DISLOCATION OF THE HIP IN CEREBRAL PALSY

NATURAL HISTORY AND PREDICTABILITY

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To determine the natural history of dislocation of the hip in cerebral palsy, and to evolve methods to predict dislocation, the notes and radiographs of 462 patients with cerebral palsy were reviewed. Dislocation occurred in 10% of patients by progressive migration and subluxation of the proximal femur in the presence of acetabular dysplasia.

Statistical analysis identified the radiographic features that helped to predict dislocation. Measurement of acetabular index, by a method that allows for rotation of the acetabulum, was the most powerful single predictor. Measurement of this index at two and four years of age could identify patients who would dislocate unless effective treatment was undertaken, those at risk of dislocation only if scoliosis developed, and those who would not dislocate. On the basis of this method of screening for dislocation, a logical system of surgical prophylaxis is proposed.

Hip dislocation in cerebral palsy is distressing, and occurs in severely handicapped patients. It is associated with problems of sitting and inability to walk, and may lead to pain (Beals 1966; Howard et al. 1985; Cooperman et al. 1987).

Little is known of the natural history of dislocation. Adductor spasticity and scoliosis have both been incriminated in its aetiology (Samilson et al. 1967; Sharrard et al. 1975) and appropriate surgery has been advocated for its prevention. Although both adductor spasticity and scoliosis are important, understanding of dislocation is incomplete. Patients may, for example, have severe adductor spasticity and scoliosis without dislocation (Fig. 1).

Current knowledge does not enable us to identify early the hips that will dislocate. We have therefore reviewed retrospectively the notes and radiographs of a group of patients with cerebral palsy to determine the course of dislocation and to identify predictive factors.

PATIENTS AND METHODS

Patients. We reviewed all patients born between 1960 and 1965 who had attended the Royal Children's Hospital, Melbourne, Australia, with a diagnosis of cerebral palsy. All 462 patients in whom cerebral palsy...
developed before the age of three years were included in the series.

Patients were classified as spastic or athetoid (displaying any athetoid features) and as hemiplegic, diplegic, or quadriplegic. Table 1 shows the distribution of patients within these categories and the predicted figures for the Melbourne region. The predicted figures were calculated from the birth rate in the Melbourne metropolitan district for the years 1960 to 1965 and from the incidence of cerebral palsy in the same period as defined in the Western Australia cerebral palsy register (the nearest geographically available and accurate figures). We concluded that the population we studied included most of the quadriplegic patients in the community, but that the proportion of diplegic and hemiplegic patients studied was less than the actual figure.

All available pelvic and hip radiographs as well as abdominal or spinal radiographs that included the pelvis were assessed. We excluded those films that showed significant rotation (Tönnis 1976), lordosis, or kyphosis (Ball and Kommenda 1968).

In all, 1,684 radiographs were reviewed from the 332 patients for whom they were available, and 72 hips in 47 patients were seen to be dislocated. Dislocation was defined as being present when there was no contact between the femoral head and the true acetabulum.

All operations, both orthopaedic and non-orthopaedic, and the age at which they were performed were recorded, along with the departments which had provided treatment. Only 48% of the patients had been seen in the orthopaedic department. Of the 72 dislocated hips, 46 had dislocated without any orthopaedic treatment, and it is from these results that we have drawn conclusions about natural history and predictability.

**Measurements.** The following measurements were made on each radiograph, and the ages in years for which each test was performed are in brackets:

- Neck–shaft angle [all ages] (Chung 1981), centre–edge angle of Wiberg [all ages] (Massie and Howorth 1950); Smith’s h/b and c/b ratios [0 to 11] (Smith et al. 1968); acetabular index [0 to 11] (Tönnis 1976); migration index [all ages] (Reimers 1980); femoral head index/epiphysreal quotient [1 to 16] (Heyman and Herndon 1950). The presence of a scoliosis was also recorded. We performed radiographic readings with overlay transparent acetate sheets marked with pencil and ruler, and angular measurements with a 180° protractor.

- The method of marking the apex of the acetabulum when drawing Perkins’ line (Perkins 1928), or measuring acetabular index and centre–edge angle, was modified to allow for the acetabular anteversion which is common in cerebral palsy (Fig. 2). The anterior and posterior walls of the acetabulum were marked on the overlay transparency, and the apex of the acetabulum was defined as the superolateral point at which the lines converge (point B). When rotation of the acetabulum was present, point B did not coincide with the most lateral point (point A) which has been commonly used for these measurements.

