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# Anterior Joint Capsule of the Normal Hip and in Children with Transient Synovitis: US Study with Anatomic and Histologic Correlation<sup>1</sup>

**PURPOSE:** To study the anatomic components of the anterior joint capsule of the normal hip and in children with transient synovitis.

**MATERIALS AND METHODS:** Six cadaveric specimens were imaged with ultrasonography (US) with special attention to the anterior joint capsule. Subsequently, two specimens were analyzed histologically. These anatomic findings were correlated with the US findings in 58 healthy children and 105 children with unilateral transient synovitis.

**RESULTS:** The anterior joint capsule comprises an anterior and posterior layer, mainly composed of fibrous tissue, lined by only a minute synovial membrane. Both fibrous layers were identified separately at US in 98 of 116 (84%) hips of healthy subjects and in all hips with transient synovitis. Overall, the anterior layer was thicker than the posterior layer. In transient synovitis compared with normal hips, no significant thickening of both layers was present ( $P = .24$  and  $.57$  for the anterior and posterior layers, respectively). Normal variants include plicae, local thickening of the capsule, and pseudodiverticula.

**CONCLUSION:** Increased thickness of the anterior joint capsule in transient synovitis is caused entirely by effusion. There is no US evidence for additional capsule swelling or synovial hypertrophy.

In patients with a painful hip, ultrasonography (US) of the hip is performed to detect effusion in the anterior recess of the joint capsule. Both thickening of the anterior joint capsule and bulging of the capsule are considered evidence of joint effusion (1-10). The hip is examined in an unconventional plane (ie, parasagittal) that parallels the femoral neck by an anterior approach. To our knowledge, however, no detailed cross-sectional anatomic study has been performed in this plane. Therefore, standardized measurements are not possible because detailed description of the local anatomy is not available. Moreover, the need for anatomic detail is increased because US techniques have improved and can depict the anatomy in greater detail.

The aim of this study was to examine the anatomy of the joint capsule of the hip in a plane that is relevant to US imaging and to investigate the appearance of the joint capsule in transient synovitis.

## MATERIALS AND METHODS

This study included (a) study of six cadaveric specimens, (b) US study of the hip in 58 healthy children, and (c) prospective US study of 105 children with transient synovitis.

The study was approved by the institutional review board. In the study of the healthy children, informed consent was obtained from parents and children before the examination.

## Cadaveric Study

Six cadavers were available for imaging, anatomic, and histologic examinations.

The cadavers were not fixated during imaging studies. All cadavers were examined with US by using a 7–10-MHz linear array transducer (Ultramark 9 HDI; Advanced Technical Laboratories, Bothell, Wash).

After imaging, two cadavers were deep frozen and sawed, by using a band saw (five teeth per inch), into 5-mm-thick slices parallel to the femoral neck, identical to the US plane, with use of a technique described by Entius et al (11) modi-

fied for the hip joint. This was followed by histologic examination of the slices; the tissues were fixed in formalin and embedded in paraffin. Sections 10  $\mu$ m thick were cut and routinely stained with hematoxylin-eosin.

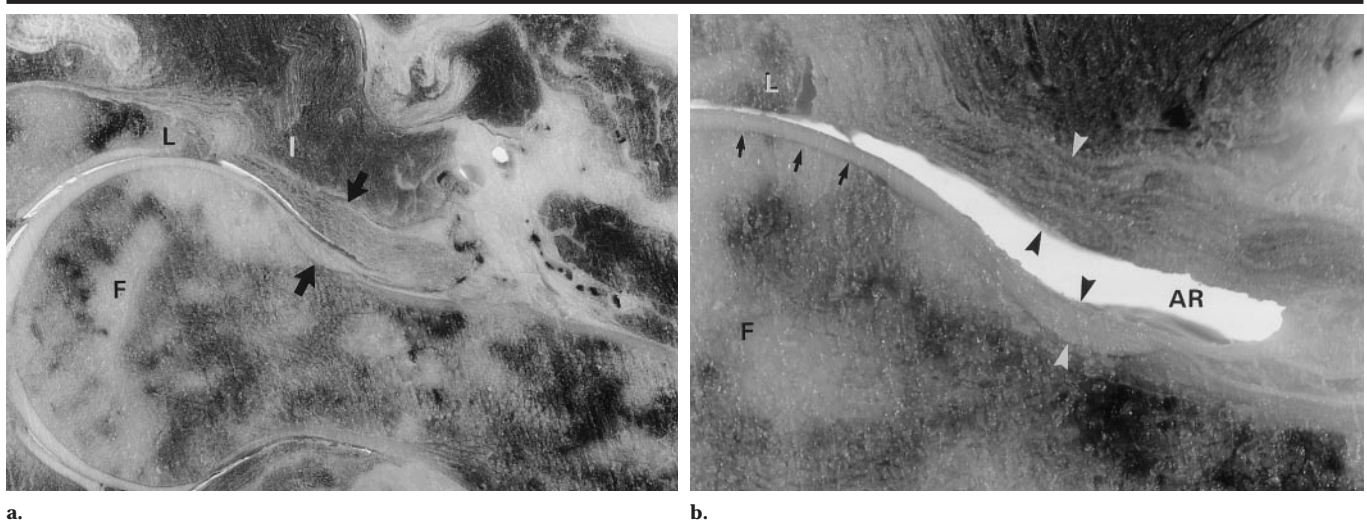
With US guidance, the remaining four cadavers (eight hips) were injected with 10 mL of saline solution (0.9% NaCl). The needle entered the joint cavity at the level of the labrum to preserve the anatomy of the anterior recess. Anatomic landmarks, such as the layers of the anterior joint capsule, were identified before and after administration of saline solution.

