versus non- symptomatic hip. Visual grading: 0 = absent; 1 = markedly reduced; 2 = slightly reduced; 3 = symmetric; 4 = increased PFE activity in the affected hip. Scintimetric evaluation: ratio symptomatic versus non-symptomatic hip.

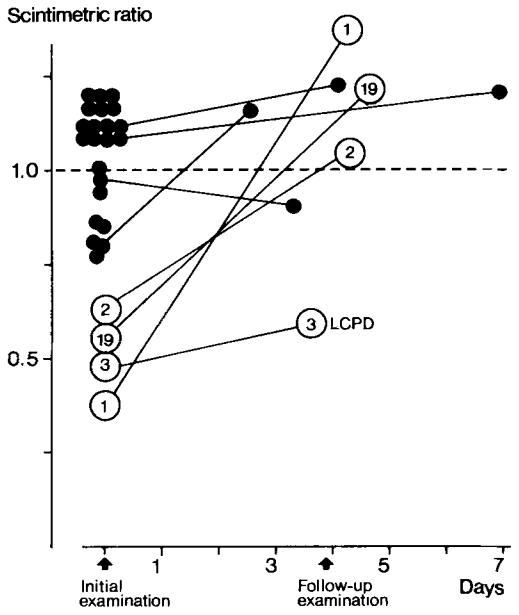


Figure 15. Scintimetric ratio (ratio symptomatic versus non-symptomatic hip) at the initial examinations and at follow-up examinations. In Case 3 the PFE defect persisted. This case subsequently developed Perthes disease.

in 11 examinations. Correlation of visual parallel-hole collimator evaluation and numerical pin-hole evaluation proved to be good (Figure 14).

In 4 children with a marked decrease or absent uptake of PFE in the initial scan (Cases 1,2,3 and 19) follow-up scintimetry, approximately 6 weeks later, revealed restitution of isotope uptake in 3, but the defective uptake persisted in one (Figure 15). This case subsequently developed radiographic evidence of Perthes disease (Case 3). In 4 children with visually symmetrical or increased PFE activity repeat scans were unaltered in 3 but in one child activity was increased (Figure 15).

Case histories: (Table 3)

Case 1 A 7-year-old boy with no previous history of hip problems presented with a 5 day history of right hip pain and limp. Scintimetry revealed a ratio of 0.38 in the affected PFE determined with the ROI technique indicating a marked disturbance of blood supply to this region (Figure 16). Clinical symptoms subsided within a week and a follow-up scan 6 weeks later showed an increased uptake (ratio 1.37) in the PFE indicating restitution of blood supply. The follow-up radiograph was normal then and again 5 months later. The boy had no further clinical symptoms.

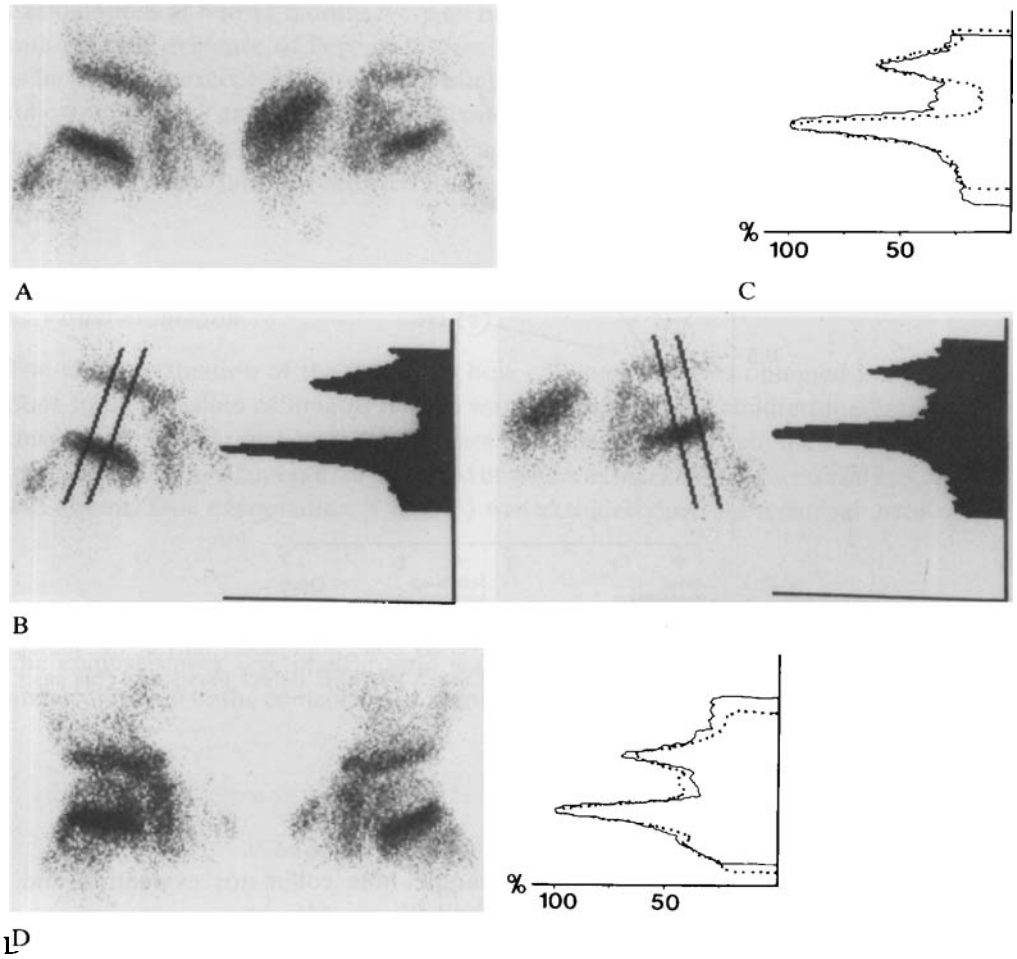


Figure 16. Case 1 with a transient ischaemia of the epiphysis of the right hip. This patient did not develop radiographic evidence of Perthes disease.

A. Initial pin-hole images of both hips in AP-views with a marked *defect* in isotope-uptake in the epiphysis of the right hip.
B. Profiles of uptake in the right and left hips respectively.
C. Profiles superimposed for visual comparison. Drawn line = left hip, dotted line = right hip.
D. Follow-up scan 6 weeks later showing an increase in uptake in the affected right hip.

Case 2 An 8-year-old boy with no previous history of hip problems presented with a two day history of intense pain in his left knee-hip region. To rule out septic arthritis the hip joint was aspirated, yielding 2 ml of clear fluid. Two days later scintimetry revealed a ratio of 0.57 in the PFE as determined with the ROI technique indicating marked disturbance of blood supply (Figure 17). Clinical symptoms subsided within a week. Six weeks later the radiograph was still normal and follow-up scan showed an increased uptake in the PFE (ratio 1.04) indicating restitution of blood supply. At follow-up, 5 months later, there had been no further clinical symptoms and the radiograph was normal.

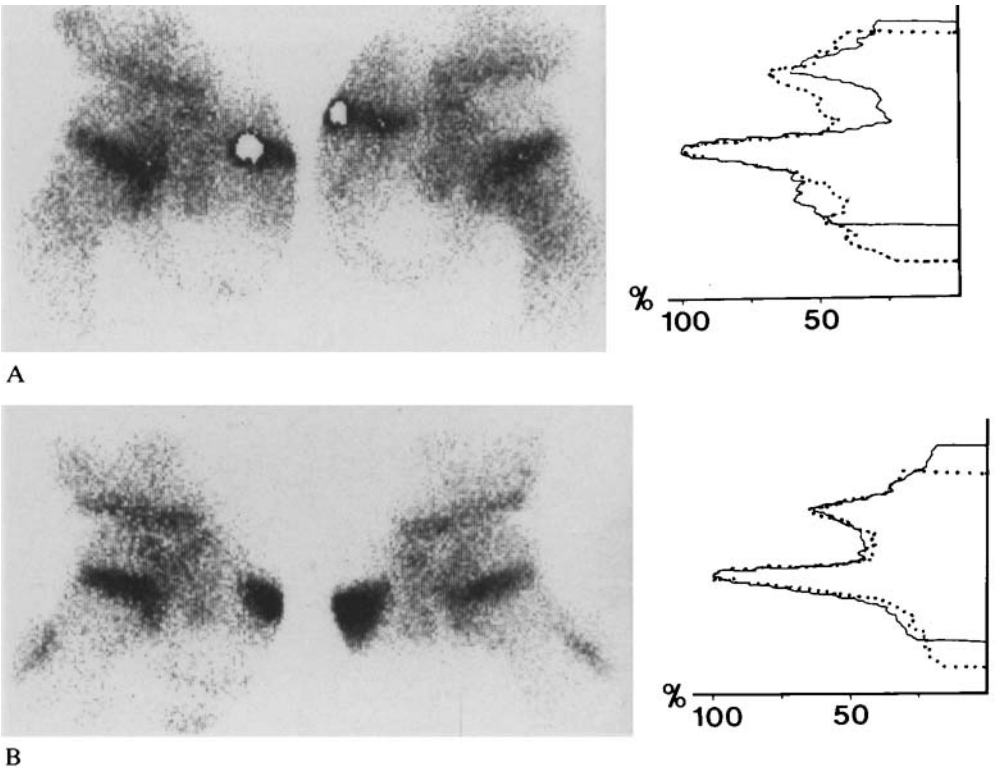


Figure 17. Case 2 with a transient ischaemia of the epiphysis of the left hip. This patient did not develop radiographic evidence of Perthes disease. Profiles of uptake superimposed as in Figure 16.

