THE FEMORAL NECK IN LEGG-PERTHES' DISEASE

Its Relationship to Epiphysial Change and its Importance in Early Prognosis

J. ROBICHON, J. P. DESJARDINS, M. KOCH and C. E. HOOPER, ONTARIO, CANADA

From the Division of Orthopaedic Surgery, University of Ottawa, Ontario

Like most other orthopaedic surgeons, we have never been satisfied with any available criteria for prognosis of Legg-Perthes' disease. Although the symptomatology is fairly consistent, the radiological changes are sometimes difficult to interpret as to the stage of the disease and its probable outcome.

Most reported studies are concerned primarily with the appearance of the femoral head. We, on the other hand, have been especially interested in the changes in shape of the femoral neck. Can these changes be explained in terms of the blood supply to the head and neck and its influence on bone growth and remodelling? We know that shortening and widening of the neck in Legg-Perthes' disease are variable. Can this be related to the extent of necrosis of the head? Furthermore, can the degree of shortening and widening in the early stages be used to predict the ultimate anatomical shape of the femoral head? The following studies were undertaken to investigate these possibilities.

CLINICAL STUDIES

MATERIAL AND METHODS

A method of measuring the ratio between the length and width of the femoral neck was devised and used on antero-posterior radiographs of patients with Legg-Perthes' disease (Fig. 1). One hundred and thirty-one radiographs of forty patients were available and met the following requirements: 1) unilateral disease, so that the normal and affected sides could be compared; 2) completion of the active phase of the disease so that a final assessment of good, fair or poor results could be made by standards similar to those of Ponseti and Cotton (1961) and of Catterall (1971), based principally on the shape of the femoral head. None of these patients underwent operation.

RESULTS

Table I shows the number of patients in each age group at the time of diagnosis and their final condition. Age did not seem to influence the result, a finding consistent with recent thinking of other investigators.

The radiographs were assessed by a variety of commonly

Fig. 1

The various radiological measurements. A–B: Line parallel to the axis of the diaphysis and passing through the highest point of the greater trochanter. C–D: Line from the base of the greater trochanter to the epiphysial plate. E–F: Line perpendicular to and bisecting C–D. G–F: Width of the neck. H–I: Line perpendicular to and bisecting G–F, passing from A–B to epiphysial plate, which is the length of the neck. \[ \frac{H-I}{G-F} = \text{length/width ratio (see text)}. \]
used criteria: epiphysial height, lateral calcification, appearance of epiphysial plate, metaphysial involvement, joint space, superior and inferior neck filling, position of the head in relation to the acetabulum, height of the greater trochanter, and angle of the neck. None appeared to offer a clear basis for prognosis.

Our measurements from radiographs of the femoral neck are expressed as the length/width index—that is, the l/w ratio of the affected side divided by the l/w ratio of the normal side, multiplied by 100 and taken to the nearest whole number. Values less than 100 indicate shortening and widening of the affected neck. Table II shows the l/w index in nine patients, three each from the category of good, fair and poor results. This sample illustrates the basis for the conclusions reached after measurements were made on all the patients. In patients with fair results, no definite trend of change in the index was detected. However, in other patients it was observed that if at the first examination the l/w index was only slightly below 100 and remained so, or was initially low but increased towards 100 with time, the outcome was generally good. However, if the index decreased progressively, whether the initial value was slightly—or considerably—less than 100, the end-results were usually poor (Table III). Thus, despite the fact that these measurements were made on available radiographs and not under uniform conditions, a direct relationship between the changes in the length and width of the neck and the final shape of the head was shown.

**TABLE I**

**Influence of Age on the Final Radiological Appearance of the Hip in Forty Cases of Legg-Perthes' Disease**

<table>
<thead>
<tr>
<th>Age at the time of diagnosis</th>
<th>Number of patients</th>
<th>Good result*</th>
<th>Fair result†</th>
<th>Poor result‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 years</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 years</td>
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<td>5 years</td>
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<td>2</td>
<td>1</td>
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<td>6 years</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
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<td>4</td>
<td>4</td>
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<tr>
<td>9 years</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>over 9 years</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>18</td>
<td>11</td>
<td>11</td>
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</tbody>
</table>

* Good result—round head, well covered. No or very slight change in the epiphysial height.
† Fair result—flattened head, slightly wider than normal. Slightly subluxated.
‡ Poor result—flat head, wider than normal, subluxated.

