Evaluation of the subchondral fracture in predicting the extent of femoral head necrosis in Perthes disease: a prospective study of 92 patients

Ola Wiig[a], Svein Svenningsen[b] and Terje Terjesen[c]

The aim of this study was to evaluate the subchondral fracture as a predictor for the extent of femoral head necrosis in Perthes disease. Out of 392 patients, 92 (23.5%) had a detectable subchondral fracture at the time of diagnosis. There was concordance between predicted Catterall groups on the basis of the extent of the subchondral fracture and the actual Catterall groups at the time of maximal resorption in 61% of the cases, when assessed by an experienced observer. When using the extent of the subchondral fracture to predict Salter–Thompson groups, this observer obtained 89% concordance with the actual Salter–Thompson groups at the time of maximal resorption. The inter-observer agreement between the experienced and a less experienced observer regarding the presence or absence of a subchondral fracture was moderate (weighted κ 0.59, 87% agreement). When using the extent of the subchondral fracture as a measure of femoral head involvement (Catterall groups), the inter-observer agreement was moderate (weighted κ 0.46). Patients with detectable subchondral fracture were significantly older (mean 6.5 years) at the time of diagnosis than those without visible fracture (mean 5.2 years). The delay in diagnosis was significantly shorter in the group with subchondral fracture (mean 3.2 months) than among patients without visible fracture (mean 4.9 months). There was no significant difference with regard to sex, pain level, pain localization, or limping gait between the two groups. We conclude that the subchondral fracture is a relatively rare early sign in Perthes disease. When present, it is a useful sign when assessed by an experienced observer as its extent was in fairly good concordance with the extent of femoral head involvement at the time of maximal resorption. Awareness of this radiographic sign will aid the orthopaedic surgeon to establish diagnosis and, to some degree, to predict prognosis early in the course of the disease. *J Pediatr Orthop B* 13:293–298 © 2004 Lippincott Williams & Wilkins.

Journal of Pediatric Orthopaedics B 2004, **13**:293–298

Keywords: Perthes disease, subchondral fracture, inter-observer agreement

[a]Orthopaedic Centre, Ullevål University Hospital, Oslo, [b]Orthopaedic Department, Sørlandet Hospital, NO-4809 Arendal and [c]Orthopaedic Department, The National Hospital, Oslo, Norway.

Correspondence and requests for reprints to Dr O Wiig, Orthopaedic Centre, Ullevål University Hospital, NO-0407 Oslo, Norway.
Tel: +47 22118080; e-mail: ola.wiig@ulleval.no

Introduction

The radiolucent subchondral crescentic line was first described by Waldenstrøm [1]. This crescentic line is regarded as the radiographic expression of a subchondral trabecular fracture [2,3], due to an initial avascular phase followed by cessation of epiphyseal growth. Furthermore it is believed that this fracture, being painful, heralds the clinical onset of Perthes disease. The prognostic significance of the subchondral fracture was established by Salter and Thompson [4], who found that the extent of the fracture correlated completely with the extent of maximum resorption according to the Catterall classification. To our knowledge this is the only study in which the prognostic significance of the subchondral fracture has been assessed. Several studies have documented the significance of the Catterall grading [5–8] for the prognosis in Perthes disease.

