ANATOMICAL FACTORS IN THE STABILITY OF THE HIP JOINT IN THE NEWBORN

B. McKibbin, Sheffield, England

*From the University Department of Orthopaedics, Sheffield*

Both the pathogenesis and management of congenital dislocation of the hip are controversial topics, not least because of lack of agreement on what constitute the essential pathological features. Studies of necropsy material have been rare, and even when a pathological change can be identified it is often uncertain whether it represents a primary feature of the disease or a secondary consequence.

It is obviously desirable therefore to take any opportunity to examine pathological material, and preferably from as young a child as possible so that there should be the least secondary changes. For this reason there are described in this paper the findings in a child with bilateral congenital dislocation who died within a few hours of birth and in whom it might be expected that only primary features would be present.

The specimen was dissected with the object of determining the essential cause of the instability and the mechanism by which stability could be restored. Particular attention was paid to the role of femoral anteversion and the orientation of the acetabulum because the significance of these features has been much disputed. This aspect of the investigation presented a problem, however, for although it was simple to measure these angles it was difficult to assess their significance.

Le Damany pointed out in 1908 that when the leg is in the neutral or anatomical position the stability of the hip is influenced by the relationship to the sagittal plane of both the femoral neck and the acetabulum, so that if the former faces significantly forwards (anteversion) and the acetabulum is also inclined to the front a stable articulation may be impossible. Although he was careful to indicate that it was the relationship between these two elements which was important, it is the direction of the femoral neck that subsequently received most attention. The normal range of femoral anteversion is well known in both the mature and the immature, and ingenious techniques have been devised for its measurement in the living subject. Measurements of acetabular orientation on the other hand have been much less frequent, and the reports that are available lack agreement. Thus Lanz (1949) gave an average figure of 42 degrees; that is, the plane of the acetabulum faces 42 degrees forward relative to the sagittal plane. Steindler (1935) also stated that 40 degrees is the normal figure but he did not disclose the source of his information. Getz (1955), working with the reconstructed pelvis of Lapps, found 38 degrees to be the average. In contrast Shiino (1915) gave values much lower than these, with an average of 15 degrees in the male and 19 in the female.

Studies of the immature pelvis show an even greater divergence. At the time of birth Lanz (1949) found the average to be 31 degrees and the figures of Dega (1933) ranged from 22 to 33. Laurent (1953) quoted still lower figures, between 10 and 25 degrees, and Fernández (1965) gave values of between 11 degrees and minus 27 degrees—that is, the acetabulum was in some instances actually facing backwards. The only finding common to all these investigations is that there is apparently an increase in acetabular anteversion with increasing maturity, although even here there is not complete unanimity, for Salter (1967) stated that the acetabulum rotates further backwards rather than forwards during early post-natal development.

Such a diverse range of normal values makes it difficult to interpret the findings in pathological material; so for the purpose of the present investigation it was necessary to try to reconcile the apparent conflict in the published figures.
A study of the methods of measurements used by the various investigators reveals a possible source of difference. Lanz (1949) chose to make his measurements with the brim of the pelvis horizontal, a practice which was also followed by Getz (1955), whereas Laurent (1953) and Fernández (1965) made their observations without specifying the position of the pelvis. Since the acetabulum not only faces forwards but also downwards, it is obvious that alterations in the relationship of the plane of the pelvic brim to the horizontal will also alter the sagittal orientation of the obliquely placed acetabulum. Thus in Figure 1, where the brim of the pelvis is horizontal, the acetabulum obviously faces forwards, but with the pelvis in
the anatomical position (Fig. 2) the plane of the brim lies some 60 degrees below the horizontal, so that a different diameter of the acetabulum is presented for measurement and the acetabulum appears to be closer to the sagittal plane.

For these reasons it was decided to make another attempt to produce figures for the normal orientation of the acetabulum in both the mature and immature pelvis by taking special care to standardise the position of the pelvis in relation to the rest of the body at the time of measurement, and to use these values for comparison with the measurements from the specimen of congenital dislocation.