## Healthy Children

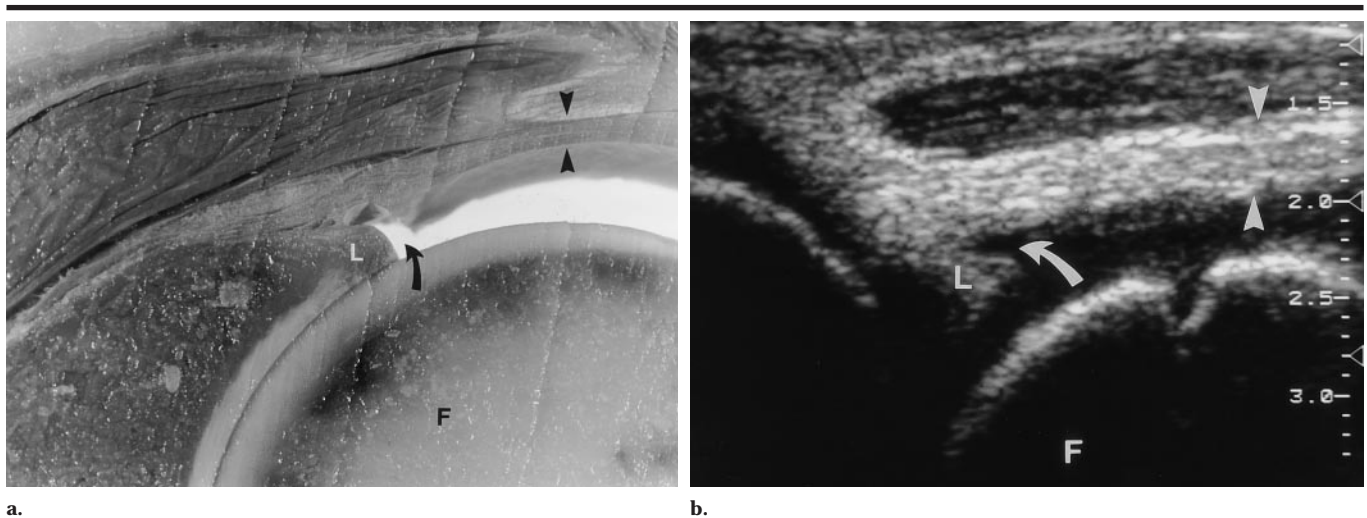
Fifty-eight asymptomatic children without a history of hip disease were examined with US. Both hips were examined ( $n = 116$ ). There were 37 boys and 21 girls, aged 1.7–12.5 years (mean, 6.7 years).

## Patients with Transient Synovitis

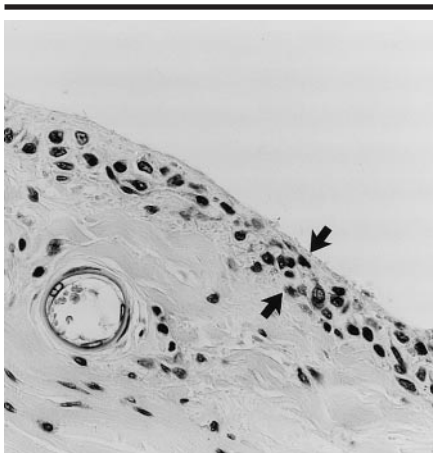
Between January 1994 and May 1997, 105 consecutive patients with transient synovitis were examined with US in a prospective study. Patients with bilateral involvement or fever were excluded.



**Figure 1.** Adult cadaver. (a) A 5-mm-thick, parasagittal, gross anatomic section parallel to the femoral neck. (b) Detail of a. Note the anterior joint capsule (arrows in a), anterior and posterior layer (arrowheads in b), and femoral cartilage (arrows in b). Heterogeneous appearance of bone marrow is caused by metastatic disease. AR = anterior recess of joint space, F = femoral head, I = iliopsoas muscle, L = labrum.



**Figure 2.** Curved arrow indicates superior articular recess, arrowheads indicate the anterior layer of the joint capsule, F = femoral head, L = labrum. (a) Adult cadaver. A 5-mm-thick, parasagittal, gross anatomic section parallel to the femoral neck. Joint space is spread open to view structures to a better advantage. (b) Normal hip in a 5-year-old child. US image shows the superior articular recess outlined by a small amount of physiologic joint fluid between the anterior layer of the capsule and labrum.



**Figure 3.** Adult cadaver. Photomicrograph of synovial membrane (arrows). (Hematoxylin-eosin stain; original magnification,  $\times 100$ .)

There were 74 boys and 31 girls, aged from 2 to 12.8 years (mean, 6.0 years). The right hip was involved in 57 patients and the left hip in 48.

Patients with an irritable hip were considered to have transient synovitis if US depicted a thickening of the joint capsule of more than 2 mm compared with that in the asymptomatic hip (6,7,10,12) and the complaints subsided completely within 4 weeks without specific therapy and the patient remained symptom free for at least 6 months thereafter.

### Methods

The US examinations were performed by one investigator (S.G.F.R.) with use of US equipment with high-frequency 7–10-

MHz (Ultramark 9 HDI; Advanced Technology Laboratories) and 7-MHz (model 128 XP10; Acuson, Mountain View, Calif) linear array transducers.

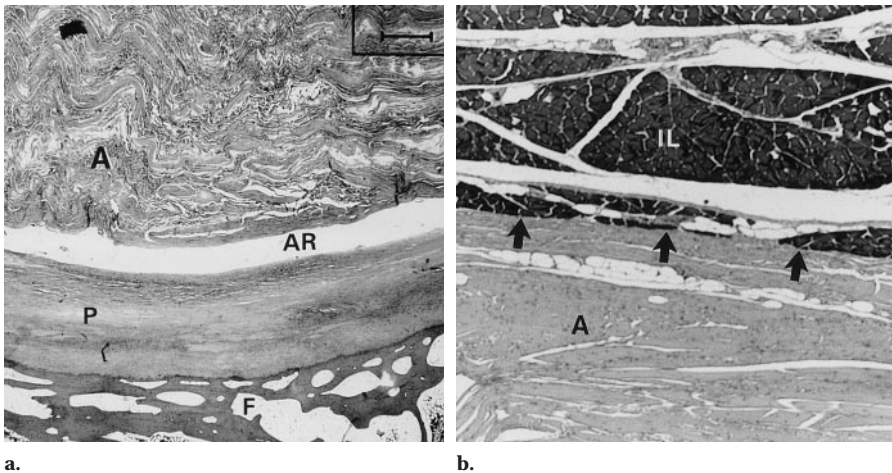
The children were examined in the supine position with the hips in neutral position (extension and slight external rotation). An anterior approach along the long axis of the femoral neck was used to visualize the anterior capsule of the hip joint to the best advantage (13,14). A similar approach was used in the cadaver study. In children with synovitis, the contralateral asymptomatic hip was used as the normal reference.

