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EARLY ASSESSMENT OF PROGNOSIS IN PERTHES' DISEASE

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A new method for early prognostication of Perthes' disease is presented. It is based entirely on radiological assessment and was developed from a review of 69 radiologic examinations performed during the first year of the disease in 27 patients with unilateral Perthes' disease. A simple mathematical function was constructed with the aid of discriminant analysis of four parameters, viz. the metaphyseal width of the femur, the position of the femoral head in relation to the acetabulum, and the acetabular height and breadth.

Key words: hip; Perthes' disease; prognosis

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The natural course of Perthes' disease has an unfavourable outcome in about 25 per cent of all cases, as assessed radiologically. However, experimental research as well as clinical investigations have shown that the outlook is much brighter if treatment is started in an early stage of the disease (Axer 1965, Salter & Bell 1968, Sommerville 1971, Salter 1972, Lloyd-Roberts et al. 1976, Brotherton & McKibbin 1977). A method for the early prediction of the further course of the disease is therefore urgently required.

Efforts have been made to predict a poor prognosis from certain radiologic features (Heyman & Herndon 1950, Harrison & Menon 1966, Kemp & Boldero 1966, Schiller & Axer 1972, Catterall 1972). Among these, Catterall's "signs of risk" are best known and have been widely applied as a guide to prognosis. However, these signs appear too late to be of therapeutic value for the individual case (Heikkinen & Puranen 1980) even though they seem to be useful in retrospective studies (Salter et al. 1977). For example the lateral calcification indicates displacement of the *already deformed* epiphysis, as can easily be demonstrated by arthrography. Moreover, of these signs neither the diffuse metaphyseal changes nor so-called Gage's sign (1933) can be quantified, and the inclination of the growth plate cannot be measured without knowledge of the femoral neck orientation, which cannot be defined at a standard radiologic examination.

In clinical practice the only reliable risk sign seems to be the degree of lateral subluxation of the femoral head (Dickens & Menelaus 1978, Hardcastle et al. 1980, Gershuni 1980), which should guide the efforts to restore the normal relationship between acetabulum and the femoral head by means of containment of the head (Petrie & Bitenc 1971, Canale et al. 1972). The lateral subluxation has usually been estimated by one of the following means:

A. Head-socket distance (Waldenström 1934).
B. Acetabulum-head quotient (Heyman & Herndon 1950).
C. CE-angle (Wiberg 1939).

However, none of these methods is without drawbacks.

The head-socket distance does not take into ac-

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Figure 1. An example of pronounced changes in the femur during the first year of the course of Perthes' disease, resulting in very slight changes after healing.
a. 11 months after diagnosis. All of the femoral epiphysis is affected, and there is pronounced lateralization and broadening of the metaphysis. The lines drawn through the caudal limits of the sacro-iliac joints and through the Y-cartilage indicate growth changes also in the acetabulum.
b and c. Right and left hip, 7 years after diagnosis. The femoral head on the affected side is somewhat enlarged, but round and covered by the acetabulum.

count the fact that the width of the femoral epiphysis is usually greater on the affected side, which influences the relation between the acetabulum and the femoral head laterally, where deformation of the physis might possibly occur. Moreover, abnormally thick articular cartilage may simulate an increased head-socket distance (Gershuni et al. 1978).

The acetabulum-head quotient expresses how much of the femoral head is covered by the acetabulum. Also this value can be misleading, as exemplified in Figure 1 where nearly two-fifths of the femoral head was not covered 11 months after diagnosis. In this case one would have expected a poor final outcome. Yet the end result was quite good with no deformation. This may be explained by the fact that abnormal growth and remodelling occurred not only in the femur but also in the pelvis (indicated in Figure 1 by the divergency between the two lines drawn through comparable points). The extent of radiographic signs of acetabular remodelling, which we think are essential in assessing prognosis, are completely camouflaged in the acetabulum-head quotient.

The CE-angle expresses substantially the same phenomenon as the acetabulum-head ratio. Since calculation of this angle in the lower age-groups requires an arthrography, the method is not convenient for routine use in most cases of Perthes' disease.