**Patient groups.** When possible, the age at dislocation was recorded from the radiographic data, but only if it could be assessed to within two years (that is if the patient dislocated within two years of birth, or within two years of a radiograph which showed the hip was not dislocated). In 47 of 72 hips the age at dislocation was established (Fig. 3).

Three populations of patients who dislocated were identified: group A, who dislocated at or within two weeks of birth (perinatal dislocation); group B, with severe spastic quadriplegia, who dislocated in the absence of scoliosis (dislocation/no scoliosis); and group C, who dislocated after scoliosis had developed (disloca-

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**Table 1. Distribution of patients with quadriplegia, diplegia and hemiplegia, and the predicted numbers for the Melbourne region**

<table>
<thead>
<tr>
<th></th>
<th>Spastic</th>
<th>Athetoid</th>
<th>Total</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriplegic</td>
<td>186</td>
<td>49</td>
<td>235</td>
<td>256</td>
</tr>
<tr>
<td>Diplegic</td>
<td>79</td>
<td>13</td>
<td>92</td>
<td>231</td>
</tr>
<tr>
<td>Hemiplegic</td>
<td>131</td>
<td>4</td>
<td>135</td>
<td>262</td>
</tr>
</tbody>
</table>

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**Figure 2a** - The apex of the normal acetabulum (A). **Figure 2b** - The apex of the anteverted acetabulum lies superolaterally (B) and is not necessarily at its most lateral point.
tion/scoliosis). The radiographs from patients in whom a dislocation occurred other than in the perinatal period were then compared with radiographs from patients known not to have dislocated by maturity (group D). Radiographs were excluded if they had been taken after dislocation or after hip or spinal surgery. The groups compared were therefore: group B, dislocation/no scoliosis (63 radiographs of 18 hips); group C, dislocation/scoliosis (80 radiographs of 28 hips); and group D, no dislocation (1,360 radiographs of 392 hips). Data were also collected for group A – perinatal dislocation.

**Statistical analysis.** Data for groups B, C, and D were analysed by comparison of the ranges of radiological values at different ages. The small sample sizes did not allow statistical comparisons of individual indices by age group.

Predictive discriminant analysis (Norusis 1985) was also performed using radiological measurements to distinguish between dislocators and non-dislocators (the data from groups B and C were pooled to form a dislocator group). This method calculates the predictive power of each radiological variable and derives equations based on them, which allows each individual case to be attributed to one or other discriminant group, that is to be predicted as a dislocator or non-dislocator.

Discriminant analysis was performed using the Statistical Package for the Social Sciences (SPSS). We selected indices with low within-group correlations as discriminant factors; these were acetabular index, neck–shaft angle, and migration index. Stepwise selection of variables was used with minimisation of Wilks’ lambda, and an F-to-enter value of 1.

The probability that the calculated discriminant score belonged to either group was then calculated from the prior, conditional, and posterior probabilities, and the outcome for each case was thereby predicted.

To allow use on other populations, or when SPSS is not available, a simplified classification technique was derived in which two classification coefficients (CCd and CCn) are calculated thus: 

\[ CCd = (\text{acetabular index} \times 1.9) + (\text{neck–shaft angle} \times 1.44) - (\text{migration index} \times 0.22) - 146.5; \]

\[ CCn = (\text{acetabular index} \times 1.17) + (\text{neck–shaft angle} \times 1.37) - (\text{migration index} \times 0.29) - 113.5. \]

In this instance, if \( CCd > CCn \) then the case is classified as a dislocator; if \( CCn > CCd \) then the case is classified as a non-dislocator.

The accuracy of this method was tested on 100 radiographs from 100 patients not in the original study, 50 of whom were known to later dislocate and 50 known not to dislocate.

**RESULTS**

Dislocation occurred in 72 hips in 47 patients (10% of patients, and 9% of affected lower limbs). Dislocation after the perinatal period was almost confined to quadriplegics, the risk of dislocation arising in a patient with spastic quadriplegia being 16%. The risk increased to 33% if athetoid features were present. Although subluxation developed in both diplegics and hemiplegics, in only one patient (age one year) did it lead to dislocation.