The anterior joint capsule was identified, and the thickness of the capsule was assessed by measuring the maximal distance between the anterior surface of the femoral neck and the posterior surface of the iliopsoas muscle (15).

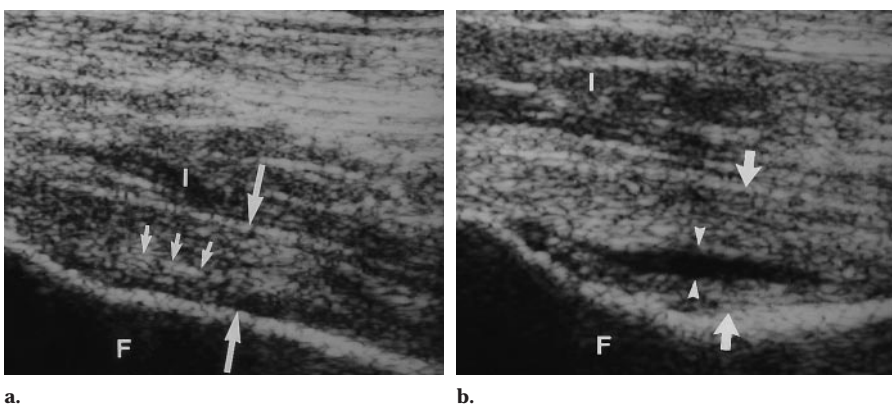
Moreover, in patients with transient synovitis, the following parameters were examined: (a) identification and measurement of both layers of the anterior joint capsule in both symptomatic and asymptomatic hips, (b) identification and characterization (clear or turbid) of the effusion in the anterior recess of the joint capsule, and (c) evaluation of the anterior contour of the joint capsule.

### Statistical Analysis

The difference in thickness of the anterior joint capsule between both sides, as well as the difference in thickness of the various layers of the anterior joint capsule of both hips, were tested by means of the paired *t* test. The correlation between the thickness of the anterior joint capsule and age was examined by calculating Pearson correlation coefficients. A *P* value less than .05 was considered statistically significant.



**Figure 4.** Adult cadaver. (a) Photomicrograph of the anterior recess of the joint space (AR) shows different orientation of fibers in the posterior (P, predominantly longitudinal) and anterior (A, mixed) layers. Scale bar indicates 0.8 mm. (Hematoxylin-eosin stain; original magnification,  $\times 3.5$ .) F = femur. (b) Photomicrograph of the anterior joint capsule shows no separate layer at the border (arrows) between the iliopsoas muscle (IL) and the anterior layer (A) of the joint capsule. (Hematoxylin-eosin stain; original magnification,  $\times 3.5$ .)



**Figure 5.** Adult cadaver. US images of the anterior joint capsule (large arrows). F = femoral neck, I = iliopsoas muscle. (a) Interface between anterior and posterior layers is seen as a linear reflection (small arrows), representing an empty anterior recess. (b) The reflection disappears after introduction of saline solution (arrowheads) into the anterior recess.

## RESULTS

### Cadaveric Study

The anatomic sections show that the space between the iliopsoas muscle and the femoral neck is occupied by a fold of the joint capsule. This fold is composed of two layers (anterior and posterior), each of considerable thickness (2–4 mm), that are separated by the anterior recess of the joint space (Fig 1). The anterior layer is slightly thicker than the posterior layer.

The joint capsule inserts at the outer labrum, runs caudally to form the anterior labrum, and inserts on the intertrochanteric line; here it blends with the periosteum. However, many fibers are reflected

upward, covering the femoral neck, to form the posterior layer of the joint capsule. The posterior layer runs upward and ends at the caudal edge of the articular cartilage of the femoral head (Fig 1b).

At the junction of the anterior layer of the joint capsule with the labrum, a slit-like indentation is identified (Fig 2a). On macroscopic inspection, this simulates an artificial tear. Microscopically, however, this indentation is lined by synovial cells and therefore represents an anatomic structure. US examination sometimes shows this structure as a hypoechoic triangular area (caused by a small amount of physiologic joint fluid, Fig 2b). This slit-like indentation is known from arthrographic studies as a small extension of contrast material adjacent to the labrum and represents the superior articular recess.

Histologic examination showed that both layers of the anterior joint capsule consist of collagen fibers, with the inner surfaces lined by a synovial membrane. The synovial membrane is synovial intima one to three cells thick (Fig 3) that lies directly on the fibrous capsule without interposition of fatty or areolar tissue.

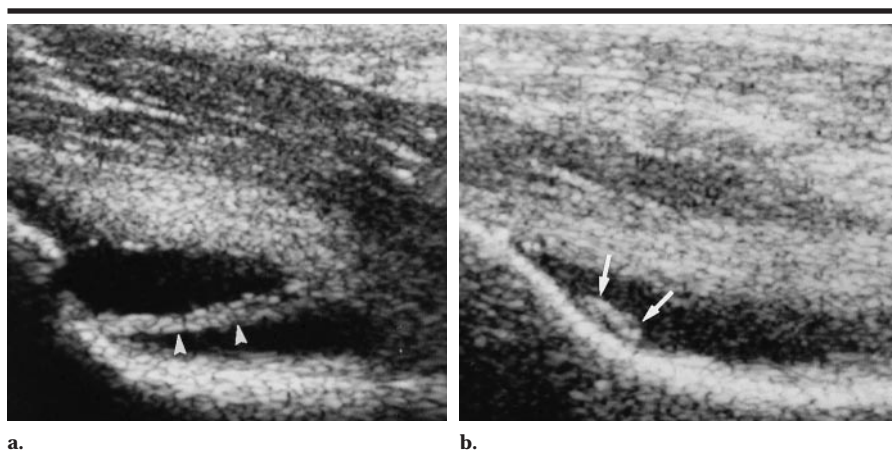
The collagen fibers in the posterior layer run strictly longitudinally; the fibers in the anterior layer show a mixed pattern because the longitudinal fibers of the capsule are traversed by circular fibers in the orbicular zone (Fig 4).