In view of the above observations we think there is still a need for a more precise assessment of the early prognosis of Perthes' disease and that this might be constituted by taking into consideration not only deformation and subluxation of the femoral head but also the growth changes of the acetabular region mentioned above. The measurements of this investigation are made accordingly, but as they are based on comparison between the sound and the affected side, unilateral cases only can be considered. It is also a prerequisite that all measuring points in the pelvis and the proximal part of the femur are symmetrically depicted on the radiographs.

PATIENTS

During the period 1938 through 1968, 94 cases of Perthes' disease were diagnosed at the General Hospital, Malmö. The treatment consisted of various conservative measures, usually crutches, in order to reduce or eliminate weight-bearing (Table 1). However, in most cases it was not possible to carry through the intended treatment, the usual reason being poor cooperation by the patients.

In accordance with other investigations (Catterall 1971, Lloyd-Roberts et al. 1976) the treatment given is considered of no essential importance for the natural course of the disease, i.e. the patients may be regarded as having had no definitive treatment.

All the patients were repeatedly examined radiologically during the first years after the diagnosis. In 60 cases the radiographs have been preserved. For various reasons (bilateral disease, contralateral hip not examined, obscuring lead shields, too few examinations, incorrect projections as defined below), the radiographs of 33 patients did not meet the requirements of the present study. The remaining 27 cases constitute the basis of the present study. There were 19 boys, aged at diagnosis 3–11 years (mean 6.5), and 8 girls, aged at diagnosis 3–8 years (mean 5.5). The children had had two or more radiologic examinations, including an AP view of the entire pelvis within 1 year after diagnosis, making a total of 69 examinations. The radiographs obtained at these examinations, as well as those from the follow-up of all the 27 patients after the cessation of growth, were analysed.

Table 1. Treatment and radiological end result

Sex	Age at diagnosis (years)	Treatment		Radiological results
		Short periods of bedrest and crutches	Thomas splint intermittently	
M	3	×		Good
M	4	×		–
F	4	×		–
F	4		40 months	–
F	5	×		–
M	5	×		–
M	5	×		–
M	5	×		–
M	6	×		–
M	6	×		–
M	6	×		–
F	6	×		–
M	7	×		–
M	7	×		–
M	8	×		–
M	9	×		–
F	6	×		Fair
M	8	×		–
M	12	×		–
M	3		30 months	Poor
M	4	×		–
F	4		10 months	–
M	8	×		–
F	8	×		–
F	8	×		–
M	9	×		–
M	11	×		–

METHODS

The 69 radiographs from the first year of the disease after diagnosis were reviewed. A search was made for changes in the proximal part of the femur as well as in the acetabulum, that were recognizable at every examination, quantifiable on the AP projections and probably influencing the later moulding of the joint. The changes found were measured in millimeters and mathematically expressed relative to the corresponding dimensions on the contralateral healthy side. These values are referred to here as risk parameters.

The risk parameters

The following changes met the above criteria:

1. Increased metaphyseal width
2. Lateral subluxation of the femoral head
3. Changed transverse and

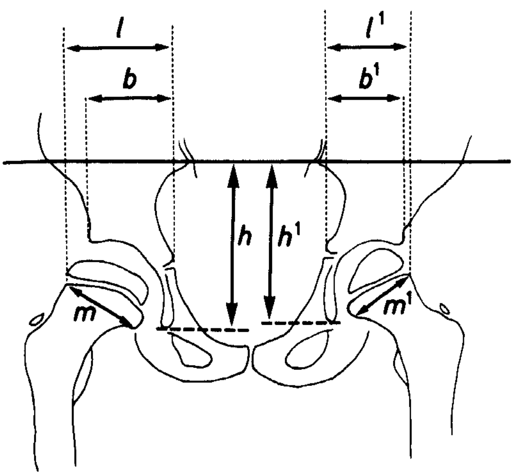

Figure 2. Measurements performed on the radiograph of the pelvis.
—— = a baseline drawn through the caudal limits of the sacro-iliac joints. ···· = lines perpendicular to the baseline through the lateral border of the actetabulum, through the medial border of the acetabulum just cranial to the Y-cartilage and through the lateral border of the metaphysis. ------ = lines parallel to the baseline through the lower borders of the tear-drop formations.
m and m′ = the metaphyseal width; l and l′ = the position of the femoral head; b and b′ = a measure of the acetabular breadth; h and h′ = a measure of the acetabular height.