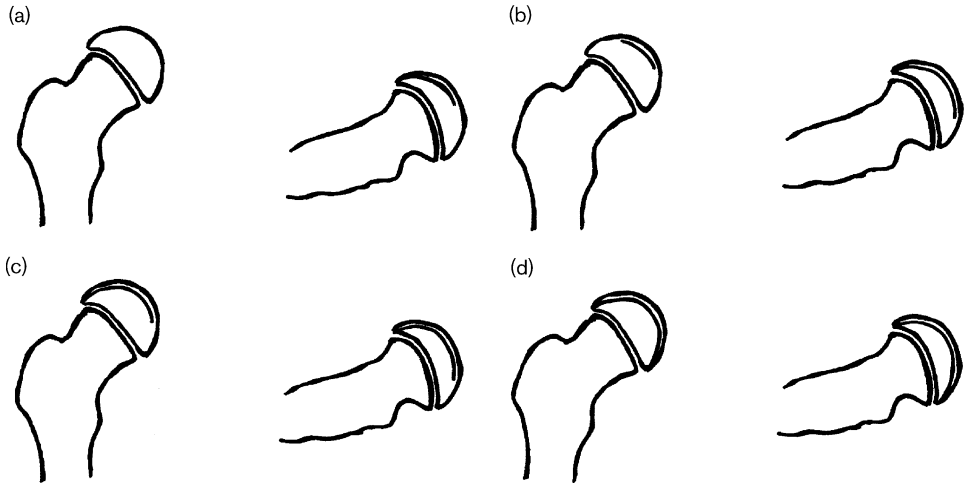
The present prospective study was undertaken to evaluate the subchondral fracture as a predictor of the extent of femoral head necrosis.

1060-152X © 2004 Lippincott Williams & Wilkins

Patients and methods

During the 5-year period 1996 to 2000 a nationwide study on Perthes disease, initiated by the Norwegian Paediatric Orthopaedic Society, was carried out. Twenty-eight hospitals in 19 counties throughout the country were asked to report all new incidents of Perthes disease. In total 392 patients were registered. The radiographs were collected and reviewed by an experienced paediatric orthopaedic surgeon (S.S.) and a less experienced orthopaedic resident (O.W.). The presence or absence of the subchondral fracture line was assessed on the primary radiographs in both the anteroposterior and Lauenstein projections. The extent of the eventual maximum resorption was predicted as being in group 1, 2, 3 or 4 of the Catterall classification [4]. Group 1 (Fig. 1a) consisted of hips in which the subchondral fracture was not visible in the anteroposterior radiograph, but the extent of the fracture was clearly visible on the lateral radiograph. Group 2 (Fig. 1b) included hips in which the fracture was visible on the anteroposterior radiograph but did not involve the lateral or medial

Fig. 1



The extent of the subchondral fracture in both planes divided into four groups. (a) Predicted Catterall group 1. (b) Predicted Catterall group 2. (c) Predicted Catterall group 3. (d) Predicted Catterall group 4.

margin, and on the lateral radiograph the fracture began at the anterior margin and extended posteriorly slightly beyond the midline of the femoral head. In group 3 (Fig. 1c) hips the subchondral fracture involved almost all of the epiphysis in both planes, and in group 4 (Fig. 1d) the subchondral fracture extended over the entire surface of the epiphysis on both the anteroposterior and lateral radiograph.

In addition, the extent of the subchondral fracture was predicted as being in Salter–Thompson group A or B. Group A consisted of hips in which less than one half of the capital femoral epiphysis was involved. Group B comprised hips in which more than one half of the epiphysis was involved. The predicted extent of maximum resorption was compared with the actual extent of the femoral head involvement on the radiographs taken at follow-up.

We evaluated the inter-observer agreement between an experienced paediatric orthopaedic surgeon (S.S.) and an orthopaedic resident (O.W.) when using the extent of the subchondral fracture as a measure for femoral head involvement as described above. The inter-observer agreement between the two observers regarding the presence or absence of the subchondral fracture was assessed. The data were analyzed by weighed κ statistics [9]. The κ value reaches a maximum of one for perfect agreement, but a value of 0 indicates agreement no better than chance, and negative values show a worse than chance agreement. As suggested by Altmann [9], we interpreted the κ values as follows: below 0.20 as poor agreement, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as good, and over 0.80 as very good agreement. The duration of the fracture was interpreted as the time between the first radiograph with detectable fracture and the last radiograph when it was still visible. Clinical data (age at diagnosis, sex, pain localization, pain level, presence of a limping gait, duration of symptoms prior to admission) were recorded. The categorical data were analyzed by the χ^2 test and logistic regression and the *t*-test and linear regression were applied to the numerical data. A P value of less than 0.05 was regarded as statistically significant.