US could visualize the anterior joint capsule in all cadaveric hips, except for one hip that was replaced by a prosthesis. The anterior joint capsule was seen at US as a band of tissue between the anterior femoral neck and the fascia of the iliopsoas muscle that is composed of two layers and is isoechoic to the iliopsoas muscle (Fig 5a). Centrally, a linear reflection was seen, thought to represent the interface between both layers (collapsed anterior recess). This was subsequently proved by means of intraarticular injection of saline solution, after which the linear reflection was replaced by hypoechoic fluid in the anterior recess (Fig 5b). Obviously, the presence of this linear reflection (stripe sign) indicates absence of effusion.

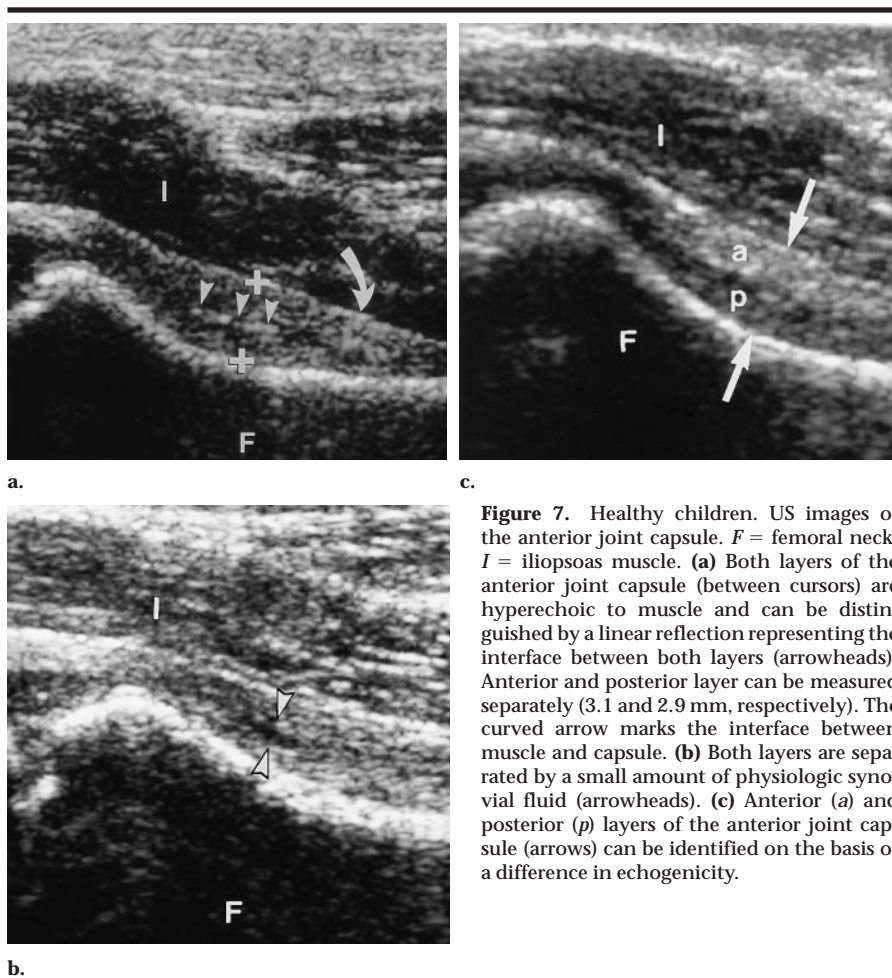
After the injection of saline solution, one cadaveric hip showed a plicalike structure within the fluid-filled joint space (Fig 6a), and two hips showed a local thickening of the posterior layer (Fig 6b).

### Healthy Children

The anterior joint capsule was easily identified in all hips ( $n = 116$ ) as a layer of



**Figure 6.** Adult cadavers. US images after injection of saline solution into the hip joint. (a) A plicalike structure (arrowheads) is seen to traverse the effusion. (b) In another cadaver, a local hump (arrows) of the posterior layer of the joint capsule is present at the insertion of the posterior layer near the articular cartilage.

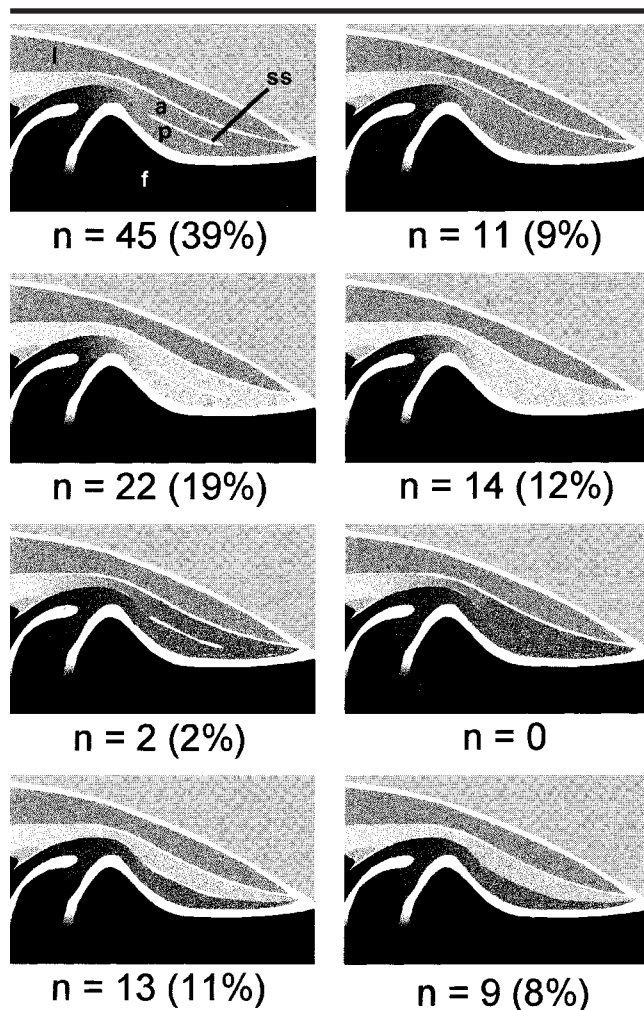


**Figure 7.** Healthy children. US images of the anterior joint capsule. *F* = femoral neck, *I* = iliopsoas muscle. (a) Both layers of the anterior joint capsule (between cursors) are hyperechoic to muscle and can be distinguished by a linear reflection representing the interface between both layers (arrowheads). Anterior and posterior layer can be measured separately (3.1 and 2.9 mm, respectively). The curved arrow marks the interface between muscle and capsule. (b) Both layers are separated by a small amount of physiologic synovial fluid (arrowheads). (c) Anterior (*a*) and posterior (*p*) layers of the anterior joint capsule (arrows) can be identified on the basis of a difference in echogenicity.