MATERIAL AND METHODS
INVESTIGATION OF ACETABULAR ORIENTATION

Fifteen intact pelves were obtained from full term infants who had died within the first two weeks of life from causes thought to be unrelated to the musculo-skeletal system. All the attached muscles were removed together with the femora but the acetabular labrum was left intact; the measurements were carried out on the material in the fresh condition within a few days of death.

Fifteen articulated adult pelves were obtained from the anatomy departments of local universities. The bones were dried in all cases but most of them were held together by the remnants of the original ligaments. Two had been reconstructed with wire. Sex was determined by inspection of the bony features in the usual way.

The measurements were made in both groups with the pelvis orientated in the anatomical position—that is, with the top of the symphysis pubis in the same vertical plane as the anterior superior spine. This position was conveniently obtained by laying the pelvis prone so that these landmarks were simultaneously in contact with a level table top. An adjustable protractor was then held in the vertical plane against the greatest diameter of the acetabulum parallel to a line drawn between the two anterior iliac spines, and the angle which this made with the sagittal plane was read off directly (Fig. 3).

In some of the newborn specimens the amount of femoral anteversion present was also measured by the method of Kingsley and Olmsted (1948).

FIG. 3
Method used for the measurement of acetabular anteversion.
INVESTIGATIONS OF A NEWBORN CHILD WITH BILATERAL CONGENITAL DISLOCATION OF THE HIPS

The child was a full term male weighing 3·26 kilograms and was delivered by breech extraction. In utero the infant had been in the extended legs position with fully flexed hips and extended knees. The legs were brought down for delivery one at a time but some difficulty was experienced with the after-coming head and the forceps was applied. The child died within a few hours of birth and necropsy revealed extensive recent cerebral haemorrhage: death was attributed to the delivery. No other congenital malformation was present.

The entire pelvis and both femora together with the muscles were removed and systematically dissected, with particular attention to the factors affecting stability. Finally the amount of femoral and acetabular anteversion was measured.

<table>
<thead>
<tr>
<th>Type of pelvis</th>
<th>Number of hips</th>
<th>Range of acetabular anteversion</th>
<th>Mean acetabular anteversion</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>30</td>
<td>5–19</td>
<td>14</td>
<td>16·5</td>
</tr>
<tr>
<td>Adult female</td>
<td>30</td>
<td>10–24</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Immature male</td>
<td>30</td>
<td>2–11</td>
<td>4</td>
<td>6·5</td>
</tr>
<tr>
<td>Immature female</td>
<td>30</td>
<td>6–16</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Congenital dislocation</td>
<td>2</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
</tbody>
</table>

RESULTS

MEASUREMENTS OF FEMORAL AND ACETABULAR ANTEVERSION

The pelvic measurements are set out in Table I. In the adult it is clear that the acetabulum always faces slightly forwards, the average angle being 17 degrees. In the female the anteversion slightly exceeds that of the male by an average of 5 degrees. In the newborn the acetabulum lies closer to the sagittal plane, the average anteversion being only 7 degrees. Again there is a slight but definite increase in anteversion in the female. In one pelvis the acetabulum faced slightly backwards. In the case of congenital dislocation of the hip acetabular anteversion measured 23 degrees, which is greater than the average normal for this age but only slightly greater than the highest normal figure obtained in the series.

In Table II acetabular anteversion is compared with the coexisting femoral anteversion in some of the neonatal specimens. There is no apparent correlation between the two—that is, a high degree of acetabular anteversion is not necessarily associated with a low degree of femoral anteversion.

FINDINGS IN THE SPECIMEN OF CONGENITAL DISLOCATION

After removal of the abductor muscles the femoral head was found to lie just above and slightly in front of the acetabulum and as a consequence there was considerable redundancy of the capsule.

With the muscles intact it was possible to reduce the dislocation by abduction and flexion (Fig. 4) or by abduction, extension and medial rotation (Fig. 5). The hip was not stable in any position other than these: in particular, any attempt to extend the joint in neutral abduction resulted in further displacement of the head (Fig. 6).