Drawn line = left hip, dotted line = right hip.

A. Marked *defect* in isotope uptake in the epiphysis of the affected left hip on the initial scan.
B. Follow-up scan 6 weeks later now showing an *increase* in uptake in the affected left hip.

Case 3 A 4-year-old boy with no previous history of hip problems presented with a 4 day history of left hip pain. Scintimetry showed a ratio of 0.48 in the PFE as determined with the ROI technique and the boy had continuing clinical symptoms. For this reason a repeat scan was performed 10 days later. It showed a persisting PFE defect (Figure 18). The joint was aspirated but with negative findings. This boy had continuing clinical symptoms with pain and restricted motion. A follow-up scintimetry 6 weeks after onset of clinical symptoms revealed a persisting PFE defect (ratio 0.58) and radiographs at that time showed conclusive evidence of Perthes disease. Further follow-up showed progressive clinical and radiographic development of the disease.

c. Profile of interest evaluation

In a second series comprising of 55 children scintimetric data were analysed using the profile of interest evaluation.

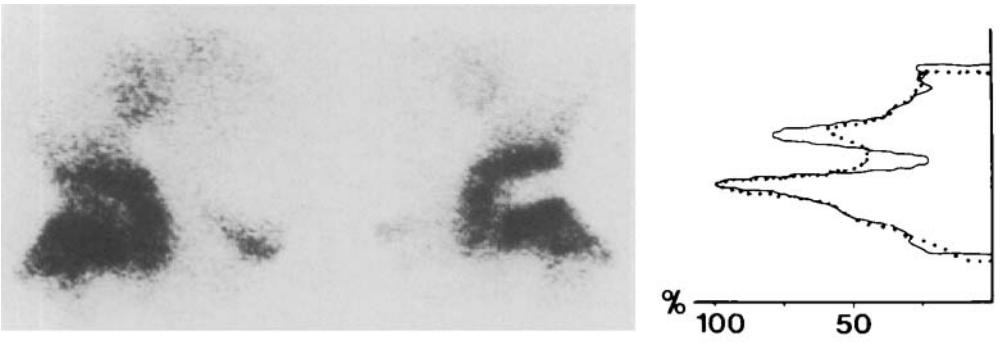
Table 4. Clinical and scintimetric data in 55 children with transient synovitis of the hip.

1	2	3	4	5	6	7	8	9
1	7	M	L	30	0.79D	1.18	0.98	
				100	1.42I	1.18	1.38I	
2	7	M	L	1	0.93	0.99	1.07	
3	7	M	R	5	1.10	0.38D	1.13	
				52	1.11	1.29I	0.97	
				247	1.11	1.13	1.10	
4	6	M	R	15	1.07	1.21I	1.17	
5	6	F	R	2	0.82	0.79D	0.87	
6	10	M	L	18	1.04	1.32I	0.96	
7	6	F	L	5	1.16	1.22I	1.13	
8	6	M	R	3	1.10	1.15	0.98	
				44	0.74D	0.89	1.01	R
9	5	M	L	8	1.57I	1.37I	1.51I	
10	6	M	L	5	0.61D	0.65D	1.06	
				30	0.95	1.38I	1.26I	
11	5	M	R	90	1.12	1.28I	0.84	
12	5	M	R	6	0.75D	0.92	1.16	
13	5	F	R	11	1.04	0.92	1.12	
14	5	M	L	22	0.73D	0.88	1.01	
15	4	F	L	2	0.86	0.66D	0.73D	
				48	0.97	1.37I	1.42I	
16	4	M	L	25	1.18	1.34I	1.08	
				92	1.11	1.36I	1.00	
17	4	M	L	2	1.03	0.82	1.07	
				16	1.13	1.04	1.44I	
18	3	F	R	6	0.93	0.94	1.11	
19	3	M	R	2	0.76D	0.79D	0.80	
20	3	M	L	19	0.78D	0.79D	0.74D	
21	13	M	L	5	0.86	0.74D	0.97	
22	12	M	L	5	0.65D	1.04	1.11	
23	11	M	R	61	0.94	1.59I	1.11	
24	10	M	L	55	0.95	0.97	1.06	
25	9	M	R	35	1.20	1.12	1.18	
26	2	M	R,L	50	–	–	–	B
27	5	M	R	66	1.07	1.19	1.06	
28	6	M	R	12	1.14	1.38I	1.26I	
29	8	F	L	5	0.88	0.79D	0.93	
30	8	F	L	2	0.72D	1.11	0.96	
31	8	M	L	3	0.57D	0.52D	0.81	
32	8	F	R	15	0.89	1.26I	0.83	
33	7	M	R	3	0.87	1.21I	1.21I	
34	8	M	L	4	0.92	0.54D	0.81	
				45	1.00	1.04	1.02	

1	2	3	4	5	6	7	8	9
35	8	M	R	7	1.18	1.30I	1.30I	
36	9	M	L	6	0.96	0.99	1.00	
37	9	M	L	34	0.99	0.98	1.29I	
38	10	F	L	32	1.01	1.43I	1.27I	
39	11	F	L	4	0.81	0.92	0.92	
40	11	M	L	49	1.20	0.99	0.98	
41	11	F	L	4	1.21I	1.09	0.84	
42	9	M	R	34	1.15	1.29I	1.23I	
43	3	F	R	5	0.87	0.83	0.81	
				138	0.67D	0.65D	0.83	R
44	6	F	R	3	1.15	1.22I	1.06	
45	11	M	R	10	1.23I	0.97	1.11	
46	8	M	R	22	1.08	1.30I	1.08	
47	6	F	R,L	17	–	–	–	B
48	5	F	R	24	1.21I	1.17	1.28I	
49	6	M	L	9	0.88	0.89	0.95	
50	3	M	L	3	0.70D	0.85	0.88	
51	2	F	L	6	–	–	–	M
52	3	M	L	3	0.91	0.72D	0.90	
				33	0.92	0.96	1.07	
53	4	M	R	10	1.00	1.19	1.12	
54	6	M	R	3	–	–	–	M
55	4	M	L	79	1.05	0.91	0.91	

1 = Patient number
2 = Age (years)
3 = Sex (M=male, F=female)
4 = Affected side
5 = Time of scintimetry from onset of symptoms (days),
6 = Ratio G/M in the affected versus non-affected hip, D=decrease in uptake, I=increase in uptake
7 = E/M as in 6
8 = A/M as in 6
9 = Comments: B=bilateral symptoms, R=recurrent episodes of pain but no definite (Legg-Calve-)Perthes development on conventional radiographs, M=excluded due to movement

G = Growth plate,
E = Epiphysis,
A = Acetabulum,
M = Metaphysis.