tissue between the femoral neck and overlying muscles (Fig 7a). The mean thickness was 4.7 mm. There was no significant difference in thickness between both sides; the maximal difference was 1 mm.

There was no significant correlation with age ( $P = .1$ )

In 98 hips (84%), the anterior layer could be differentiated from the posterior layer. (a) In 82 hips (70%), a linear reflec-



**Figure 8.** Healthy children. Schematics show the echogenicity of the anterior (a) and posterior (p) layers of the anterior joint capsule in 116 hips. The echogenicity of each layer is expressed as shades of gray compared with that of the iliopsoas muscle (l). f = femur. In the images on the left, the white line between the layers represents the interface between the layers, or stripe sign (ss), which was seen at US as a linear reflection. In the images on the right, there was no stripe sign.

tion was visible centrally in the anterior joint capsule paralleling the femoral neck, representing the interface between the anterior and posterior layer of the joint capsule (stripe sign) (Fig 7a). (b) In seven hips (6%), a small amount of synovial fluid was present in the anterior recess, separating both layers (Fig 7b). (c) In nine hips (8%), both layers could be distinguished by a difference in echogenicity (Fig 7c).

In the majority of the children (81%), the anterior layer of the joint capsule had the same echogenicity as the posterior layer, being isoechoic to psoas muscle in 48%, hyperechoic in 31%, and hypoechoic in 2%. In 19% of the children, both layers had a different echogenicity; the anterior layer always showed in-

creased echogenicity compared with that of the posterior layer (Fig 8).

In each individual child, both hips were identical with respect to the echogenicity of both layers of the anterior joint capsule.

#### Patients with Transient Synovitis

**Anterior capsule of the hip joint.**—The anterior capsule could be visualized in all hips, both symptomatic and asymptomatic. In all symptomatic hips, both layers of the capsule could easily be distinguished from surrounding bone, muscle, and anechoic effusion and could be measured (Table 1, Fig 9).

In the asymptomatic hip, the posterior layer could be differentiated from the

anterior layer in 83 patients (79%). This was facilitated by the stripe sign in 65 (62%), a small amount of physiologic joint fluid in 12 (11%), and a difference in echogenicity between both layers in six patients (6%). In these asymptomatic hips, both layers could be measured separately (Table 1). The anterior layer was thicker than the posterior layer in both symptomatic ( $P = .01$ ) and asymptomatic hips ( $P < .001$ ). However, there was no difference between symptomatic and asymptomatic hips with regard to the thickness of the anterior layer ( $P = .24$ ) or posterior layer ( $P = .57$ ).

Similar to findings in the study of healthy subjects, the thickness of the anterior joint capsule of the asymptomatic hip showed no correlation with age ( $P = .1$ ). However, the amount of effusion in the symptomatic hip did show a positive correlation with age ( $P = .001$ ).

In 50 of the symptomatic hips (48%), a local thickening of the posterior layer of the anterior joint capsule, referred to as the "hump," was visible. The thickness of this hump varied considerably, but it was invariably localized at the insertion of the posterior layer near the cartilage of the femoral head (Fig 10a). This phenomenon was almost exclusively observed in hips with effusion. Occasionally, an identical structure was seen on the anterior layer (Fig 10b).

**Effusion.**—In all symptomatic hips, the effusion in the anterior recess could be clearly differentiated from the surrounding layers of the anterior joint capsule (Fig 9). The effusion was anechoic in 95 patients (90%) and showed some reflections in nine patients (9%) (Fig 11). In one patient (1%), an obese boy, the visualization of the anterior recess was insufficient for reliable evaluation of the clarity of the effusion.

A small amount of joint fluid was also present in the anterior recess of 12 (11%) asymptomatic hips. The fluid in the anterior recess of the asymptomatic hips was always clear. The mean thickness of this layer of synovial fluid was 1.0 mm (range, 0.2–1.6 mm).

**Anterior bulging of the capsule.**—The results are shown in Table 2. Convex bulging of the anterior joint capsule has a sensitivity of 94%, specificity of 91%, positive predictive value of 92%, and negative predictive value of 94% for effusion.

None of the patients with a concave border had an effusion; therefore, the presence of a concave border virtually rules out effusion.

**Additional findings.**—In four patients (4%), a linear structure traversing the

fluid-filled anterior recess, identical to the structure seen in one of the cadaveric hips (Fig 6a), demonstrated the same echogenicity and texture as did both layers of the anterior joint capsule.

In two patients (2%), a thin-walled cystic protrusion of the joint effusion was seen. This arose from the synovial surface of the anterior layer of the capsule and protruded through the anterior layer into the space between the iliopsoas muscle and anterior border of the joint capsule with a collar-button configuration (Fig 12).

All patients with additional findings had an uneventful recovery.

## DISCUSSION

### Normal Anatomy

The US technique for investigation of the hip joint to evaluate painful hip was first described by Seltzer et al (16), to our knowledge, and has not changed thereafter. An anterior approach is used in the parasagittal plane parallel to the femoral neck with the leg in slight exorotation. Some investigators included additional planes and rotation of the femur, but this did not improve reproducibility (5,7,8,10,15,17–19).

In numerous reports, the thickness of the anterior joint capsule is addressed without a discussion of its separate layers (4,6,7,9,14,20).