When all the muscles had been removed the capsule was seen to be redundant in all its parts, particularly when the hip was in flexion (Fig. 7). With the hip in this position it was possible to pull the femoral head a considerable distance away from the side of the pelvis, drawing the capsule out into a horizontal tube. As a consequence the head could be lifted...
FIG. 4
Arthrograph of the right hip showing reduction of the dislocation with the thigh in flexion and abduction (the Lorenz position).

FIG. 5
Arthrograph of the right hip showing the dislocation reduced in abduction, extension and medial rotation.

FIG. 6
Arthrograph of the right hip in neutral abduction and full extension. The hip is dislocated.
clear of all bony contact with the acetabulum and placed in front of, above or behind it, so that it was meaningless to describe the dislocation as either anterior, posterior, etc., as the position was determined purely by external forces.

When the hip was abducted the inferior part of the capsule became tight and began to act as a fulcrum, so that further abduction movement had the effect of levering the head into the acetabulum. Even in this position, however, although the head was reduced it could still be displaced both anteriorly and posteriorly because of the laxity of the remainder of the capsule.

### TABLE II
**Acetabular Anteversion and Coexisting Femoral Anteversion in Neonatal Specimens**

<table>
<thead>
<tr>
<th>Type of hip</th>
<th>Acetabular anteversion (AA)</th>
<th>Femoral anteversion (FA)</th>
<th>Instability index (AA : FA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal neonatal hips. Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>47</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>51</td>
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<tr>
<td>-2</td>
<td>24</td>
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</tr>
<tr>
<td>Mean</td>
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<td>30</td>
</tr>
<tr>
<td>Normal neonatal hips. Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>38</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>38</td>
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</tr>
<tr>
<td>Mean</td>
<td>9</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td>Congenital dislocation</td>
<td>23</td>
<td>21</td>
<td>45</td>
</tr>
</tbody>
</table>

If medial rotation were then added to the abduction the rest of the redundant capsule became "wound up" and thereby tightened (Fig. 8), so that the head became firmly fixed in the acetabulum and resisted displacing forces from all directions. The same effect could be produced by abducting the hip in flexion into the "Lorenz" position (Fig. 9). Once again all parts of the capsule were tightened, this time in the opposite direction.

The effect was observed of forcibly extending the hip in neutral rotation. As was pointed out earlier, when the muscles were intact this manoeuvre resulted in further displacement of the head (Fig. 10). When the psoas had been divided, however, it was possible to extend the hip much further in neutral rotation, whereupon the lax capsule became tightened and the hip reduced in the anatomical position (Fig. 11). All parts of the capsule were tight in this
position so that the reduction was stable and attempts to displace the head by “telescoping” the leg were ineffectual. As soon as the joint was flexed, the capsule became slack again and the head could be displaced.

Figure 7—Dissection of the right hip in flexion. The capsule is extremely lax and the head is easily displaced. Figure 8—Dissection of the right hip in abduction and medial rotation after removal of all the muscles. The redundancy of the capsule can be seen to have been abolished by a winding-up mechanism and the hip is reduced.

Figure 9—Dissection of the right hip in flexion and abduction after removal of all the muscles. The redundancy of the capsule has been abolished by a winding-up mechanism and the hip is reduced. Figure 10—Dissection of the right hip in neutral abduction and full extension. The iliopsoas muscle and the capsule are intact. The hip is dislocated anteriorly and cannot be reduced in this position.

With the capsule removed it was possible to inspect the acetabulum (Fig. 12). Perhaps the most striking feature was the great length of the ligament of the femoral head, which was quite a strong structure, being as thick as the tendon of the iliopsoas. The base of the
acetabulum contained a quantity of fat which was more than the normal, and the cavity as a whole had a slightly oval outline. The acetabular labrum appeared to be normal.

Figure 11—Dissection of the right hip in full extension and neutral abduction after removal of all the muscles. The dislocation is reduced and the capsule has been wound up, abolishing the redundancy. Figure 12—Dissection of the right hip after division of the capsule and the ligament of the femoral head. The redundancy of the capsule can be seen. The configuration of the acetabulum is normal apart from a slight increase in the quantity of fat which it contains.