A

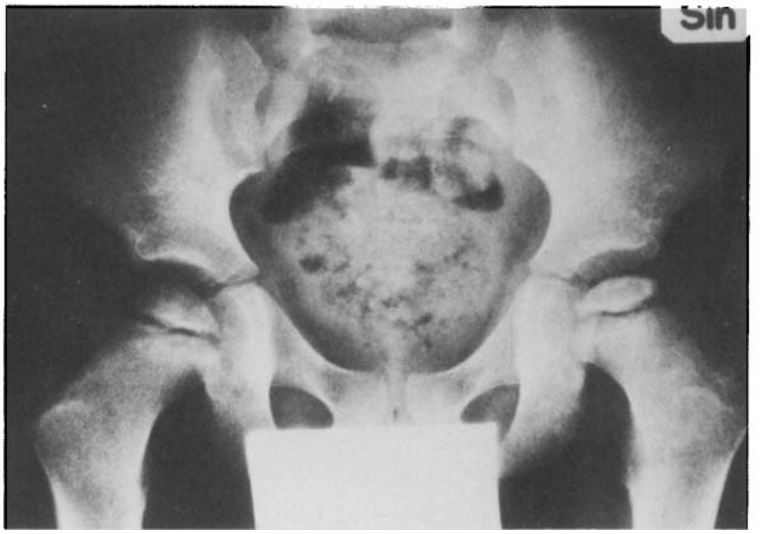


Figure 18. Case 3 with left hip pain and initial normal radiographs but with future Perthes disease development. Profiles of uptake superimposed as in figure 16. Drawn line = left hip, dotted line = right hip.

A. Scintimetry 10 days after the initial scan showing a remaining defect of isotope uptake in the epiphysis of the affected left hip.

B. Radiographs 6 weeks after onset of symptoms now revealing evidence of Perthes disease in the affected left hip.

Scintimetric data are listed in Table 4. Two patients were excluded because of movement during the examination. A decrease in uptake in the PFE (>20 per cent) was noted in 13 initial examinations and the mean time from onset of symptoms to the initial scintimetric examination was 5 (2–19) days in these patients. In 19 examinations an increase (>20 per cent) in uptake in the PFE was noted, and the duration of symptom in these children was 30 (3–92) days. A follow-up scintimetry was performed in 5 out of the 13 children with a decrease in PFE activity. Normalization occurred in two of these patients and increased activity (>20 per cent) in the PFE was noted in 3 children.

A decrease in growth plate activity was noted in 12 children. Follow-up scintimetry in two of these showed a normalization or increase of isotope uptake.

An increase in acetabular roof activity was noted in 12 children, and a decrease in two.

A clinical and radiographic follow-up was performed at 4–11 months. Five patients had had a recurrent episode of pain but none of the patients had Perthes disease on the conventional radiographs.

2. Parallel-hole collimator series

This study comprised 14 consecutive children analyzed numerically. Scintimetric results were correlated to sonographic findings and intracapsular pressure/volume recordings. The results are reported in the following Chapter IV.E.

E. Intracapsular pressure

1. Transient synovitis

Patients and methods are described in Chapters II.D and III.D

The presence of a sonographically diagnosed intracapsular effusion was verified in all 14 patients on aspiration. The intracapsular pressures with the hips in the various positions described are listed in Table 5 and 6. Mean intracapsular pressure (kPa) showed a maximum of 22.6 (SD 7.7) with the hips in extension and maximum inward rotation and a minimum of 2.3 (SD 1.1) in 45° of flexion. After aspiration, which was performed stepwise with simultaneous pressure recording, and with the hips in extension and neutral position, the pressure was around 0 kPa. In some cases a slight increase (<1.3 kPa) in pressure was noted in extension and maximum inward rotation after aspiration; other positions of the hip did not induce any increase in pressure but in flexion of 45° there was in some cases a slight negative pressure.

a. Capsular compliance

From the pressure/volume reduction graphs (Figure 7) the capsular compliance could be calculated in each patient. Within the range 0–8 kPa (0–60 mm Hg) compliance varied from 0.05–0.85 (mean 0.34, SD 0.22) ml/kPa (Figure 19).

A positive correlation (r=0.6) was found between capsular compliance and the age of the patient in this pressure range but, as might be expected from the magnitude of the variation in capsular compliance, there was no correlation between aspirated volume and pressure (r=0.04), nor between pressure and age of the patient (r=0.1). The mean aspirated volume was 3.8 (SD 2.0)(0.5–7.5) ml.

Following aspiration the children experienced marked relief of pain and an increase in active and passive motion.

Table 5. Observations in 14 patients with transient synovitis of the hip.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	9	M	L	6	4	37.5	1.18		4.5	3.3	Yes	11.6	18.6	9.7	2.0
2	12	M	L	1	5	36.4	0.93		5.0	5.5	No	11.0	24.2	23.3	1.9
3	4	M	R	1	4	36.8		1.03	4.3	2.8	No	12.1	21.3	7.8	0.0
4	6	M	L	1	15	38.2		1.08	5.0	1.6	No	14.5	21.4	7.4	2.5
5	3	M	R	2	3	37.6	1.02		4.6	0.5	No	10.5	16.0	8.6	2.0
6	8	M	R	2	7	37.5		1.26	6.8	5.5	No	17.3	28.6	25.9	2.0
7	10	M	R	2	7	37.5	0.82	1.09	8.1	7.5	Yes	11.8	21.9	13.7	3.3
8	6	M	L	1	3	38.1		1.35	5.4	2.8	Yes	14.9	26.3	20.0	4.0
9	4	M	L	1	5	37.0	0.80	1.02	2.7	3.5	Yes	7.6	16.0	18.0	0.7
10	4	M	L	1	7	36.9	0.99		2.7	2.0	No	17.3	22.6	15.7	2.3
11	5	M	R	1	3	37.2		1.23	5.0	6.0	No	11.4	18.0	8.3	2.7
12	4	M	R	2	3	37.0		0.95	5.0	5.0	No	13.0	18.6	10.6	2.7
13	4	F	L	2	13	37.0	0.89		5.3	5.0	Yes	16.6	45.9	30.6	3.7
14	6	F	L	1	4	37.6	1.13		4.7	1.5	No	11.4	16.6	10.9	2.4

A = Patient number
B = Age (years)
C = Sex (M=male, F=female)
D = Left/right symptomatic hip
E = Duration of symptoms at time of aspiration (days)
F = ESR (mm/hour)
G = Body temperature (°C)
H = Preoperative scintimetric ratio (symptomatic/non-symptomatic proximal femoral epiphysis)
I = Postoperative scintimetric ratio as in H
J = Preoperative sonography; capsular distension (mm)
K = Aspirated volume (ml)
L = Previous episode of transient synovitis
M–P = Intracapsular pressure in extension neutral position, extension inward rotation, extension outward rotation and in flexion 45° respectively (kPa)

Table 6. Intracapsular pressure in various positions of the hip.

Position of hip joint	Intracapsular pressure (kPa)		
	min–max	mean	SD
Extension, neutral	7.6–17.3	12.9	2.8
Extension, inward rotation	16.0–45.9	22.6	7.7
Extension, outward rotation	7.4–30.6	15.0	7.5
Flexion 45°	0.0– 4.0	2.3	1.1

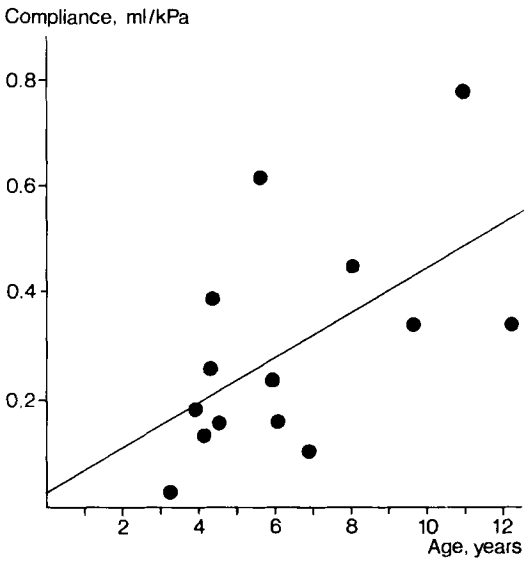


Figure 19. Capsular compliance (ml/kPa) in the range 0–8 kPa (0–60 mm Hg) in the 14 patients related to age.

b. Correlation to epiphyseal isotope uptake

Eight children were examined with ^{99m}Tc-MDP scintimetry prior to aspiration and another 6 after it. In 3 of the children the scintimetric ratio of the symtomatic/non-symptomatic proximal femoral epiphysis was ≥ 1.0; i.e. there was symmetrical or increased isotope uptake in the symptomatic side. In 5 children the ratio was <1.0, and in two of these children (Cases 7,9) there was a marked decrease, the ratios being 0.82 and 0.80 respectively indicating a disturbance of blood supply to the epiphysis. Follow-up scintimetry 3 days after aspiration revealed ratios of 1.09 and 1.02 respectively in these two cases, i.e. a restitution of blood supply to the epiphysis (Figure 20).