Despite the severity of the disease, the mortality rate by age 20 of patients with dislocation (9.8%) was not significantly greater than that for the cerebral palsy population as a whole (9.2%).

We identified three populations that seem to be at risk of dislocation.

**Perinatal dislocation.** There was a high frequency of dislocation at or within two weeks of birth (group A). Nine hips out of a total of 683 in patients with cerebral palsy originating at or before birth showed a complete dislocation, demonstrated radiographically. All had pronounced acetabular dysplasia. In this group, one patient with hemiplegia had a unilateral dislocation of the affected hip. The remaining eight dislocations were bilateral, affecting two patients in whom spastic features developed, and two with athetoid features.

**Dislocation without preceding scoliosis.** Thirteen patients with spastic quadriplegia and no scoliosis were known to have dislocated between four and 11 years of age. The method of collection of data allows for a skew to the right for age up to two years. Even allowing for the maximum skew in each case, no dislocation in this group occurred outside the age range three to 11. Although no patient had a scoliosis at the time of dislocation, scoliosis subsequently developed in six (46%).

**Dislocation with scoliosis.** Twenty-five of the 76 patients known to have a scoliosis subsequently dislocated. The rate of dislocation in this group was relatively constant at all ages up to 18 years. Allowing for the maximum skew in each case, dislocation still occurred at 16 or more years of age in at least two patients.

One patient in this group (dislocation at age one
Comparison of the range of migration index by age in the patient groups. Figure 4a: Patients who dislocated without a scoliosis (group B) and those who did not dislocate (group D). Figure 4b: Patients who dislocated only if scoliosis developed (group C) and group D.

Comparison of the range of acetabular index by age in the patient groups. Figure 5a: Patients who dislocated without a scoliosis (group B) and those who did not dislocate (group D). Figure 5b: Patients who dislocated only if scoliosis developed (group C) and group D.

year) had a hemiplegia, all the remainder had tetraplegia. Sixteen of the 25 patients (64%), including all those dislocating at 14 years of age and over, had severe athetosis.

**Progression of migration and predictability of dislocation.** When the radiographic data from the three groups above were compared, there were no differences in values of the neck-shaft angle or femoral head index between the groups, although all showed a tendency to a high neck-shaft angle and low femoral head index.

The ranges of the centre–edge angle, Smith’s h/b ratio, Smith’s c/b ratio, and the migration index differed in hips that dislocated (groups B and C) and those that did not (showing progressive changes with time in patients who dislocated). The findings were much the same in all four indices, and are therefore not shown separately.

Figure 4 shows the ranges of migration index at different ages in the three groups. The group that did not dislocate (group D) showed migration index values of up to 45% at any age. The graphs for the groups that did dislocate (groups B and C) demonstrated an increasing migration index with time. In individuals, sequential radiographs showed progressive migration, and although the rate of migration varied between patients, the migration index always increased and dislocation never occurred as a spontaneous or sudden event.

Despite the differences between values for those who dislocated and those who did not, the ranges of the migration index for the groups who dislocated overlapped with the ranges of those who did not do so until the ages of eight years (group B) and 13 years (group C). The findings were much the same for the other radiographic measurements, except for the acetabular index. The predictive value of any one of these measurements taken in isolation is accordingly low.
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The ranges of acetabular index for the three groups showed more discrete differences than did the migration index (Fig. 5): the differences between groups were greater, allowing earlier identification of children who will dislocate. These graphs can be used to predict the group into which a child should be classified. Patients in group D (who did not go on to dislocate) had acetabular index values close to those of normal children (Tönnis 1976). In contrast, patients in groups B and C (who went on to dislocate) had ranges of acetabular index that were higher than normal. Acetabular dysplasia always developed well before dislocation, and its presence in every patient who dislocated suggests that it may be a prerequisite to dislocation.

Those patients without scoliosis who would dislocate unless measures were taken to avoid it could be identified, by age three to four, by plotting the acetabular index on the graph shown in Figure 5a, and attributing the case to the appropriate group; patients who would dislocate if scoliosis developed could be identified at the latest by age six to seven years, by plotting the acetabular index on the graph shown in Figure 5b. Individual cases of dislocation could always be identified at least 12 months before dislocation occurred. In some patients the index will fall into the range of both groups B and C, but this is of little practical consequence.