DISCUSSION

The figures obtained for acetabular anteversion in this investigation are considerably lower than in many other studies, although the values for the adults correspond almost exactly with those of Shiino (1915). In the neonatal pelves the figures are again lower than many, but fall within the range of a series reported by Fernández (1965). The difference between the present figures and the much higher values of Lanz (1949) and Getz (1955) may be explained by the fact that when the measurements are made with the pelvis in the anatomical position the acetabular diameter used is almost at 60 degrees to the diameter measured by the latter authors who took the measurements with the pelvic brim horizontal. It follows therefore that whenever values for acetabular orientation are quoted the orientation of the pelvis itself must be specified. An important corollary of this is that the usefulness of measurements made at the time of surgical operations such as those of Laurent (1953) and Fernández (1965) is seriously limited by the difficulty of determining, under these circumstances, the exact position of the pelvis itself.

For clinical purposes it seems more satisfactory to deal always with the pelvis in the anatomical position, because it is the stability of the hip in the standing position which is the main concern in congenital dislocation.

It was confirmed that the acetabulum in the adult is more anteverted than in infants by an average of about 10 degrees. This forward inclination presumably represents a post-natal continuation of the medial torsion which is a feature of the intra-uterine development of the lower limb bud, and serves to some extent to explain the relatively laterally rotated position
of the legs in the newborn, and the fact that the adult pelvic brim is relatively wide posteriorly compared with the more circular outline of the neonate.

By using these measurements as a baseline, together with the observations on the solitary specimen of congenital dislocation, it is possible to offer certain comments on both the etiology and the management of the disease.

**ETIOLOGY**

While it is generally allowed that there are genetic and environmental influences in this condition several different explanations have been advanced for the actual mechanism by which the dislocation occurs. The oldest of these is the concept of primary acetabular dysplasia, but support for this idea has gradually waned in recent years. This is because the disease is now more commonly diagnosed in the very early stages, when dysplasia can be seen to be minimal, suggesting that it is the result rather than the cause of the dislocation. The occasional finding of considerable acetabular dysplasia at birth can be accounted for by assuming that intra-uterine dislocation has been present for some time (Stanisavljevic and Mitchell 1963).

In the specimen described here the dislocation, although complete, was easily reducible and in this respect was typical of most dislocations recognised at birth. The acetabulum was well developed, and although there was a slight increase in the amount of intra-acetabular fat (Fig. 12) this could not of itself account for the instability. The acetabular rim was intact and no defect could be found in the limbus such as those noted by Ortolani (1948), again suggesting that these changes, when present, are secondary. In short, therefore, the dissection yielded nothing to support the idea of a primary acetabular dysplasia.

A second group of theories derive from the concept of Le Damany, referred to earlier, that there is incompatibility between the orientation of the femoral neck and of the acetabulum. This idea was developed by Badgley (1943), who pointed out that during the development of the lower limb bud there is a process of medial torsion which necessarily requires adjustments in the orientation of both the femoral neck and the acetabulum. He postulated that these alterations are normally coordinated in a reciprocal fashion and that it is a breakdown of this coordination which leads to a combination which is incompatible with joint stability. Another version of this was proposed by Somerville (1953) who suggested that the incompatibility was produced by a failure of foetal anteversion to mould away as the leg extended after birth, the back of the femoral neck being made to lever against the posterior acetabular lip by the extension movement forcing the head forwards and distending the capsule.

There are a number of objections to these ingenious theories, the chief of which relates to the implication in all of them that the actual dislocation occurs after birth. Incompatibility between femoral and acetabular anteversion is relevant only when the hip is extended, and this has led to the notion that "so long as the hip remains flexed it is safe" (Somerville 1953) and that it is only when post-natal extension occurs that the disparity becomes displayed and the dislocation produced. This concept does not accord with the facts. In the first place, the occurrence of dislocation in the foetus is well documented (Masie and Howorth 1951), and there is no evidence that the number of diagnosable displacements increases after birth; on the contrary, Barlow (1962) has shown that there is a tendency towards stabilisation.