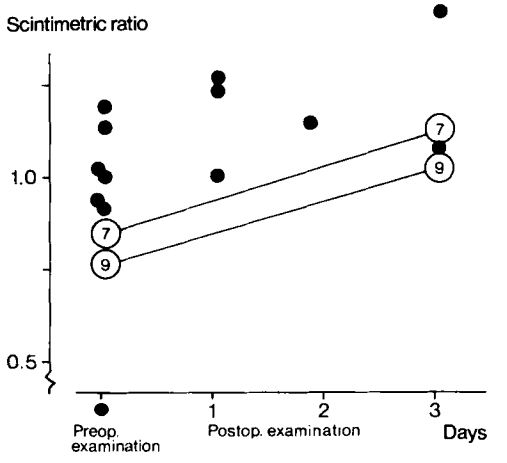


Figure 20. Scintimetric ratios (symptomatic/non-symptomatic PFE) pre- and postoperatively. In Cases 7 and 9 there was a photopenia in the PFE, reversible following aspiration.

Cases 7 and 9 with transient ischemia in the epiphyses are illustrated in Figures 21 and 22, respectively. Case 9 is of special interest since, to my knowledge, for the first time in the literature it demonstrates an episode of transient ischaemia in the epiphysis in a patient with manifest Perthes disease in the contralateral hip.

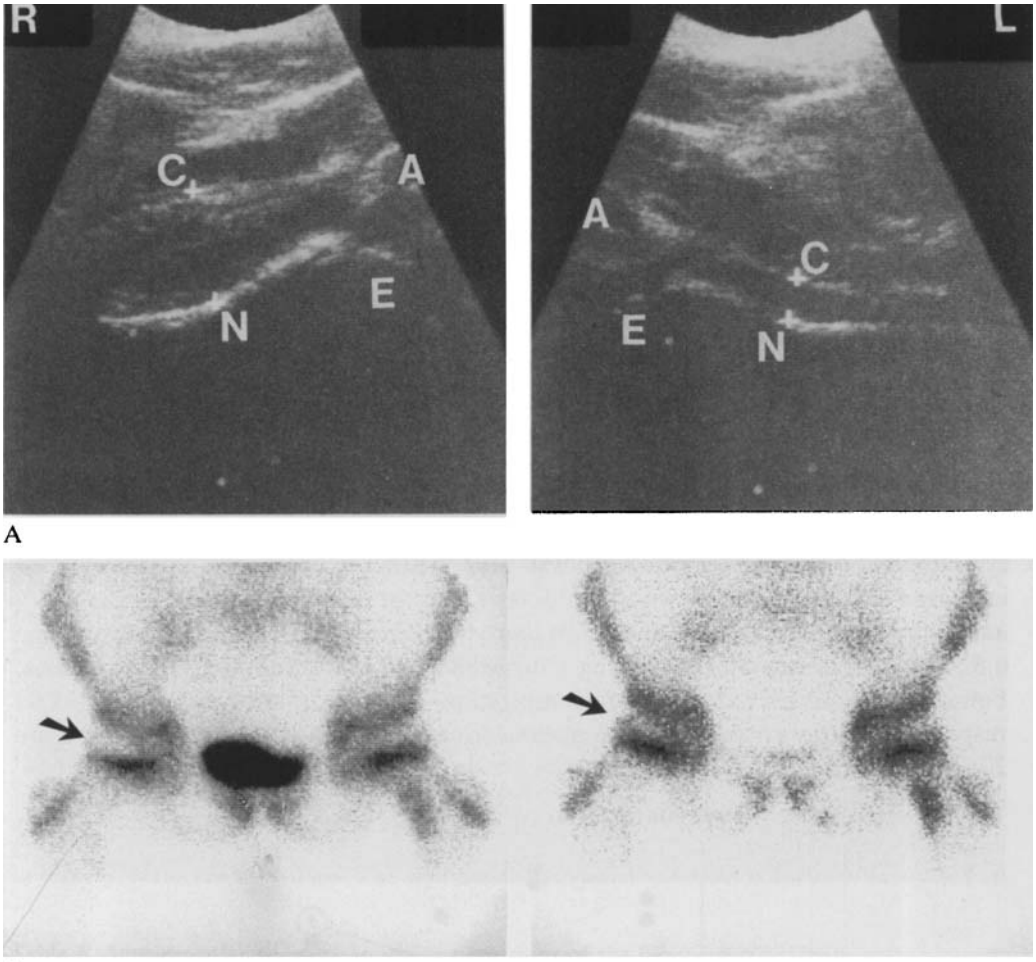


Figure 21. Case 7 with a transient photopenia in the right proximal femoral epiphysis (PFE).

A. Preoperative sonography of the right (R) symptomatic hip with a capsular distension of 8.1 mm as compared to the non-symptomatic left hip (L). Epiphysis (E), neck of femur ventral aspect (N), acetabular labrum (A) and joint capsule (C).

B. Preoperative scintimetry with photopenia of the PFE in the right hip (left) as compared to restitution in uptake following aspiration (right). (This patient also has a non-ossifying fibroma with increase in isotope uptake in the neck of femur of the non-symptomatic left hip.)

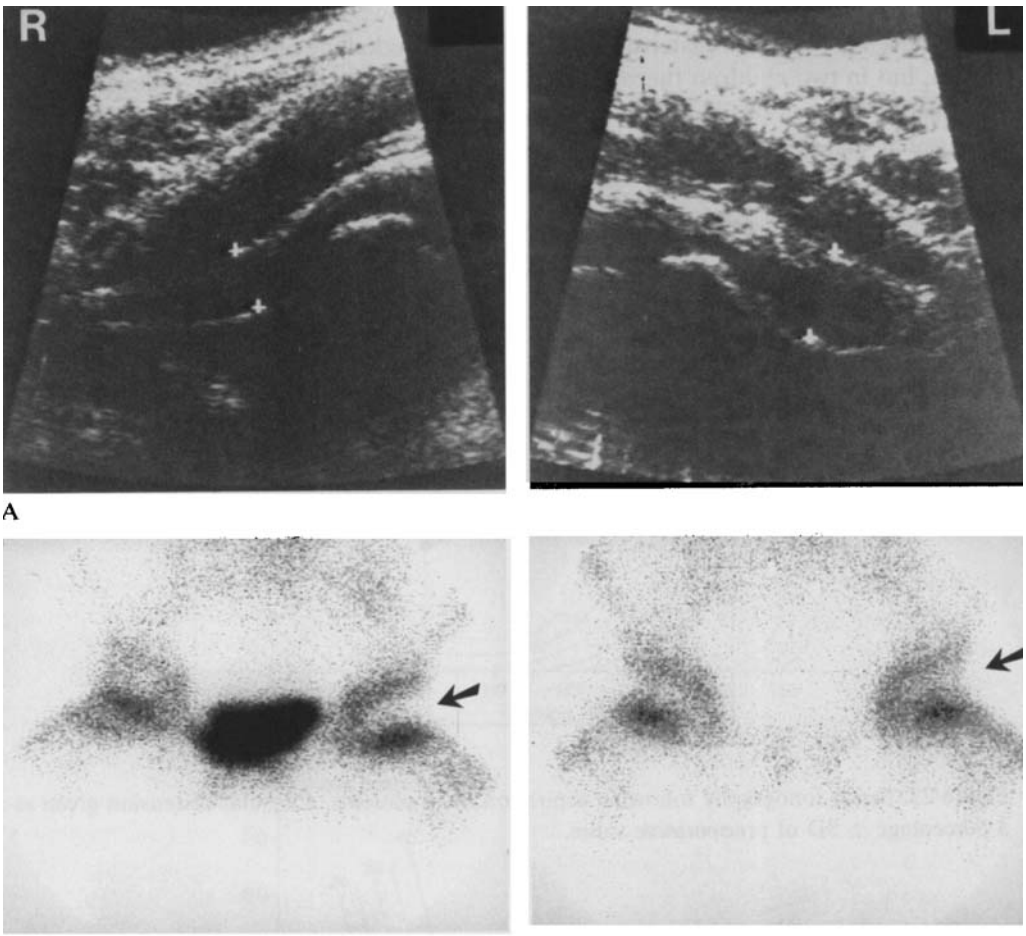


Figure 22. Case 9 with a transient photopenia in the left proximal femoral epiphysis (PFE).