Findings in the present cadaveric study show that the anterior joint capsule is composed of two layers. Both layers have a thickness substantial enough to enable US measurements with state-of-the-art equipment. This was confirmed at US in the adult cadavers that demonstrated both layers of the anterior joint capsule (Fig 5). Knowledge of this anatomy is essential for accurate measurements and good interpretation.

The border between the iliopsoas muscle and the joint capsule is visible as a hyperechoic line (Fig 7a), but it does not represent an anatomic structure (Fig 4b). This line should not be interpreted as the fibrous capsule (14,15,18,19,21,22) but merely represents the interface between muscle and joint capsule. The thickness of this line depends on, among other factors, the transducer frequency (23–25).

In previous studies, a wide range of values are reported for thickness of the anterior joint capsule. These values can be divided into two main groups: those with a mean of 5 mm, comparable to that in the present study (6,15,23,26,27), and those with a mean of 2–3 mm (2,4,12,13,28). This discrepancy was already observed by Terjesen and Osthus (7), who found it “difficult to explain, as similar US tech-

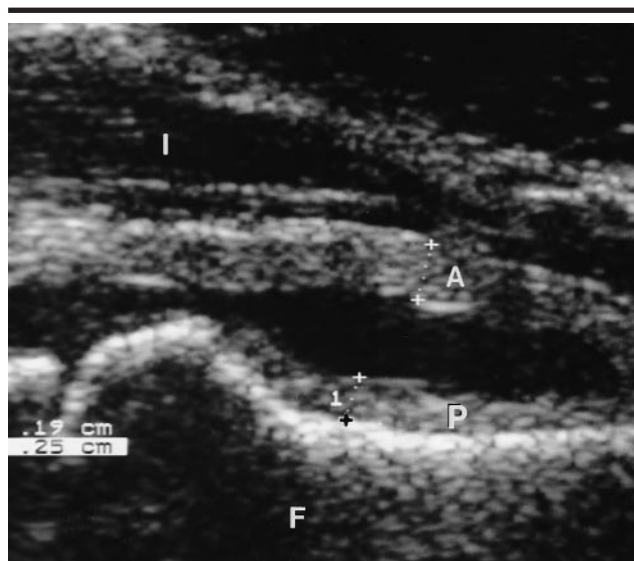
**TABLE 1**  
Measurements in the Anterior Joint Capsule of Both Hip Joints in 105 Patients with Unilateral Synovitis

Location	No. of Patients	Mean Thickness (mm)	SD
Symptomatic hip			
Joint capsule	105	9.91	1.71
Anterior layer	105	2.38	0.66
Posterior layer	105	2.14	0.44
Asymptomatic hip			
Joint capsule	105	4.90	1.02
Anterior layer	83	2.51	0.63
Posterior layer	83	2.10	0.58

**TABLE 2**  
Shape of the Anterior Border of the Anterior Recess of the Hip Joint in 105 Patients with Transient Synovitis

Shape	Symptomatic Hip	Asymptomatic Hip
Convex	99 (94)	9 (9)
Straight	6 (6)	31 (29)
Concave	0 (0)	65 (62)
Total	105 (100)	105 (100)

Note.—Data are the number of patients. Numbers in parentheses are percentages.



**Figure 9.** Sagittal US image depicts the anterior recess in a patient with transient synovitis. The anterior (A) and posterior (P) layers of the joint capsule are separated by anechoic effusion and can be easily identified and measured (between cursors, 2.5 and 1.9 mm, respectively). F = femoral neck, I = iliopsoas muscle.

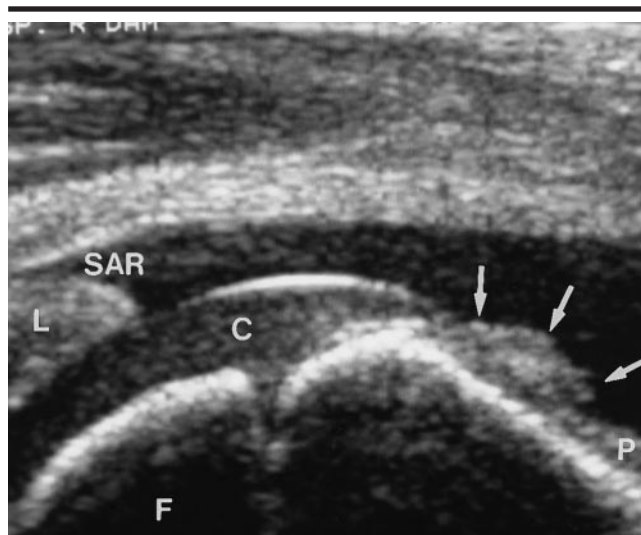
niques and anatomic landmarks seem to have been employed.” Apparently, this discrepancy is largely caused by unfamiliarity with the anatomy. In the latter studies, the distance was measured between the femoral neck and the interface between both layers of the joint capsule (stripe sign); therefore, only the posterior layer of the anterior joint capsule was measured instead of the total capsule. Even the cartilage of the femoral head was sometimes mistaken for anterior recess (12).

According to Rohrschneider et al (15), there was no statistically significant correlation between age and thickness of the anterior joint capsule in normal hips (in children aged more than 3 years). This finding was confirmed in the present study.

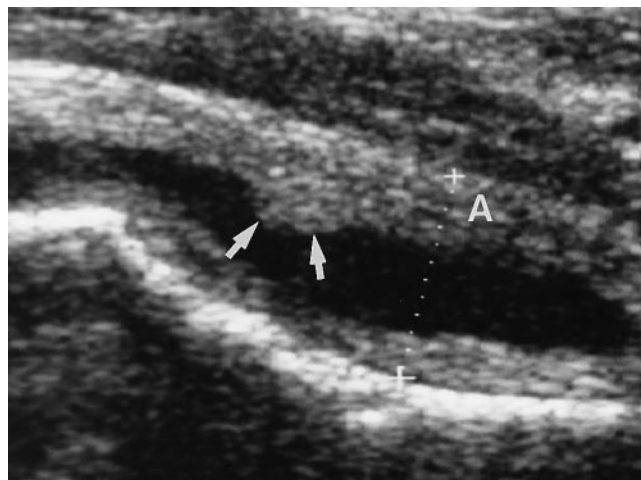
Histologic examination shows that both layers of the joint capsule are com-

posed mainly of collagen fibers lined by only a thin synovial membrane. The thickness of the synovial membrane is approximately 0.025 mm (29), which exceeds the spatial resolution of modern radiologic techniques such as US. Moreover, the synovial membrane of the anterior recess is of the fibrous type. In contrast to the areolar and adipose types of synovial membrane—in which the synovial intima is separated from the fibrous capsule by loose connective tissue or adipose tissue—in the fibrous type, the synovia rests directly on the fibrous layer (30). This also contributes to the inability of US to visualize the synovial membrane as a distinct layer.