Results

During the 5-year period 392 patients with Perthes' disease (284 boys and 108 girls) were registered. A subchondral fracture was detected at the time of diagnosis in 92 patients (23.5%). Five had bilateral disease, but none of the patients had bilateral subchondral fracture. At the time of diagnosis, based on the subchondral fracture, none of the hips were categorized as Catterall group 1, 16 hips were categorized as Catterall group 2, 64 as being in Catterall group 3, and 12 as Catterall group 4. Of the 92 patients with detectable subchondral fracture at the time of diagnosis, we were able to assess the radiographs of 71 hips in the phase of maximum resorption. Table 1 shows the predicted Catterall groups on the basis of the extent of the subchondral fracture at the time of diagnosis, compared with the Catterall grouping at the time of maximal resorption assessed by the experienced observer (S.S.). There was concordance between the extent of the subchondral fracture and the extent of maximum resorption according to the Catterall classification in

43 (61%) of the cases. However, assessed in the Lauenstein projection alone, we found nearly complete concordance (95%) between the extent of the fracture and the extent of the necrosis at the time of maximal resorption.

Five hips initially categorized as Catterall group 2 changed to Catterall group 3 in the phase of maximal resorption and one hip changed to group 4, whereas 20 hips changed from group 3 to group 4, one hip from group 3 to 2 and one hip from group 4 to 3 (Table 1). The less experienced observer (O.W.) obtained a concordance of 50%, and as with the experienced observer the most significant group shift was between hips predicted as group 3 which were actually Catterall group 4 (Table 2).

O.W. found a subchondral fracture in 68 (17.3%) of the primary radiographs. The inter-observer agreement between S.S. and O.W. regarding the presence or absence of a subchondral fracture was moderate (weighed κ 0.59, 87% agreement) (Table 3). When using the extent of the subchondral fracture as a measure of femoral head involvement, the inter-observer agreement between the orthopaedic resident (O.W.) and the experienced paediatric orthopaedic surgeon (S.S.) was moderate (weighted κ 0.46) (Table 4).

Table 1 Concordance between predicted Catterall groups on the basis of the extent of the subchondral fracture and actual Catterall groups at the time of maximal resorption, based on assessment by an experienced observer

Predicted Catterall groups	Actual Catterall groups			
	1	2	3	4
1				
2		5	5	1
3		1	30	20
4			1	8

Table 2 Concordance between predicted Catterall groups on the basis of the extent of the subchondral fracture and actual Catterall groups at the time of maximal resorption based on assessment by a less experienced observer

Predicted Catterall groups	Actual Catterall groups			
	1	2	3	4
1				
2		1	7	1
3		3	21	13
4			3	5

Table 3 Inter-observer agreement with regard to presence or absence of subchondral fracture between the experienced observer and the less experienced observer

Presence of subchondral fracture (experienced observer)	Presence of subchondral fracture (less experienced observer)	
	Yes	No
Yes	54	38
No	14	286

Table 4 Inter-observer agreement regarding predicted Catterall groups between the experienced observer and the less experienced observer

Predicted Catterall groups (experienced observer)	Predicted Catterall groups (less experienced observer)			
	1	2	3	4
1				
2		8	5	
3		5	27	2
4			3	4

Table 5 Concordance between predicted Salter–Thompson groups and actual Salter–Thompson groups at the time of maximal resorption (experienced observer)

Predicted Salter–Thompson groups	Actual Salter–Thompson groups	
	A	B
A	5	6
B	2	58

When using the extent of the subchondral fracture to predict Salter–Thompson groups (Table 5), the experienced observer obtained 89% concordance with the actual Salter–Thompson groups at the time of maximal resorption. The less experienced observer obtained a concordance of 79%. The inter-observer agreement between the two observers was moderate (weighted κ 0.49).