A. Preoperative sonography of the left (L) symptomatic hip with a capsular distension of 2.7 mm as compared to the right hip (R).
B. Preoperative scintimetry with photopenia of the PFE in the left hip (left) as compared to restitution in uptake following aspiration (right).
(This patient has a manifest Perthes disease in the contralateral right hip).

c. Correlation of sonography and intracapsular volume and pressure

All 14 patients had intracapsular effusions diagnosed sonographically. Capsular distension (symptomatic minus non-symptomatic hip) was 2.7–8.1 (mean 5.0 SD 1.0) mm (Table 5). Case 9 was excluded due to Perthes disease in the contralateral hip. A positive correlation was observed between capsular distension and the volume of fluid aspirated ($r=0.6$) but, as a consequence of the variation in capsular compliance there was no correlation between capsular distension and the intracapsular pressure ($r=0.06$).

Serial postoperative sonographic examinations showed a recurrence of the effusion. In 3 children the capsular distension equalled or exceeded the preoperative value within 5 days, but in two children there was no recurrence. The postoperative development of capsular distension is illustrated in Figure 23. After two weeks the mean asymmetry in capsular distension was reduced to 1.2 (mean SD 0.8) mm.

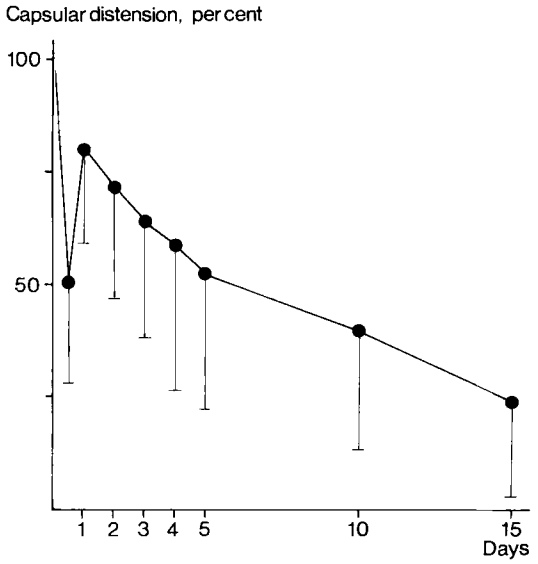


Figure 23. Serial sonography following aspiration in 13 patients. Capsular distension given as a percentage ± SD of preoperative value.

In all children clinical symptoms subsided within two weeks with a restoration of a full range of movements. Cases 7 and 9 have had normal radiographic follow-up at 8 and 12 months respectively and have had no clinical symptoms.

2. Cadaver study

The findings with regard to the correlation of the intracapsular pressure and the rotation of the joint around the axis of the femoral neck were consistent in all 3 specimens. There was an increase in intracapsular pressure with increasing rotation in the direction of extension as well as in flexion, with minimum pressure in the neutral position i.e. in the position between maximum extension and flexion (Figure 24). The compliance of the joint capsules differed in that in one joint the intracapsular volume was markedly less. In the normal condition, i.e. without intracapsular saline, rotation within physiological limits did not produce an increase in intracapsular pressure indicating that under these conditions there is no tension in the capsular structures. Thus, under these conditions, the joint is stabilised by the atmospheric pressure. In specimen 2, as calculated from the diameter of the head of femur and the vaporizing

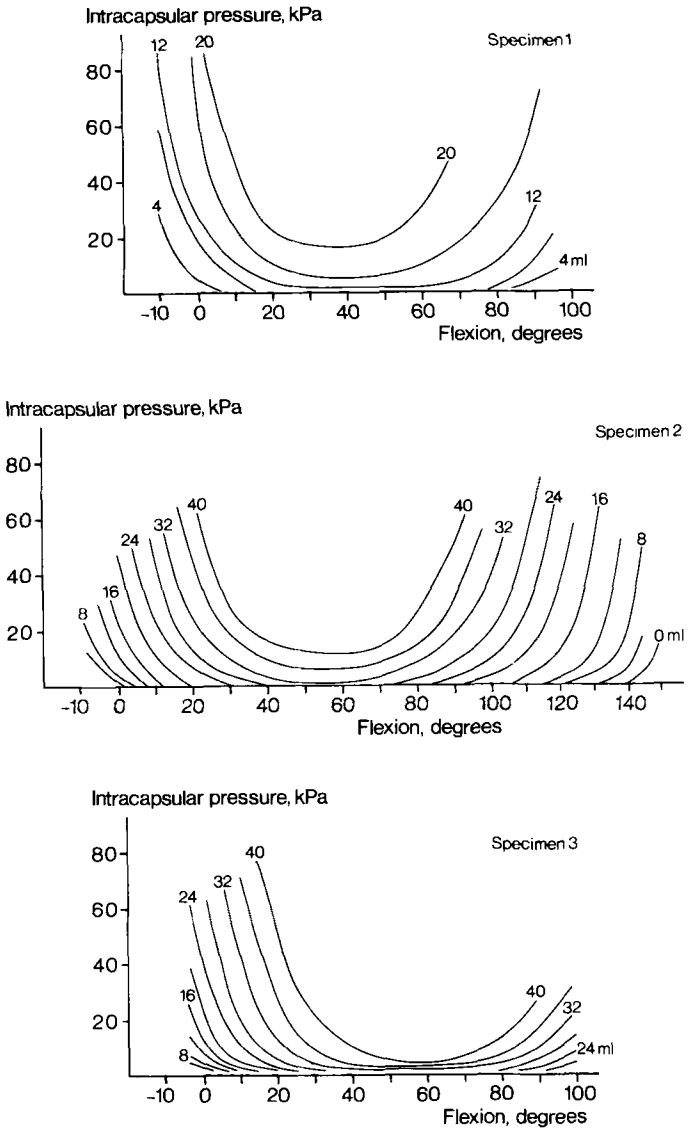


Figure 24. Correlation of rotation around the axis of the neck of femur, volume of intracapsular saline and intracapsular pressure in the right hip joints of 3 accidentally killed individuals aged 19, 19 and 52 years respectively.

pressure at 37°, approximately 220 N of traction was theoretically needed to dislocate the head.

When saline is infused intracapsularly the pressure-less mechanism is distorted and the pressure-less range of the rotational movement decreases with increasing intracapsular volume as illustrated in Figure 25. The same phenomenon is illustrated in measurements of the moment needed to rotate the joint under the various conditions.

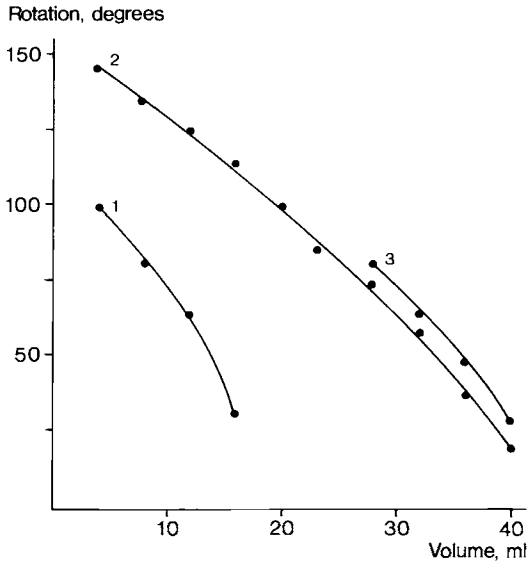


Figure 25. Range of rotation around the axis of the neck of femur in the 3 cadaver specimens if pressure is not allowed to exceed 6.7 kPa (50 mm Hg). The range of rotation decreases with an increasing volume of saline. Specimen 1 has a markedly less compliance when compared to specimens 2 and 3.

Under normal conditions, without intracapsular saline, no measureable moment was needed to rotate the femoral neck within physiological limits whereas with an increasing intracapsular volume the moment increased in both flexion and extension as illustrated in specimen 3 (Figure 26).

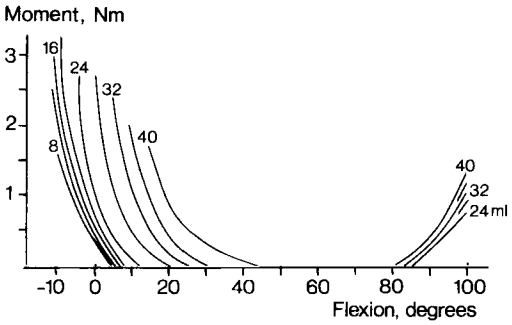


Figure 26. Correlation of rotation around the axis of the neck of femur, volume of intracapsular saline and the moment needed to rotate the femur in specimen 3.