4. Changed vertical dimensions of the acetabular region.

In order to quantify these changes the following lines were drawn (Figure 2):

a. A baseline connecting the caudal borders of the sacroiliac joints;
b. Lines perpendicular to the baseline through the lateral border of the metaphysis, through the lateral border of the acetabulum and through the medial border of the acetabulum just cranial to the Y-cartilage, respectively;
c. Lines parallel to the baseline, through the caudal border of each of the so-called tear drop formations.

Using these lines the following dimensions were measured:

1. *The metaphyseal width:* the distance between the lateral and medial borders of the metaphysis (m and m′ on the affected and healthy side, respectively).
2. *The position of the lateral border of the metaphysis:* the distance between the lines through the lateral border of the metaphysis and the medial border of the acetabulum (1 and 1′, respectively).
3. *A transverse dimension of the acetabular region:* The distance between the lines through the medial and lateral borders of the acetabulum (b and b′, respectively).
4. *A vertical dimension of the acetabular region:* The distance between the baseline and the line through the caudal border of the so-called tear drop formation (h and h′, respectively).

Using these measurements, the risk parameters were defined as follows:

The relative increase in metaphyseal width: $\frac{m - m'}{m + m'} = M$

The relative subluxation of the femur: $\frac{l - l'}{l + l'} = L$

The relative change of the transverse acetabular dimension: $\frac{b - b'}{b + b'} = B$

The relative change of the vertical acetabular dimension: $\frac{h - h'}{h + h'} = H$

There were thus two parameters (M and L) describing the change in the proximal femur and two (B and H) describing the changes in the acetabular region.

The dimensions were measured to the nearest 0.5 mm. Earlier radiologic investigations (Schiller & Axer 1972) have shown that differences in pelvic tilt have not any noteworthy effect on such measurements. This was also verified in model tests during the present study. As for the effect of a rotation of the pelvis or the orientation of the femur on the values found, measurements made on the AP projections were accepted only if they fitted the following criteria:

1. The median through the sacrum should not deviate from the centre of the symphysis by more than 0.5 cm.
2. The difference in femoral abduction and adduction between the right and the left side should not exceed 5°.
3. The degree of femoral rotation should be the same on both sides.

With these requirements any divergencies due to differences in projection fell within the limits of the measuring error.

The radiological outcome of the disease in each patient was judged from the radiographs obtained during follow-up and classified according to Catterall (1972) as good, fair or poor. A *good* result was one in which the head was round and well contained within the acetabulum, which had no adaptive changes. Some loss of epiphyseal height was accepted provided the head was round. A *fair* result was one in which the head was round but slightly broadened and not fully contained within the acetabulum, i.e. up to one-fifth uncovered. Some adaptive changes in the acetabulum were accepted provided the head was round. A *poor* result was defined as one in which the head was flattened, broad, irregular and/or at least one-fifth was uncovered by the acetabulum, in which adaptive changes were demonstrable.

The values of the risk parameters at each examination, and the interval (in months) between diagnosis and the examination from which the radiographs evaluated were obtained were matched against the outcome of the disease in each patient. Using discriminant analysis with the aid of a computer, all possible combinations of the risk parameters at each examination were tested to find the mathematical function that best discriminated between the patients with a good outcome and those with a poor outcome. In addition the risk parameters were studied for intercorrelations.

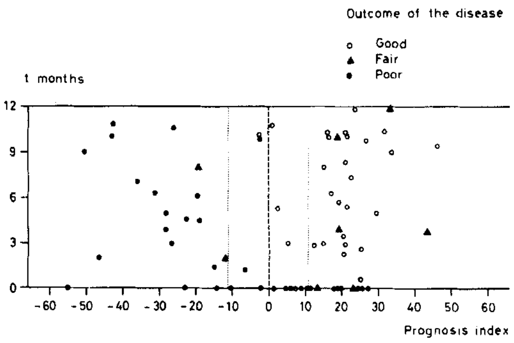

Figure 3. Prognoises index calculated in the 69 radiographs reviewed, and the outcome of the disease in each case examined.
P = prognosis index; t = interval in months between diagnosis and radiologic examination; ○ = good outcome of the disease (according to Catterall); ▲ = fair outcome of the disease (according to Catterall); ● = poor outcome of the disease (according to Catterall).