The findings in the specimen described here do not support the idea that the displacement was a post-natal event. The child died within a few hours of birth, by which time the displacement had occurred and capsular laxity was already present. It seems inconceivable that this can have been produced as a single traumatic incident following the bringing down of the legs at delivery, particularly as the ligamentum teres was both thicker and longer than normal so that it must be assumed that the redundancy was present before birth. If the hips were flexed into the position they occupied in utero the capsular laxity was intensified (Fig. 7), since the capsule is normally tightest in extension (Walmsley 1928), so that far from the hips being safe only while in flexion, it was in just this position that they were most unstable.
Dislocation in every direction was possible in this position but the effect of axial thrust along the femur made posterior displacement the most likely.

Even if it could be established that the dislocation was indeed a post-natal phenomenon the anteversion theory still does not provide an adequate explanation for its occurrence. From the measurements reported in Table II it appears that there is no very close relationship between femoral and acetabular anteversion in a given individual; or at least it seems that there is quite a wide range of combinations of the two which are compatible with stability. A measure of the inherent liability to dislocate can be obtained by adding the amount of femoral anteversion to the amount of acetabular anteversion to give an "instability index" and even in the small number of specimens investigated here the range of this was from 20 to 58 (Table II). The significant observation is that the specimen of congenital dislocation had an index of only 45, which is less than that from some completely stable hips: therefore the dislocation cannot be blamed on this alone and indeed Le Damany himself suggested that a value of 60 represented the upper level of normal. It is true that acetabular anteversion in the dislocated specimen was high but this was more than offset by the relatively low figure of 22 degrees for femoral anteversion.

The final proof that there was no incompatibility between the femoral and acetabular orientation was provided by the finding that when the muscles were removed the hip was stable in full extension (Fig. 11). This represented a greater degree of extension than was present with the muscles intact; so that there can have been no question of the head's having been previously levered out by contact of the femoral neck on the pelvis.

O'Malley (1965) has suggested that the basic cause of the dislocation is shortening of the psoas muscle and has shown how this can displace the head when the limb is extended. This mechanism was well demonstrated in this specimen (Fig. 10), the effect being abolished when the muscle was divided (Fig. 11). However, to regard shortening of the psoas as the primary fault again implies that the dislocation occurs after birth, raising all the objections to this idea which have been previously mentioned. The fact that shortening of the psoas at birth is common in normal hips suggests that some additional factor must be operative.

It appears therefore that in the specimen discussed here the only finding which was unquestionably outside normal limits was the excessive laxity of the capsule but that this was by itself sufficient to account for the dislocation as suggested by Massie and Howorth (1951).

However, a clear distinction must be drawn between those factors which are responsible for the initial displacement and those which influence its future progress. Barlow (1962) has shown that a substantial proportion of those hips which are unstable at birth become normal spontaneously, and there is no way of knowing whether or not the example discussed here would have been such a one. It is likely, however, that the progress of spontaneous stabilisation will be influenced by a variety of other factors. Both Somerville (1962) and Salter (1966) have stressed the necessity of avoiding forcible extension of the joint and the importance of this in the presence of a tight iliopsoas was confirmed in the present dissection. Again, while the relationship between the femoral neck and the acetabulum was within normal limits in this instance, it is likely that a high "instability index" will militate against spontaneous recovery. If so, one might expect by a process of "natural selection" that there would be a disproportionately high percentage of cases of established dislocations in which there is an increase in either femoral or acetabular anteversion, and indeed it is widely believed that this is so, although this might equally well be explained by the subsequent development of secondary changes.

It seems probable therefore that the sequence of events in the production of the dislocation begins in utero where a primary laxity of the capsule permits the flexed hip to dislocate irrespective of the bony conformation, and the likelihood of this could be influenced by the posture of the foetus. Once the head has left the acetabulum the development of the latter is interfered with and a degree of dysplasia will be present at birth whose extent will depend on
the length of time interval involved. At birth there appears to be a spontaneous tendency for the capsular laxity to diminish and for the hip to become stable. This tendency is opposed by a variety of additional factors of which the most potent appears to be the levering action of the short iliopsoas muscle produced by the assumption of the extended posture: this mechanism is potentiated by acetabular or femoral anteversion and by any degree of dysplasia which may have developed. Upon the balance of all these factors the fate of the hip depends.