F. Proteoglycan fragments in joint effusion

Patients and methods are described in Chapters II.E and III.E
For individual clinical data and findings see Table 7. Hip joint synovitis as diagnosed sonographically prior to aspiration was confirmed in all children with transient synovitis as well as in the 4 children with manifest Perthes disease. The mean aspirated volume in the children with transient synovitis was 3.5 (0.5–7.5) ml, in the children with Perthes disease it was 1.5 (0.5–3.0) ml but in the 3 children with dislocation of the hip aspirated volumes were around 0.2 ml in all.

The concentration of proteoglycan fragments in joint fluid (given as μg/ml of proteoglycan antigen) was significantly higher in the children with transient synovitis; mean concentration was 238 (SD 151) μg/ml as compared to 65 (SD 79) μg/ml in the patients with Perthes disease ($p<0.01$). In the 3 children with dislocated hips the mean concentration was 13 μg/ml (Figure 27).

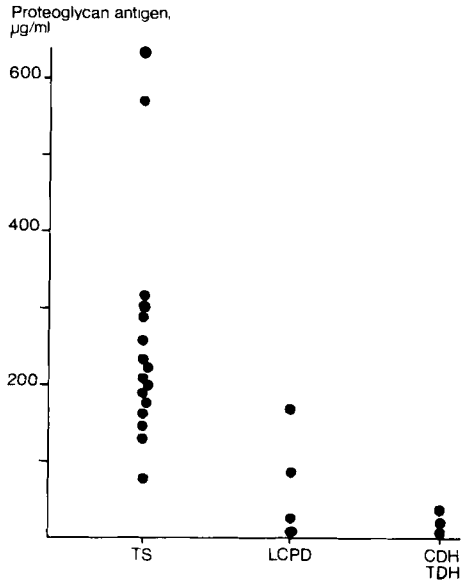


Figure 27. Concentration of proteoglycan antigen in the joint fluid in 16 children with transient synovitis of the hip, 4 children with Perthes disease and 3 with dislocation of the hip.

The two children with Perthes disease with the highest concentrations of proteoglycan fragments had both an episode with the acute onset of pain and limitation of active and passive movement of the hip, i.e. the symptoms of an episode of synovitis, whereas the other two, with low concentrations of proteoglycan antigen, had only minor symptoms at time of aspiration.

There was no correlation between the level of proteoglycan antigen concentration and the volume of aspirated fluid, nor with the level of intracapsular pressure.

Table 7. Data in 23 children analyzed for proteoglycan antigen in hip joint fluid.

A	B	C	D	E	F	G	H	I	J	K	L
1	9	M	L	Yes	4	37.5	6	3.3	11.6	73	TS
2	4	M	R	No	4	36.8	1	2.8	12.1	185	TS
3	6	M	L	No	15	38.2	1	1.6	14.5	257	TS
4	3	M	R	No	3	37.6	2	0.5	10.5	185	TS
5	8	M	R	No	7	37.5	2	5.5	17.3	299	TS
6	10	M	R	Yes	7	37.5	2	7.5	11.9	186	TS
7	6	M	L	Yes	3	38.1	1	2.8	14.9	142	TS
8	4	M	L	Yes	5	37.0	1	3.5	7.6	298	TS
9	4	M	L	No	7	36.9	1	2.0	17.3	162	TS
10	5	M	R	No	3	37.2	1	6.0	11.5	177	TS
11	4	M	R	No	3	37.0	2	5.0	13.1	307	TS
12	4	F	L	Yes	13	37.0	2	5.0	16.7	212	TS
13	6	F	L	No	4	37.6	1	1.5	11.5	144	TS
14	5	F	L	Yes	5	37.2	1	2.5	15.2	214	TS
15	14	M	L	No	16	37.4	10	2.0	4.0	570	TS
16	10	F	L	No	63	38.1	4	4.0	4.3	635	TS
17	7	M	L		17	37.0	2 m	3.0	9.5	169	LCPD
18	6	M	L		20	36.9	1 y	0.5	6.0	2	LCPD
19	7	M	R		18	37.2	2.5 y	2.0	5.5	84	LCPD
20	10	M	R		3	37.0	20 m	0.5	11.1	6	LCPD
21	3	M	R	No	28	37.8	2	0.2	–	27	TDH
22	4m	F	L		3	37.0	–	0.2	–	3	CDH
23	4m	F	R		4	37.6	–	0.2	–	10	CDH

A = Patient number
B = Age (years/months)
C = Sex (M=male, F=female)
D = Symptomatic hip left/right
E = Previous episode of transient synovitis?
F = ESR (mm/hour)
G = Body temperature (°C)
H = Duration of symptoms at time of aspiration (days/months/years)
I = Aspirated volume (ml)
J = Intracapsular pressure with the hip in extension and neutral position (kPa)
K = Proteoglycan antigen in joint fluid (μg/ml)
L = TS=Transient synovitis, LCPD=Legg-Calvé- Perthes disease, CDH=Congenital dislocation of the hip, TDH=Traumatic dislocation of the hip

V Discussion

1. Conventional radiography

Since the report by Lange (1927), regarding swelling of the internal obturator muscle as an early radiographic sign of infectious arthritis of the hip, several authors have advocated dislocation and blurring of the fat planes surrounding the hip joint as a reliable sign of joint disease in children (Drey 1953, Ferguson & Howorth 1954, Hermel & Skaloff 1954, Hermel & Albert 1962, Adams 1963) as well as in adults (Reichmann 1965, Bartley & Chidekel 1966). Other authors found the changes in the soft tissues unreliable for assessing joint disease (Arcomano et al. 1963, Hardinge 1970). In 1963 Valderrama reported that the variations in the fat planes depended upon the position of the femur but still regarded a bulging lateral fat plane, interpreted as capsular swelling, as a sign of joint disease. Vandeputte (1971) explained the displacement of the fat planes by increased muscular contraction. Brown (1975) showed that the position of the fat planes were related to the position of external rotation and abduction of the femur and Guerra et al. (1978), in an anatomical study, showed that the distance between muscle fat planes and the joint capsule makes it unlikely that a joint effusion could have any direct influence on the position of the fat planes. In agreement with this it can be concluded from this study that the medial iliopsoas shadow is not related to the hip joint capsule or to synovitis. The lateral fat plane, however, is positioned between the gluteus minimus, tensor fascia lata, iliopsoas and, more distally, the rectus femoris muscles as evidenced by the CT examinations (Egund et al. 1986 b). Thus, the most posterior portion of these planes seen in the CT and AP projection has an intimate relationship to the hip capsule anteriorly. At this level of the head of femur, however, capsular distension is minimal even in large effusions and does not affect the position of the fat plane (Figure 10).

The present study, the first in which conventional radiography and CT have been compared in transient synovitis of the hip, confirms the statement of Brown (1975) and Guerra et al. (1978) that the lateral capsular shadow fat plane is related to the position of the leg, particular in abduction. It can be concluded that "pericapsular swelling" can not be interpreted as a sign of hip joint effusion.

Resnick & Niwayama (1981) and Andersen & Stewart (1970) suggested that an increase of the joint space was a more reliable sign of hip joint effusion. This is contradicted by the findings in this study that the increase in medial joint space is not

useful diagnostically in the acute stage of hip joint synovitis although statistically significant. It is however of interest with regard to the cartilage reaction as evidenced by the increase in proteoglycan fragments in the joint fluid of our patients which is further discussed below.

2. Computed tomography (CT) and sonography

Since conventional radiographic examination does not provide sufficient information about effusion of the hip joint (Brown 1975, Resnick & Niwayama 1981) alternative diagnostic measures would be CT, with additional radiation to the patient, or diagnostic aspiration of the hip which in this age group requires general anaesthesia.

Kramps & Lenschow (1979) showed that hip anatomy could be demonstrated by sonography and Wilson et al. (1984) visualized intraarticular fluid collection in 16 patients. However, they felt not able to decide the sensitivity of the method and concluded that a difference of more than 3 mm between the two hips was suggestive of an effusion.

In the present investigation the normal CT and sonography anatomy of the hip joint was described as well as the anatomy of joint effusion. The high degree of correlation between CT and sonography measurements shows that the capsular sonographic echo used in this study represents the ventral aspect of the joint capsule. The CT and sonography measurements of capsular distension were calculated in each patient as the difference between the affected and non-affected side. By comparison with the 14 non-symptomatic children, we conclude that the non-symptomatic hips in our symptomatic children were unaffected, i.e. as judged from sonography there was no synovitis in these hips, and that a difference in the distance between the ventral aspect of the neck of femur and that of the capsule of more than 0.5 mm is pathological in the individual case.

