

Radiographic threshold values for hip screening in cerebral palsy

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Abstract

Purpose To analyse the consequences of using different radiographic measurements and different threshold values for hip screening in children with cerebral palsy (CP).

Methods In a total sample of children with CP a standardised radiological follow-up of the hips was carried out as a part of a hip prevention programme. Acetabular index (AI) and migration percentage (MP) were measured on all radiographs. In this study, 1,067 radiographs of 272 children born 1992–1998 were analysed.

Results Lateral displacement of the femoral head was common without acetabular dysplasia, and acetabular dysplasia occurred at a later stage than femoral head lateralisation. Hip dysplasia without lateral displacement of the femoral head was rare. In 16 of the 56 hips (29%) with $AI \geq 27^\circ$ and in 23 of the 71 (32%) hips with $MP \geq 33\%$ the values decreased below the threshold value without operative treatment. In hips with $AI \geq 30^\circ$ only 2 of 31 hips (6%) and in hips with $MP \geq 40\%$ only 5 of 44 hips (11%) decreased below the threshold values without operative treatment.

Conclusions Radiographic follow-up with only measurement of the MP seems sufficient in screening for dislocation in children with CP. $MP \geq 33\%$ is recommended as threshold for reaction or intensified observation. In children with $MP \geq 40\%$, the lateral displacement increased over time in most hips, thus indicating the need for operative intervention. In children with $MP 33\text{--}40\%$, treatment should be based on other clinical signs and the progression of MP over time.

Keywords Cerebral palsy · Children · Hip dislocation · Prevention · Radiograph

Introduction

Hip dislocation in children with cerebral palsy (CP) is preventable by radiographic screening and early preventive treatment [1, 2]. The CP hip is normal at birth. The change that occurs in the structure of the joint, either on the femoral or acetabular side, is the result of eccentric forces from spastic adductors and flexors acting on the developing hip [3]. Migration percentage (MP) [4] and acetabular index (AI) [5] are the most commonly used measurement for hip lateralisation and acetabular dysplasia in these children. However, recommended threshold values for reaction or intervention vary in the literature: for MP between 30 and 40% [1, 4, 6], and for AI between 27° and 30° [1, 7]. The reason for this variation is probably that no study of a total population of children with CP has analysed the prognostic risk of progression to dislocation in relation to the degree of femoral head lateralisation or acetabular dysplasia.

In a screening programme comprising all children with CP born in southern Sweden from 1992 the children's hips were radiographically examined from age at diagnosis, and both AI and MP were measured on all radiographs [2]. We analysed the consequences of using different threshold values in this sample.

Materials and methods

All children with CP in the study area in southern Sweden, with a population of 1.3 million, were identified and offered participation in the prevention programme [8]. In this

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study, radiographs of the children born 1992–1998 were analysed. There was a total of 283 children with CP in this age group. All but seven participated in the follow-up programme. Of the 276 children, three children died within two years of the first examination and were excluded. One boy who had a dislocated hip when he moved into the area was also excluded, making 272 children remaining for the study (Table 1).

The programme included a continuous follow-up of the child's diagnosis, gross motor function, clinical findings and treatment [9, 10]. The subtype of CP was determined according to Hagberg et al. [11]. Gross motor function was classified according to the gross motor function classification system (GMFCS) [12]. A standardised radiological follow-up of the hips was carried out [2]. The hips were examined on anteroposterior radiographs at diagnosis, then at least once a year in children with diplegic, tetraplegic or dystonic type of CP until eight years of age, then on an individual basis. Children with spastic hemiplegia or pure ataxia were examined at four years of age. If the radiograph was normal, no further examinations were undertaken, unless the clinical follow-up showed decreasing range of motion of the hips.

Migration percentage and AI were measured on all radiographs (Fig. 1). All measurements were performed by one of the authors. In hips with a *Gothic arch* formation of

the lateral margin, the midpoint of the arch was used as reference point according to Cooke et al. [7] (Fig. 2).

On 1 June 2005, 1,067 radiographs had been taken of the 272 children. The children were 6.5–13.5 years of age at latest examination. The hips with AI and/or MP exceeding different threshold values (AI 27° and 30°, MP 30, 33 and 40%) were further analysed. Only one hip in each child was included, that with the highest MP or AI. Once a hip had been operated, it was excluded from further analysis. In the analysis of the different threshold values we have used cumulative data, which means that hips with MP and AI above the higher levels are included in the number of children above the lower threshold levels.