In the present study, the anterior layer showed an increased echogenicity compared with that in the posterior layer in



a.



b.

**Figure 10.** Sagittal US images depict a hump in two patients with transient synovitis. (a) Local thickening (arrows) of the posterior (P) layer of the joint capsule at its insertion near the articular cartilage (C) of the femoral head (F). L = labrum acetabulare, SAR = superior articular recess. (b) Local thickening (arrows) at the anterior layer (A) of the joint capsule (cursors).

19% of the hips of healthy subjects. This difference in echogenicity may, in part, be attributed to the difference in fiber texture of both layers, as demonstrated in the histologic examination (Fig 4a).

The superior articular recess can be seen at US as a small band of decreased echogenicity adjacent to the labrum at the insertion of the joint capsule at the labrum. This should not be mistaken for a pathologic condition, such as a rupture.

### The Anterior Joint Capsule in Transient Synovitis

Results in the study of patients with transient synovitis are compatible with those in

the cadaveric study: Both layers of the joint capsule can be readily visualized and measured separately with US in all hips, facilitated by the effusion. In the contralateral normal hip, the thickness of the anterior and posterior layers of the anterior joint capsule could be measured in 79% of the patients and compared with measurements in the symptomatic hip.

In both symptomatic and asymptomatic hips, the anterior layer of the joint capsule was significantly thicker than the posterior layer (Table 1), which is consistent with findings in the cadaveric study. The anterior layer is thicker probably because it is reinforced by the iliofemoral ligament and the orbicular zone.

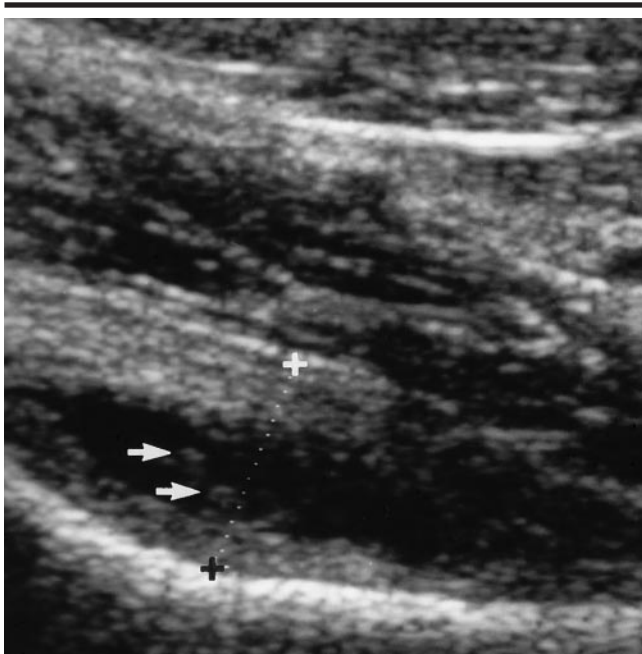
Moreover, the anterior and posterior layers of the anterior joint capsule showed no statistically significant difference between the symptomatic and asymptomatic sides (Table 1). Synovitis apparently does not cause a measurable thickening of the anatomic components of the joint capsule. Theoretically, the synovial membrane is thickened in synovitis, but because it forms only a minute part of both layers of the anterior joint capsule, its thickening cannot be appreciated at US.

In many articles dealing with transient synovitis, both layers of the anterior joint capsule are either not identified or not mentioned, probably due to use of inadequate equipment or unfamiliarity with the anatomy of the anterior joint capsule. However, those articles that do describe both layers erroneously identify them as synovium or synovial hypertrophy or thickening (3,9,14,18,28). According to results in the present study, neither of the layers of the anterior joint capsule are diffusely thickened in transient synovitis. Moreover, “synovium or synovial membrane” is a misnomer because the joint capsule is composed of a fibrous capsule with only a minute layer of synovial membrane.

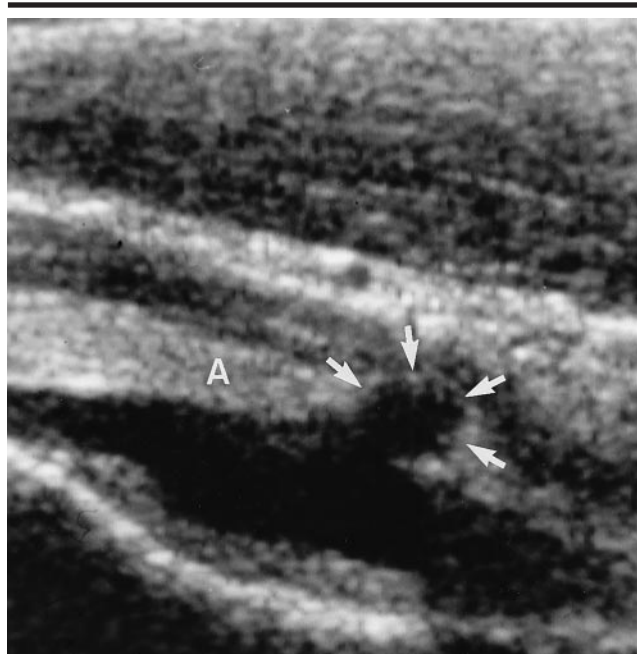
Because (a) both layers of the anterior joint capsule are not thickened, and (b) the effusion was always discernible, it seems more rational to detect effusion by visualizing the effusion itself rather than by relying on indirect signs such as differences between hips in measurements of the joint capsule (4–10,28). In cases of poor US visualization of the joint capsule, this indirect method can be a good alternative, although it should be realized that it fails when bilateral effusions are present.