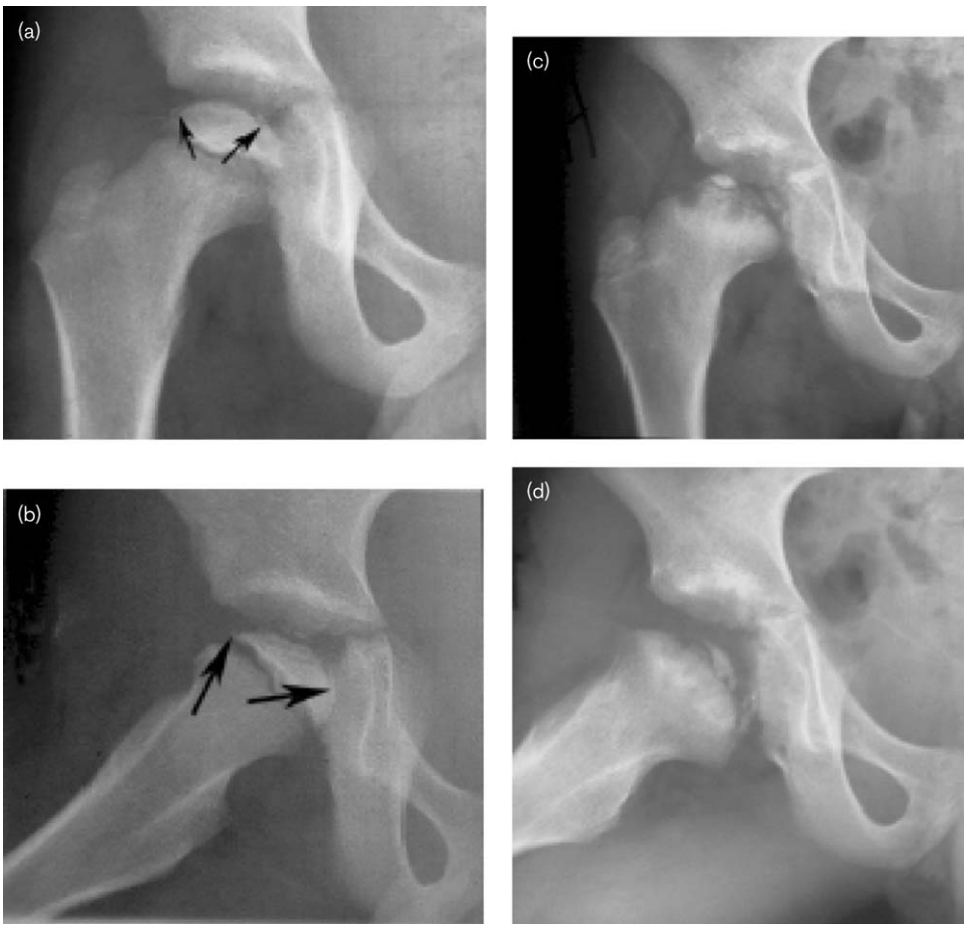
Patients with detectable subchondral fracture were significantly older (mean 6.5 years) at the time of diagnosis than those without visible fracture (mean 5.2 years) ($P = 0.001$). The delay in diagnosis (time from initial symptoms to the first consultation with the orthopaedic surgeon) was significantly shorter in the group with subchondral fracture (mean 3.2 months) than among patients without visible fracture (mean 4.9 months) ($P = 0.002$). The mean duration of the subchondral fracture was 3.0 months (SD 0.6) and there was no significant variation with the age of the patient (mean 2.8 months under age 6 years, and 3.0 months over age 6 years). We found no statistical difference between the two groups regarding bilateral disease (five patients in the group with subchondral fracture had bilateral disease whereas there were 34 patients, 11%, in the group without visible fracture). There was no significant difference with regard to sex, pain level, pain localization or presence of a limp between patients with and without subchondral fracture.