No attempts were made to compare the CT and sonography measurement of capsular thickness and the width of effusion since the width of the sonography echogenic zones obtained from the capsule are of a technical nature and depend upon the transducer frequency amongst other factors (Walter 1985).

The tension of the hip capsule is increased in extension and internal rotation, especially in hips with effusion (Wingstrand et al. 1985 c) – a fact that may result in a changed distribution of the fluid within the joint. This may explain the slight discrepancy between CT and sonography measurements obtained in those hips with the largest effusion since the reproducibility of hip flexion and rotation between the two examinations was probably less accurate in the most painful patients. Similarly a more pronounced displacement of the capsule medial and posterior to the femoral neck was observed in the CT examination of these hips which may also contribute to this discrepancy.

This investigation shows that CT and sonography are comparable diagnostic methods for the evaluation of an effusion in the hip joint of a child, and I feel confident to diagnose effusions with a difference in capsular distension of 1 mm. Thus sonography should be the method of choice for the assessment of joint effusion in transient synovitis

of the hip in children. However, the diagnostic accuracy of sonography depends on a correct examination technique and knowledge of normal anatomy. CT requires less individual examination skill, and provides an excellent alternative method; the radiation dose is well within acceptable limits (Bankvall et al. 1982).

3. ^{99m}Tc-MDP scintimetry

Most previous investigators have assessed scintigraphic results in the child's hip qualitatively. In the Department of Orthopaedics, University Hospital, Lund with its long experience of isotope techniques (Bauer et al. 1955, Bauer and Wendeberg 1959, Bauer 1968) and in quantitative assessment in particular (Bauer et al. 1980, Brümmer 1983, Strömquist 1983) isotope studies in children were focused on the possibility of numerical analysis. Good quantitative assessment of femoral head involvement in Perthes disease was reached by LaMont et al. (1981) and Hasegawa (1985) using a pin-hole collimator. In spite of the methodological pitfalls in quantification with the use of a pin-hole collimator, it does provide the resolution necessary for good anatomical definition in children. LaMont et al. (1981) claimed that a reduction of isotope uptake over the proximal femoral epiphysis amounting to $\geq$40 per cent was indicative of Perthes disease. This is in accordance with the one case in this material which developed radiographic evidence of Perthes disease but it also occurred in 3 children with a transient episode of epiphyseal ischaemia without subsequent radiographic necrosis.

The correlation of the visual parallel-hole collimator evaluation and the quantitative pin-hole collimator evaluation of the isotope uptake in the proximal femoral epiphysis was good in this material (Figure 14). However, in the later stages of Perthes disease there is an increase in metaphyseal isotope uptake (Bohr 1973, Danigelis et al. 1975, Bensahel et al. 1983). In the presence of this activity the epiphyseal activity may be visually underestimated due to an optical illusion.

The pin-hole technique makes direct visual comparison between the two hips difficult. In this respect the profile of interest technique provides a graphic finger print of the activity in the various anatomical regions of the hip making possible a direct visual comparison of the uptake pattern in the two hips. Further the region of interest may be difficult to define optimally when studying the growth plate uptake or the acetabular uptake with its sharp and well defined peak activity where the profile across the hip provides better resolution.

Several investigators have reported normal or diffusely increased scintigraphic uptake in transient synovitis of the hip (Ash et al. 1975, Danigelis et al. 1975, Fasting et al. 1978, Bensahel et al. 1983). By contrast, Kloiber et al. (1983) reported a series of 19 cases of transient synovitis with decreased PFE scintigraphy in 6 cases. After joint aspiration in these cases isotope uptake 1–10 days later showed a return to normal suggesting that the procedure had been therapeutic. However, Sutherland et al. (1980) reported two cases of transient synovitis with an initial PFE isotope defect that spontaneously returned to normal two weeks later. Sty et al. (1983) reported on "a few" children with transient synovitis with an initial defect where joint aspirations were

negative but in whom the isotope uptake had returned to normal in a scan 24 hours later.

We have found that among children presenting with the clinical picture of transient synovitis, there are a number of cases with transient ischaemia of the PFE. The concept of ischaemic episodes in the PFE raises interesting suggestions about the relationship between transient synovitis and LCPD and would also be in accordance with the histological findings of Inoue et al. (1976), suggesting repeated vascular insults in LCPD. The duration and/or severity of a single, or possible repeated, episode of ischaemia of the PFE would determine the development of radiographic changes of LCPD.

Reduced uptake in the growth plate was observed in 12 children in our material. This phenomenon has not previously been reported but in a paper by Minikel et al. (1983) a patient with transient synovitis of the hip and PFE ischaemia is illustrated where reduced growth plate uptake is visually obvious. Recently, initially reduced growth plate activity has also been reported experimentally in induced synovitis of the knee in mongrel puppies (Hansen et al. 1985). The phenomenon may be explained by the fact that the proximal part of the growth plate, the location of chondrocyte proliferation (Trueta et al. 1960), is also supplied by intracapsular vessels, potentially sensitive to increased intracapsular pressure. This may also explain the growth plate-metaphyseal engagement and subsequent growth disturbance observed in patients with transient synovitis and in patients with manifest Perthes disease (Barnes 1980, Catterall et al. 1982, Wolinski et al. 1984, Wingstrand et al. 1985 a).

Increased uptake in the acetabular roof was noted in 5 children indicating increased metabolism in this region. This is in accordance with the histological findings of Adams (1963) of vascular proliferation in the acetabular part of the joint following experimental synovitis. It also agrees with the findings of acetabular cartilage hypertrophy following experimental synovitis (Gershuni et al. 1974, Gershuni et al. 1981) or following transient synovitis as demonstrated by acetabular roof overgrowth on conventional radiographic follow-up in this study, a phenomenon that has also been demonstrated in manifest Perthes disease (Danielsson et al. 1982, Wingstrand et al. 1985 a, Yngve & Roberts 1985).

Scintigraphy has been reported to have very high diagnostic sensitivity as well as specificity in Perthes disease (Danigelis et al. 1975, Fasting et al. 1978, Bensahel 1980, Sutherland et al. 1980, Tachdjian 1980, LaMont et al. 1981). However, this does not apply to the findings in early scintimetry in acute hip pain where a typical defect of uptake in the epiphysis is potentially reversible and not followed by radiographic evidence of necrosis or clinical symptoms (Wingstrand et al. 1985 b). However, negative scintimetry should effectively exclude Perthes disease.

Because of the very high diagnostic sensitivity of scintimetry in the early stages of Perthes disease, preceding the diagnostic capacity of conventional radiography by months, scintimetry should be performed in children with radiographically silent hip pain in order to rule out Perthes disease or, in cases with epiphyseal uptake defect, to initiate further examination.

4. Intracapsular pressure

The vascular supply to the proximal femoral epiphysis changes with age as clarified by Trueta (1957) and Ogden (1974). The epiphysis is supplied mainly via lateral, intracapsular branches emanating from the medial circumflex artery with no contribution across the growth plate and a very small contribution via vessels in the ligamentum teres. Since the arteries and veins are located intracapsularly they may be sensitive to increased intracapsular pressure. It has been shown in puppies (Woodhouse 1964, Lucht et al. 1983) and suggested clinically in intracapsular fractures and septic arthritis (Minikel et al. 1983, Wingstrand et al. 1986 c) and in transient synovitis (Kloiber et al. 1983, Wingstrand et al. 1985 c) that an intracapsular hematoma or effusion with an ensuing increase in intracapsular pressure compromises blood flow through the proximal femoral epiphysis. This is also a probable cause in the development of Perthes-like radiographic changes in children with spontaneous intracapsular bleeding in the hip associated with hemophilia (Ahlberg 1965, Minikel et al. 1983)

Animal studies with experimentally induced hip joint tamponade have shown the development of necrosis or decreased circulation in the proximal femoral epiphysis of the hip. Intracapsular pressures of the magnitude noted in this series should be sufficient to cause ischaemia in the epiphysis due to venous, and even arterial occlusion (Woodhouse 1964, Kemp 1981, Luch et al. 1983).