EXPERIMENTAL STUDIES

**MATERIAL AND METHODS**

Experiments were designed to simulate Legg-Perthes' disease in animals and to examine the macroscopic and microscopic changes in the head and neck. Rabbits and dogs were used in the first experiments. The hip joint was exposed by the approach described by Bassett, Wilson, Allen and Azuma (1969) and a chromic ligature was tied around the femoral neck outside the capsule to interrupt blood flow to the head. The femoral neck of the rabbit proved to be too short for our purposes and in dogs collateral circulation allowed too rapid revascularisation.
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Young pigs proved to be more satisfactory. The right femoral neck was ligated in fourteen piglets, the undisturbed left side serving as a control. Each animal also received an injection of tetracycline forty-eight and twenty-four hours before operation for a total dose of 15 milligrams per kilogram of body weight. Animals were killed at weekly intervals from two to seven weeks.

**TABLE II**

**LENGTH/WIDTH INDEX** \(^a\) OF FEMORAL NECK IN LEGG-PERTHES' DISEASE

<table>
<thead>
<tr>
<th>Case number</th>
<th>Year</th>
<th>1/w index</th>
<th>Case number</th>
<th>Year</th>
<th>1/w index</th>
<th>Case number</th>
<th>Year</th>
<th>1/w index</th>
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<td>89</td>
<td>4</td>
<td>1962</td>
<td>94</td>
<td>7</td>
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<td>63</td>
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<tr>
<td>1</td>
<td>1972</td>
<td>87</td>
<td>7</td>
<td>1967</td>
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<td>90</td>
</tr>
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<td>1968</td>
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<td>1961</td>
<td>88</td>
<td>17</td>
<td>1968</td>
<td>78</td>
<td>18</td>
<td>1969</td>
<td>74</td>
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<tr>
<td>3</td>
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<td>95</td>
<td>19</td>
<td>1972</td>
<td>85</td>
<td>20</td>
<td>1972</td>
<td>69</td>
</tr>
</tbody>
</table>

1/w ratio on affected side

\(^a\) 1/w index \(=\) \(\frac{\text{Length}}{\text{Width}}\) × 100.

Values less than 100 in the 1/w index show shortening and widening of the affected femoral neck.

**TABLE III**

**CHANGE IN LENGTH/WIDTH INDEX DURING THE ACTIVE PHASE OF LEGG-PERTHES' DISEASE IN FORTY PATIENTS**

<table>
<thead>
<tr>
<th>Length/width index</th>
<th>Number and percentage of patients</th>
<th>Number and percentage of patients</th>
<th>Number and percentage of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same or improved</td>
<td>16 (89)</td>
<td>6 (55)</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Worsened</td>
<td>2 (11)</td>
<td>5 (45)</td>
<td>8 (73)</td>
</tr>
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</table>

The uppermost third of each femur was excised and bisected longitudinally in the coronal plane, thus cutting through the middle of the head and greater trochanter. One half was fixed in 10 per cent neutral formalin, decalcified in 5 per cent formic acid and embedded in paraffin. A Zeiss sliding microtome was used to obtain sections approximately 6 μ thick which were stained with haematoxylin and eosin, and with toluidine blue. These sections were used to study the general histological appearance and to measure the thickness of the joint cartilage and the epiphysial plate.

The other half of the femur was fixed in 70 per cent alcohol. Non-decalcified sections from each femur were ground by hand to a thickness of 75–120 μ and stained by the osteochrome method of Villanueva (1967). Cross sections at different levels of the metaphysis were also obtained and treated in the same manner. These non-decalcified sections were photographed under ultra-violet illumination (Klosevych 1971) to show the distribution of tetracycline.
RESULTS