Discussion

Salter and Thompson [4] found the subchondral fracture in only 23% of the children who were initially studied. The present study supports this as the experienced

observer was able to detect the subchondral fracture in 23.5% of the children. A complete correlation between the extent of the fracture and the extent of maximum resorption according to Catterall was reported by Salter and Thompson [4]. Our study showed concordance between predicted Catterall groups on the basis of the extent of the subchondral fracture and the actual Catterall grouping at the time of maximal resorption in 61% of the cases when assessed by the experienced observer and in 50% when assessed by the less experienced observer. Thus, the predictive value of the subchondral fracture was markedly lower in our study than in the experience of Salter and Thompson [4]. The greatest shift of hips was seen between predicted group 3 and actual group 4 for both observers. Salter and Thompson [4] described the difference between these two groups as follows: in group 3 hips the subchondral fracture involved almost all of the epiphysis in both planes, and in group 4 the subchondral fracture extended over the entire surface of the epiphysis on both the anteroposterior and lateral radiograph. In our experience, the distinction between a fracture extension over 'almost all' and 'the entire epiphysis' is difficult to make. Figure 2 illustrates a hip predicted to be in Catterall group 3 on the basis of the subchondral fracture, which involves the lateral margin of the femoral head on the anteroposterior radiograph and extends over almost all of the epiphysis on the Lauenstein projection. The hip was classified as Catterall 4 at the time of maximal resorption. Similarly, we found a shift from predicted Catterall group 2 to actual group 3 most likely due to the difficult distinction between fracture extension posteriorly slightly beyond the midline of the femoral head (group 2), and almost to the posterior margin (group 3) on the Lauenstein projection [4]. Furthermore, we found it difficult to determine the extent of the fracture on the lateral margin of the femoral head on the anteroposterior radiograph, making the distinction between predicted groups 2 and 3 additionally complicated. Figure 3 shows an example as the subchondral fracture is barely visible on the

Fig. 2



Radiographs of the right hip of a 6-year-old boy, 1 month after onset of the disease. The hip was predicted to be in Catterall group 3 on the basis of the extent of the subchondral fracture on (a) anteroposterior radiograph and (b) Lauenstein projection. It was classified as Catterall group 4 at the 1-year follow-up on (c) on anteroposterior radiograph and (d) Lauenstein projection.

Fig. 3

The left hip of girl aged 6.5 years, 3 months after onset of the disease. This hip was predicted to be in Catterall group 3 on the basis of the extent of the subchondral fracture on (a) anteroposterior radiograph and (b) Lauenstein projection. It was classified as Catterall group 2 at the 1-year follow-up on (c) anteroposterior radiograph and (d) Lauenstein projection.

anteroposterior radiograph but is clearly seen on the Lauenstein projection. This hip was classified as Catterall 3 on the basis of the extent of the subchondral fracture at the time of diagnosis. However, the lateral margin is preserved and so the hip was classified as Catterall 2 at the time of maximal resorption. We found 95% concordance between the extent of the subchondral fracture and the extent of the necrosis assessed in the Lauenstein projection alone, thus the necrosis develops directly beneath the subchondral fracture assessed on this projection. However, the ability to predict the extent of the necrosis on the basis of the subchondral fracture in the Lauenstein projection does not make the actual Catterall classification easier to make. These difficulties demonstrate the problems related to describing the extent of pathological features in a three-dimensional spherical object such as the femoral head with the aid of two-dimensional radiographs.