### Hump of the Posterior Layer

This phenomenon was observed almost exclusively in hips with effusion, probably because the effusion facilitates demarcation of the synovial surface. This hump could be interpreted as debris or flocculation, but several facts argue against this. (a) In some patients, we were able to demonstrate vessels in this hump at Doppler US; and (b) in the supine position, the hump does not migrate to the most dependent section of the recess. The stripe sign phenomenon does not offer enough anatomic detail to confirm the presence of such a local thickening in hips without an effusion. However, evidence of a hump was present in one asymptomatic hip, and moreover we observed this structure in one cadaveric hip



**Figure 11.** Sagittal US image depicts the anterior joint capsule (cursors) in a patient with transient synovitis of 7 days duration. Small particles (arrows) are floating in the effusion.



**Figure 12.** Sagittal US image of the anterior joint capsule in a patient with transient synovitis depicts a cystic protrusion of effusion through the anterior layer (A), with the appearance of a pseudodiverticulum (arrows).

(Fig 6b). Apparently this local hump is not restricted to synovitis but should be regarded as a normal anatomic landmark representing the insertion of the capsule in the femoral neck. Marchal et al (13) observed an identical local thickening in a patient with septic arthritis, but findings in the present study demonstrate that this sign certainly is not pathognomonic for septic arthritis.

### Effusion

Because both layers of the anterior joint capsule are not thickened in transient synovitis, the widening of the anterior recess can be attributed solely to effusion. In all symptomatic hips, the effusion could be readily discriminated from the layers of the anterior joint capsule and measured separately.

In nine patients, the effusion was not completely clear. None of these patients had clinical signs of septic arthritis, and all had an uneventful recovery. This phenomenon was also observed by Dörr et al (18) and Marchal et al (13) in 21% and 10% of their patients, respectively, and Zawin et al (3) demonstrated that turbid effusion is not diagnostic for infection. We found that the mean duration of complaints in patients with turbid effusion was considerably longer than in the patients with a clear effusion (7.2 vs 4 days,  $P < .001$ ). This may be the result of

progressive accumulation of cellular debris in effusion of longer duration. Obviously, the presence of turbid effusion is associated with the duration of the disease, but it has no further diagnostic value.

Surprisingly, the amount of fluid in transient synovitis shows a positive correlation with age ( $P < .001$ ). Assuming that the pathophysiologic mechanism of transient synovitis is age independent, this correlation must be attributed to geometric factors. Because the anterior recess is larger in older children, the same pressure will induce more expansion, according to the physical law of Laplace.

A small layer of joint fluid in the anterior recess of the asymptomatic hip was present in 12 patients (11%), with a mean thickness of 1.0 mm and a maximum of 1.6 mm (Fig 7b). This finding is similar to that of Rohrschneider et al (15), who found this in 12% of healthy children, with a maximum thickness of 1.5 mm. Therefore, 2 mm seems to be a sound threshold to differentiate a pathologic from a physiologic effusion. This is in keeping with a difference of more than 2 mm between both symptomatic and asymptomatic anterior joint capsules that is considered pathologic in several reports (7,8,12–15,19,28). The stripe sign, representing the collapsed anterior recess, can be of additional value in excluding small amounts of effusion in the joint. This sign is visible only when both

layers lie close together, that is, in the absence of effusion (Figs 5, 7a).

### Bulging of the Capsule

Some authors consider anterior bulging of the joint capsule the best criterion for effusion (1–3). However, the contour of the joint capsule depends on rotation, being concave in exorotation and convex in endorotation (15). Moreover, joint capsules of normal hips can have a straight or convex contour (15). This is also true in the present study, in which 9% of the asymptomatic hips showed anterior bulging in the absence of effusion, making this sign less reliable. Six percent of the symptomatic hips had no convex contours, despite the fact that a substantial amount of effusion was present. On the other hand, a concave border of the anterior joint capsule seems to be a reliable indicator for the absence of effusion, because in the present study, none of these hips showed joint fluid at US.

### Plica

In six patients (6%), a platelike structure traversed the effusion, mostly running from the hump of the posterior layer to the anterior layer. The structure and echogenicity were identical for both layers of the anterior joint capsule. This structure was also demonstrable in one of



the cadaveric hips after intraarticular injection of saline solution. It probably represents a plica, comparable to the well-known plicae in the knee joint.

None of the patients with such a plica had previous complaints, and all had an uneventful recovery.

### Diverticulum

The cystic protrusion of joint effusion through the anterior layer of the anterior recess probably represents a herniation of the synovial membrane through a defect in the fibrous capsule, which creates a pseudodiverticulum of the synovial membrane. The thin wall also suggests it is a pseudodiverticulum of the synovial membrane rather than a real diverticulum of the joint capsule.

### Conclusions

Findings in this study show that the anterior capsule of the hip joint is composed of anterior and posterior layers that were visualized separately at US in 84% of healthy children. Both layers are composed mainly of fibrous tissue (representing the fibrous capsule) and lined by only a minute layer of synovial membrane, which is too thin to be visualized separately at US. No measurable thickening of both layers of the anterior joint capsule is present in transient synovitis. Therefore, enlargement of the anterior joint capsule in transient synovitis is caused solely by the presence of effusion.

It is more rational to detect effusion by visualizing the effusion itself than by relying on indirect signs such as contours of the capsule or differences in joint capsule measurements between hips. These indirect methods can be good alternatives only in cases of poor US visualization of the joint capsule, although the latter method fails when bilateral effusions are present.

Knowledge of the US anatomy of the capsule of the hip joint is essential for future studies, especially since state-of-the-art US equipment with high-frequency transducers allows visualization of the hip joint in greater detail. Correct identification of both layers, especially

the posterior layer, will prevent erroneous measurements and interpretation.

Moreover, findings in this study describe normal variants that can be visualized with state-of-the-art US equipment. Sonologists should be aware of these findings to prevent misinterpretation of normal variants mistaken for pathologic conditions.

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