RESULTS

Of the 27 patients, 16 had a good, 3 a fair, and 8 a poor outcome of the disease.

At the statistical analysis it became evident that the function which, at each radiologic examination during the first year after diagnosis, best discriminated the patients in whom the course of the disease proved favourable from those in whom it was unfavourable appeared to contain all the risk parameters and was as follows

$$P = 7 + t - 320M - 480L + 460B + 1\,130H$$

where P denoted the "prognosis index" that expresses the prognosis of the patient examined, t is the interval (in months) after diagnosis and the risk parameters M, L, B and H are defined as above.

Using this function the values of P according to the interval after diagnosis are given in Figure 3. Each symbol in the figure also indicates the radiological outcome of the disease. The dotted lines (P = ± 11) were computed in such a way that there is a 95 per cent probability that P values outside the lines indicate a poor or good prognosis, respectively. Twenty per cent of the cases will fall between the lines, and in these cases it is not possible to predict the late results with that certainty.

Table 2 gives the correlation coefficients between the risk parameters. Thus, there was a strong correlation between L and M and a moderate correlation between M, L and B, while H was not correlated with any other risk parameter.

Table 2. Intercorrelations between the risk factors

	M	L	B	H
M	1			
L	0.74	1		
B	0.46	0.53	1	
H	0.09	0.08	0.12	1

DISCUSSION

The patients constituting the basis of the present study may be regarded as having had virtually no treatment, as in Catterall's study (1972). Judging from the clinical files, there were no differences between the patients included in the present study and those who were not, apart from the patients with bilateral disease. Thus, there was no significant difference in sex or age distribution, treatment given or final outcome from a clinical point of view. The present study thus involved unselected patients who had had virtually no treatment, thus representing the natural course of the disease.

However, the present method for prognostication is entirely based on radiological assessment. No regard whatsoever was payed to sex or age of the patients, début, clinical course or outcome of the disease. The study was founded on quantifiable differences of the X-rays from the affected and the healthy side in each patient. Therefore we could not use the method in those 10 per cent of the children in whom the disease is bilateral.

When using radiologic changes as prognostic signs a fundamental requirement is the reproducibility of the recording method, i.e. defined comparable projections with known measuring errors must be used. Experience has also shown that qualitative parameters are difficult to reproduce and therefore the possibility of describing changes numerically, as offered by the present method, is of greatest importance.

Early prognosis is important for modern treatment. As shown in Figure 3, the prognosis index P often permitted prognostication already at the first examination although its reliability increased with time after diagnosis. On the other hand, the value of treatment late in the course of the disease is uncertain.

It is noteworthy that the changes in the femur affected were given a negative sign in the function constructed by the computer, indicating a poor prognosis, while the changes in the acetabulum got a positive sign, indicating a brighter outlook. This might mean that the growth changes in the acetabulum compensate for the changes primarily induced by the disease of the proximal femur. The frequency of such a compensatory reaction may decrease with advancing age, explaining the better prognosis in the younger child.

The statistical analysis also included calculation of the correlation coefficients between the variables M, L, B and H (Table 1). The highest correlation was between M and L. This is probably due to the projection of M constituting a substantial part of L. In a similar way the rather high correlation between B and L might be explained. However, the low correlation coefficient between B and H is more difficult to explain. These two parameters represent the growth of the acetabular region. According to Bösch (1978) there is a continuous expansion of the acetabulum during growth and at the same time adaption of the socket to the growing femoral head. In relation to a fixed point in the ilium the acetabular socket shifts laterally, ventrally and, above all, distally and this movement corresponds to changes of B and H. The poor correlation between these two parameters may denote asymmetric growth of the pelvis caused by the laterally subluxated femoral head.

Though the present results were calculated from a retrospective study, the best way to test the method is, of course, a prospective study, in which various therapeutic methods can also be evaluated. Such a comparative prospective study is now in progress in most hospitals in Sweden.

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