Predictive discriminant analysis showed the standardised function coefficients of the variables; acetabular index, neck–shaft angle and migration index to be 0.76, 0.20 and 0.28 respectively, confirming the relative importance of acetabular dysplasia as a predictor.

Table II shows the results of the discriminant analysis. Using predictive equations, dislocation was predicted in over 95% of cases from a single radiograph taken at any age between one and 11 years. The false negative prediction rate was 4.2%.

Using the simpler technique of calculating correlation coefficients, an overall accuracy of 92% was achieved, with a 10% false positive, and 6% false negative prediction rate.

(The accuracy of this method is likely to be lower than this if applied to other populations with cerebral palsy, and should always be verified against a series of patients of known outcome which is geographically and temporally similar to the study population.)

**DISCUSSION**

The patients with cerebral palsy reported here differ from those reviewed previously. A broader spectrum of disease is presented, including many cases not normally referred to orthopaedic surgeons.

The findings of other authors that dislocation occurs predominantly in severely affected quadriplegic patients was confirmed (Howard et al. 1985). Patients with athetoid features were at particular risk, especially after the age of about 10 years, and dislocation was more likely to occur if a scoliosis was present. The mortality rate in those who dislocated and those who did not was much the same, and it cannot be assumed that a patient with dislocation necessarily has a poor outcome.

Review of serial radiographs of patients with dislocation occurring after the perinatal period showed that hip dislocation developed progressively, with increasing subluxation before dislocation. Furthermore, dislocation occurred only in the presence of a dysplastic acetabulum. Adductor spasm and scoliosis did not seem to cause dislocation when the acetabulum was normal.

The high frequency of perinatal dislocation suggests that hypotonia may be important in the development of this acetabular dysplasia, particularly since increased muscle tone is rare at this age.

**Scoliosis and dislocation.** From observations of the development of dislocation relative to scoliosis, it seems that dislocation may occur either before or after scoliosis. Some patients, especially those with severe spastic quadriplegia, dislocated without preceding scoliosis. In such patients dislocation occurred at an age when spastic features of the disease were increasing, and was often followed by the development of a scoliosis. The dislocation might therefore cause the scoliosis, or both events may reflect increasing muscle tone and imbalance.

In other patients scoliosis developed first, and although the scoliosis did not necessarily cause the dislocation, it seemed to potentiate it, and allowed it to occur in the presence of less severe acetabular dysplasia than would otherwise have been the case.

**Screening procedures.** From our findings, measurement of the acetabular index seems to make possible in clinical practice the prediction of patients with cerebral palsy at risk of dislocation. The method is simple and provided radiography is done at suitable ages, it is more accurate than methods derived from discriminant analysis. The appropriate use of this latter, more complex method is to identify at-risk groups as target populations in clinical research. In this instance only a single radiograph (taken at any age from one to 11 years) is needed.

We would suggest that radiographic screening for dislocation of the hip in cerebral palsy should be performed by measurement of the acetabular index at two and four years, and the graphs shown in Figure 5 should be used to classify patients. Three groups of
patients can then be identified, corresponding to the three groups reported here:
1) patients who if untreated will dislocate with no scoliosis (group B),
2) patients that may dislocate if scoliosis develops (group C), and
3) patients who are not at risk of dislocation (group D).
Radiographs should be repeated at yearly intervals in patients in group C if scoliosis develops.
Within the study group, we were able to accurately classify all the patients who had had radiography at these ages. It should, however, be noted that the method identifies patients likely to dislocate, rather than specific hips, and both hips should be considered at risk if spasticity is bilateral.

**Treatment.** Early prediction is only useful if appropriate action is taken to avoid dislocation. Although increased understanding of the progressive nature of hip migration and dislocation and the importance of acetabular dysplasia does not tell us how to treat the condition, it does provide principles upon which to base therapeutic regimes.

Treatment should overcome muscle imbalance, but in addition it should either induce normal acetabular development or provide acetabular cover. Prophylactic treatment aimed at allowing normal development of the acetabulum should be performed early, since the ability of the acetabulum to develop normally decreases with age (Sherlock, Gibson and Benson 1985).

We suggest that release of affected structures should be performed early in cases with adductor or psoas spasm and acetabular dysplasia, but that if this treatment does not result in increased acetabular development on follow-up, operation to improve acetabular cover will be necessary.

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**REFERENCES**