Several studies have shown relatively low inter-observer agreement with the Catterall classification [7,10,11]. The relatively low agreement (weighted κ 0.46) between the two observers in predicting Catterall groups on the basis of the subchondral fracture may indicate that it is not easier to use the subchondral fracture as a determinant of femoral head involvement than to use the extent of necrosis of the femoral head according to Catterall. Both observers found a better concordance when using the extent of the subchondral fracture to predict Salter–Thompson groups (S.S. 90%, O.W. 79%). Several studies [4,12,13] have pointed out advantages with this classification, and our results show an additional advantage of this two-group classification.

Salter and Thompson [4] reported that the duration of the subchondral fracture varied directly with the age of the patient at the onset of the disease, ranging from an

average of 3 months when the patient's age at onset was 4 years or less to an average of 8.5 months when the onset was at the age of 10 years or more. We could not reproduce this in our study, but we were able to determine the duration of the subchondral fracture in only 30 out of 92 patients.

We found that patients with detectable subchondral fracture were significantly older and had a significantly shorter delay of diagnosis than those without visible fracture. However, there were no differences between the two groups regarding the clinical parameters (sex, pain level and localization or limping gait). This may indicate that the subchondral fracture is more likely to be radiographically detectable when the diagnosis is made early (within 3 months), which is in accordance with Salter and Thompson [4]. They postulated that the subchondral fracture, being painful, heralded the clinical onset of the disease. This is hardly in accordance with our results since the group with a subchondral fracture did not have more pain than the group without a fracture.

We conclude that the subchondral fracture is a useful early radiographic sign as its extent is in fairly good concordance with the extent of femoral head involvement at the time of maximal resorption. The experienced observer obtained better concordance than the less experienced one. Awareness of this radiographic sign will aid the orthopaedic surgeon to establish diagnosis and to some degree to predict prognosis early in the course of the disease.

References

1 Waldenstrøm H. The first stages of coxa plana. *J Bone Joint Surg* 1938; **20**:559–566.
2 Caffey J. The early radiographic changes in essential coxa plana: their significance in pathogenesis. *Am J Roentgenol* 1968; **103**:620–634.
3 Normann A, Bullough P. Radiolucent crescentic line: early diagnostic sign of avascular necrosis of the femoral head. *Bull Hosp Joint Dis* 1963; **24**:99–104.
4 Salter RB, Thompson GH. Legg-Calvé-Perthes disease: The prognostic significance of the subchondral fracture and a two group classification of the femoral head involvement. *J Bone Joint Surg Am* 1984; **66A**:479–488.
5 Catterall A. The natural history of Legg-Calvé-Perthes Disease. *J Bone Joint Surg Br* 1971; **53B**:37–53.
6 Dickens DRV, Menelaus MB. The assessment of prognosis in Perthes' Disease. *J Bone Joint Surg Br* 1978; **60B**:189–194.
7 Hardcastle PH, Ross R, Hamalainen M, Mata A. The Catterall grouping of Perthes' disease: an assessment of observer error and prognosis using the Catterall classification. *J Bone Joint Surg Br* 1980; **62B**:428–431.
8 Kahmi E, MacEwen D. Treatment of Legg-Calvé-Perthes Disease. *J Bone Joint Surg Am* 1975; **57A**:651–654.
9 Altmann DB. *Practical statistics for medical research*. London: Chapman & Hall; 1999.
10 Cristensen F, Søballe K, Ejsted R, Luxhøj T. The Catterall classification of Perthes: an assessment of reliability. *J Bone Joint Surg Br* 1978; **60B**:614–615.
11 Ritterbush JF, Shantaram SS, Gelinas C. Comparison of lateral pillar and Catterall classification of Legg-Calvé-Perthes' disease. *J Pediatr Orthop* 1993; **13**:200–202.
12 Simmons ED, Graham HK, Szalai JP. Interobserver variability in grading Perthes disease. *J Bone Joint Surg Br* 1990; **72B**:202–204.
13 Wiig O, Terjesen T, Svenningsen S. Inter-observer reliability of radiographic classifications and measurements in the assessment of Perthes' disease. *Acta Ortop Scand* 2002; **73**:523–530.