Evidence of ischaemic damage and of recovery was observed to a varying extent in the heads of all the femora operated upon. Extreme changes with some areas of recovery were seen at two weeks and were also present at seven weeks after operation. Bone marrow cells were reduced or absent in all specimens. The extent of necrosis of the trabeculae in the head varied from a few small areas in the centre to involvement of the entire head. In some, the head was collapsed and filled only with a rather cellular connective tissue with no marrow or fat cells, osteoblasts or bone. In those femora in which vascular ligation produced marked changes the joint cartilage was much thickened (Figs. 2 and 3). This has been interpreted as the result of continued growth of cartilage which was still nourished by synovial fluid, whereas replacement by bone had ceased because of the ischaemia (Zahir and Freeman 1972). The cartilaginous layer of the epiphysial plate was not measurably altered in thickness but there were signs of decreased germination of cells. The columns of cartilage cells were more irregular, with a smaller number of plumper cells in each column. In some animals the epiphysial plate was more severely damaged and disorganised, with fibrous invasion, fissures and even signs of collapse. Osteoblastic activity was apparently undiminished below the epiphysial plate and in the periosteum. The zone of the primary spongiosa was slightly narrower. It was also observed that the number of osteoclasts was definitely reduced on the periosteal side of the neck of animals with severely affected epiphyses, indicating a decrease in resorptive remodelling in this area.
The localisation of tetracycline in non-decalcified longitudinal sections showed that the normal "funnel" arrangement described by Leblond, Wilkinson, Bélanger and Robichon (1950) was present on the normal side but grossly disturbed on the side operated upon. In cross-sections of the metaphysis it was clearly seen that the bone labelled with tetracycline was farther away from the outer edge on the side operated upon than on the normal side (Figs. 4 and 5). This indicated to us that apposition of new bone had continued but that there was probably a decrease of resorption in this area—which is consistent with the observed decrease in number of osteoclasts. We consider that the overall picture clearly indicated that the blood supply to the head was reduced in the femora operated upon, causing ischaemic necrosis and reduced activity of the germinal layer of the epiphysial plate, but that appositional growth had continued.

**DISCUSSION**

Suggested forms of treatment of Legg-Perthes’ disease vary from the conservative to the extremely radical. Consequently, much of the literature is concerned with evaluation of different forms of treatment. Both qualitative criteria (Ponseti and Cotton 1961, Catterall 1971) and quantitative systems of measurement (Heyman and Herndon 1950, Meyer 1966) for assessing the results radiologically are primarily concerned with the shape of the femoral epiphysis. Extensive experimental work has elucidated the cause and development of epiphysial changes (Lemoine 1957; Trueta and Amato 1960; Salter, Kostuik and Dallas 1969) but not,
to our knowledge, changes occurring in the femoral neck. From radiological observations Ponseti and Cotton (1961) described increased apposition of bone throughout the length of the neck. Edgren (1965) felt that although appositional growth did contribute to increased width to some extent, the principal cause was “growth phenomena” in the metaphysis where widening was first observed. He also observed that longitudinal bone growth was decreased. Edgren concluded that the degree of shortening and widening of the neck corresponded to the degree of malformation of the head and that the repair processes took place in parallel, but could not explain this relationship.

We wish to offer an explanation based on established knowledge of normal bone growth and of the vascular supply to the femoral head which is supported by our experimental results. From the work of Trueta and Harrison (1953), Trueta (1957) and Trueta and Morgan (1960) we know that the femoral head and the germinal cells of the epiphysial plate are dependent on epiphysial blood vessels for their nutrition. It is generally accepted that Legg-Perthes’ disease is the result of diminished blood flow to the femoral head. This at the same time affects the reproduction of the germinal cells, as seen in our pigs, and therefore reduces longitudinal bone growth (Brashear 1963). However, appositional growth in the metaphysis continues as this area remains vascularised. Decrease in longitudinal growth with continuing appositional growth will result in abnormal remodelling and therefore a short, wide neck. The decreased osteoclastic activity on the periosteal surface of the metaphysis observed in our pigs would also contribute to the formation of a wider neck.

That these conclusions can be applied to Legg-Perthes’ disease is shown by the result of measurement in the length/width ratio of the femoral neck of patients. Even though the radiographs were not taken under uniform conditions, a change in the degree of shortening and widening for better or worse was found to reflect the course of ischaemic change in the head. We hope that standardised positioning of patients and more frequent measurements during the early stages of treatment would provide a more accurate index. It might also be possible to predict the extent of damage that is likely to occur in the femoral head. The treatment of Legg-Perthes’ varies widely, from none at all, to bed rest, to bracing and even to surgical intervention, so that the ability to give an early prognosis would be of great assistance in deciding on the best treatment for each patient.

**SUMMARY**

1. Experimental work with piglets supports the theory that diminished blood supply to the femoral head not only causes necrosis of the epiphysis but also a decrease in cartilage cell production in the germinal layer of the epiphysial plate, thus causing decreased longitudinal bone growth. Appositional growth continues in the metaphysis because its blood supply remains intact or, at least, is less impaired. The resulting disturbance of the normal remodelling must lead to a short wide neck such as occurs in Legg-Perthes’ disease.

2. Measurements were made of the length and width of the femoral neck on radiographs of forty patients with Legg-Perthes’ disease. The results showed that the degree of shortening and widening is related to the extent of structural change in the head.

3. Repeated measurements in the early stages of the active disease may permit an early prognosis which may be of great assistance in selecting the treatment suitable to each patient.

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**REFERENCES**