Thus if a distinction is made between those factors which lead to the initial dislocation in the foetus and those which tend to perpetuate the condition after birth it becomes possible to reconcile almost all the theories of pathogenesis which have been previously proposed.

**MANAGEMENT**

A great variety of methods of treatment has been described, many based upon principles which appear to have little relationship to one another and which are in certain instances directly conflicting. Nevertheless the fact that most of them produce a high proportion of satisfactory results suggests that, however diverse they may appear, they must have certain features in common. It is perhaps more profitable therefore to consider what these common features are, rather than to argue the case in favour of any one particular method.

One of the first differences to be encountered concerns the position of the hip which is chosen in order to reduce the dislocation. Two positions are commonly employed: the one, full abduction and flexion, the Lorenz or "frog" position, and the other, abduction extension and medial rotation. It is not immediately apparent what these two positions have in common, and when in some instances it proves possible to stabilise the hip in one of them and not the other it is not always evident which anatomical factor is responsible for this preference.

The efficacy of each position is usually explained on its ability to neutralise the effects of bony deformity. This is readily seen when the hip is in extension and the head is tending to dislocate forwards; in this position an increase in femoral or acetabular anteversion can be offset by medially rotating the leg, and if in addition the acetabulum is more vertical than normal (Salter 1961) it is evident that abduction will restore this relationship to normal.

Once the hip is flexed, however, as in the Lorenz position, a completely different set of relationships between femur and acetabulum now obtains for reasons pointed out earlier. Inspection of the dried bones shows that flexion eliminates the effects of femoral anteversion as the head and neck now no longer point forwards, but the advantages of abduction are more difficult to see since if anything this tends to decrease the cover of the head anteriorly, especially if there is increased acetabular anteversion. However, it must be remembered that although anterior dislocation is the hazard when the hip is in extension (Fig. 10) in the flexed position the head tends to leave the acetabulum posteriorly (Fig. 7), a circumstance which is actually rendered less likely by increased acetabular anteversion, and also by abduction, since in this position the axial thrust along the femur is directed against the bony pelvis instead of the more yielding posterior capsule. Although the head is substantially uncovered anteriorly in this position anterior displacement is resisted by the capsule, which is now stretched tightly across the front of the joint (Fig. 9).

While these explanations satisfactorily account for the behaviour of a dislocated hip in the presence of bony deformity, a difficulty arises when the mechanism has to be explained in its absence. In the present dissection the relationship between the acetabulum and the femoral neck was normal, yet it proved possible to stabilise the hip in both positions in the usual way, suggesting that some other common factor must be involved.

This was revealed when the dissection was carried down to capsular level, when it was seen that in both positions the capsular redundancy which is the primary cause of the instability had been eliminated by a twisting mechanism, opposite in direction in the two instances, and which when taken to extremes resulted in the head being virtually screwed into the joint. In addition there was a third position in which these conditions were fulfilled;
full extension and neutral rotation, so that the previous failure to reduce in this position was attributable, not to any bony abnormality, but to a restriction of extension imposed by the tight flexor muscles.

It follows therefore that the efficacy of these positions has a twofold explanation: capsular laxity is eliminated, and the effects of alterations in the orientation of both the acetabulum and femoral neck are offset. It is a fortunate coincidence that the interests of all can be served simultaneously in both positions. But because a dislocated hip can be stabilised in a certain position this does not necessarily provide evidence that any particular bony abnormality is present; and when reduction is possible in one position and not in the other it is likely that this is occasioned by a limitation imposed by the soft tissues rather than on a particular bony deformity. From the clinical standpoint, therefore, before the need for any bony correction is determined it seems logical first to eliminate any tightness of the soft tissues and in particular of the iliopsoas.

SUMMARY

The findings in a child with bilateral congenital dislocation of the hips who died shortly after birth are described. The only significant abnormality present was redundancy of the capsular ligaments and elongation of the ligament of the femoral head. The relationship between the orientation of the femoral neck and of the acetabulum was within normal limits. The significance of these findings in relation to etiology and management are discussed.

REFERENCES