Soto-Hall et al. (1964) reported intracapsular pressures of 68 and 78 mm Hg (9.1 and 10.4 kPa) in transient synovitis in two patients with the hips in a neutral position. Kloiber et al. (1983) found pressures of 22–66 mm Hg (2.9–8.8 kPa) in 8 patients. However, as shown here, and by Kallio and Ryöppy (1985) the intracapsular pressure in these patients is very much dependent on the position of the hip joint; in extension a significant rise in intracapsular pressure is produced. Theoretically, any increase in intracapsular pressure above the level of the pressure in the veins decreases the pressure-gradient across the capillary bed in the epiphysis with an ensuing decrease in blood flow (Madsen, 1980) up to a point where the metabolic demands of the epiphyseal cells are no longer met. This mechanism could explain the findings in two of our cases with a decrease in isotope uptake in the epiphysis, which proved to be reversible following aspiration. One of these children (Figure 22) is of special interest since, to my knowledge for the first time in the literature, he documented an episode of transient epiphyseal ischaemia in a patient with manifest Perthes disease in the contralateral hip.

Why do not all children with initial epiphyseal ischaemia develop epiphyseal necrosis? If these children are allowed free movements of the hip, as in this series, they only intermittently adopt an unfavourable position, i.e. extension. This would explain why scintimetry does not reflect high intracapsular pressure in all cases. In flexion the pressure drops drastically to a less harmful level, and thus, if the patient is allowed free active or passive movements of the hip following injection of isotope the position of the hip in the following hour would determine the scintimetric outcome as would the duration of symptoms at the time of scintimetry. The duration and/or severity of a single or repeated episode of reduced blood flow through the epiphysis would

determine the development of irreversible damage and thus the radiographic development of Perthes disease. This concept of ischaemic episodes, possibly repeated, in the epiphysis due to intracapsular tamponade would be in accordance with the histologic findings of Inoue et al. (1976) suggesting repeated vascular insults in the development of Perthes disease.

The correlations of intracapsular pressure, rotation of the hip joint and intracapsular volume in the cadaver study are consistent with the clinical findings. The cadaver study confirms that the intracapsular pressure is determined to a high degree by the position of the joint with regard to rotation, with a minimum pressure in the neutral position, i.e. in between maximum extension and maximum flexion around the axis of the femoral neck and with a marked increase in intracapsular pressure in the direction of extension, as noted clinically, but also in flexion. This is consistent with the findings of Walmsley (1928) who claimed that the hip capsule becomes tight only in the position of extension and slight internal rotation and that it was slack in all other positions of the joint. It is also consistent with the observation of increased intracapsular pressure in the treatment of congenital dislocation of the hip in "frog-leg" or "human" position i.e. extreme flexion or extension and subsequent avascular necrosis of the PFE (Wingstrand and Sundén 1986 b). The presence of intracapsular effusion, or saline, distorts the mechanism and decreases the pressure-less range of movement around the rotational axis of the femoral neck (Figure 25). This is also consistent with the clinical finding that patients with an intracapsular effusion or bleeding spontaneously adopt the position of flexion and slight outward rotation in order to reduce pain. It also agrees with the observation in this study and in patients with traumatic hip joint tamponade (Wingstrand et al. 1986 a) that aspiration, and thus reduction of pressure, has an immediate palliative effect. Histologically (Kellgren et al. 1950) and biochemically (Grönblad et al. 1985) pain-transmitting nerves have been identified in the synovial membrane. The prerequisite for the pressure-less rotation around the axis of the femoral neck under physiologic conditions is the geometrical design of the joint capsule. Its hyperboloid shape has a minimum diameter over the midpart of the femoral neck and maximum diameters at the sites of insertion, i.e. around the intertrochanteric region and around the acetabular rim. This design tightens the capsular structures only in maximum extension and in maximum flexion around the axis of the femoral neck whereas in all other positions the capsule is slack. With increasing intracapsular volume the shape of the capsule schematically changes towards a more cylindrical design which explains why the pressure-less interval decreases. However, even with a pathological intracapsular volume of fluid, the moment needed to rotate the joint in the direction of extension is well below the moment produced by the weight of the leg itself if the patient is placed supine. This manoeuvre therefore produces a significant rise in intracapsular pressure. On the other hand even in the slack positions of the joint under normal conditions the capsule serves to stabilize the joint since atmospheric pressure has to be overcome to dislocate the joint. For instance in specimen No 2 (Figure 24), as calculated from the diameter of the head of femur, and the vaporizing pressure at 37°C the theoretical traction needed to dislocate the head of femur from the acetabular socket was 220 N.

5. Proteoglycan fragments in joint fluid

Several experimental animal models have been used to mimic synovitis. Gershuni et al. (1974) injected surgical talcum (magnesium-silicate) intracapsularly to induce synovitis and demonstrated articular cartilage thickening in the femoral head as well as in the acetabulum with subsequent incongruency in the joint (Gershuni-Gordon & Axer 1974, Gershuni et al. 1979). It was also demonstrated by Gershuni et al. (1981) that there is an immediate response in the cartilage with increased cartilage volume due to increased hydration and decrease in glycosaminoglycan concentration following experimentally induced synovitis. As a consequence of this there is an early deterioration of the mechanical properties of the joint cartilage with increased deformability of the femoral head cartilage as well as that of the acetabulum (Gershuni & Kuei 1984). However, 3 weeks after induction of synovitis there is an increase of cartilage mass due not only to hydration but also to an increase in matrix metabolism and production. The subsequent incongruency of the joint and deterioration of the mechanical properties may harm the pattern of force transmission to the underlying epiphyseal bone.

In view of the findings of the present study with a substantial increase in proteoglycan fragments in the joint fluid it can be proposed that the joint cartilage in the child with transient synovitis may be affected in a similar way to Gershuni's experimental model (Lohmander et al. 1986). This is also in accordance with the radiographic and scintimetric findings indicating an increase in epiphyseal as well as acetabular increase in metabolism with subsequent cartilage overgrowth. The experimental finding of immediate cartilage oedema is in accordance with the findings that there is an immediate lateral displacement of the femoral head as judged from the increase in medial joint space. This would certainly result in an incongruency in the joint with increased stress on the anterolateral border of the femoral head and may suggest that these children should abstain from weight-bearing for a period of time.

In two of our patients with manifest Perthes disease there was an increase in proteoglycan fragment concentration. It is interesting to notice that these two children had an acute episode of pain and limitation of movement and sonographic evidence of active synovitis whereas the other two children with very low concentrations had only minor symptoms at time of aspiration.

The concentration levels of proteoglycan fragments found in our patients with transient synovitis are comparable to those found in adults with reactive arthritis and are increased when compared to patients with rheumatoid arthritis without radiographically obvious cartilage destruction (Saxne et al. 1985).

The intraarticular injection of glucocorticoids has a therapeutic effect on the pathological cartilage metabolism as reflected in decreased proteoglycan fragment concentration in synovial fluid (Saxne et al. 1986). These findings demonstrate a possible role of glucocorticoids in inhibiting cartilage degradation in arthritis and synovitis.

VI. Conclusions

The observations presented have permitted the following conclusions concerning the diagnosis, development and treatment of transient synovitis of the hip in the child:

1. Radiographic examination; the so called capsular and iliopsoas shadows and widening of the medial joint space are not diagnostic in the acute stage of the condition. However, at a later stage radiography reflects cartilage hypermetabolism in the head of femur as well as in the acetabulum.
2. Computed tomography and sonography are reliable diagnostic tools with respect to intracapsular hip joint synovitis; an increase in the capsule – femoral neck distance in the frontal plane of more than 1 mm by CT or sonography is pathological.
3. The intracapsular pressure in these children is elevated and very dependent on the position of the hip joint. Due to the effect of torque on the hip joint capsule, the pressure is markedly increased in extension and well exceeds the intra-arteriolar pressure in the vessels supplying the proximal femoral epiphysis.
4. In a few of the children, transient ischaemia of the proximal femoral epiphysis may be seen using radionuclide scintimetry. This ischaemia is reversible, spontaneously or following aspiration of the hip joint.
5. The rotational moment needed to produce these pressures is below the moment produced by the weight of the leg if the patient is placed supine with the hip extended. This potentially hazardous increase in intracapsular pressure may persist for several days. The children should be placed with the hip in 45° of flexion to minimize intracapsular pressure.
6. The development of Perthes disease following transient synovitis was rare in this study. Only one child out of 26 developed radiographic evidence of Perthes disease.
7. There is an increase in proteoglycan fragments in the joint fluid indicating an imbalance in cartilage metabolism and a deterioration of the mechanical properties.

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