Results

Of the 272 children, 56 (21%) developed acetabular dysplasia with AI $\geq 27^\circ$ and 81 (30%) developed lateral displacement of the femoral head with MP $\geq 30\%$. Of the 56 children with AI $> 27^\circ$, 30 (54%) reached AI $\geq 30^\circ$. Of the 81 children with MP $\geq 30\%$, 71 (88%) reached MP $\geq 33\%$ and 44 (54%) reached MP $\geq 40\%$. Most of the children with increased MP or AI had spastic diplegia, spastic tetraplegia, or the dystonic type of CP, and most of them were classified at GMFCS levels III, IV or V (Table 1).

Table 1 Number of children above different threshold values in relation to CP subtype and gross motor function classification system (GMFCS) level. Number of children in total sample for comparison

	AI $\geq 27^\circ$	AI $\geq 30^\circ$	MP $\geq 30\%$	MP $\geq 33\%$	MP $\geq 40\%$	Total material
Subdiagnosis						
Spastic						
Hemiplegia	2	0	3	2	1	88
Diplegia	32	15	44	38	21	112
Tetraplegia	11	7	15	14	12	17
Ataxic	0	0	1	1	1	12
Dyskinetic						
Athetotic	2	2	4	3	1	12
Dysthonic	9	7	13	12	7	26
Not classified	0	0	1	1	1	5
Total	56	31	81	71	44	272
GMFCS level						
I	7	2	8	7	2	127
II	5	1	6	4	3	34
III	12	6	20	17	9	34
IV	17	11	24	21	12	39
V	15	11	23	22	18	35
Not classified						3
Total	56	31	81	71	44	272

AI acetabular index, MP migration percentage

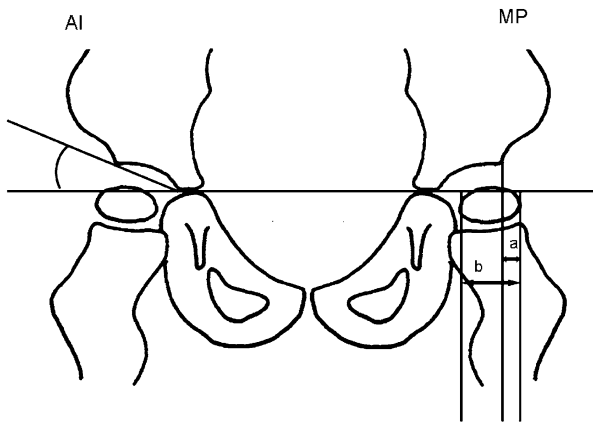


Fig. 1 Measurement of the acetabular index (AI) and migration percentage (MP; $MP = a/b \times 100$)

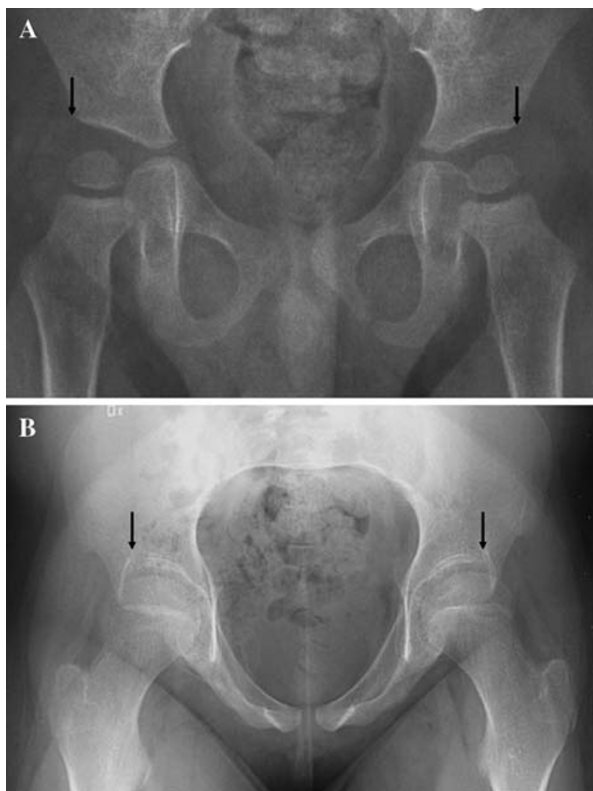


Fig. 2 The point used for measuring the lateral margin of the acetabulum (a). In radiographs with oblique view of the pelvis, the top of the Gothic arch, which corresponds to the apex of acetabulum, was used (b), and if possible repeat examination with positioning using fluoroscopy

The majority of hips with increased AI also showed an increased MP, while many hips with increased MP had an AI below 27° or 30° (Table 2).

In those hips with both increased MP and AI, the MP was most often seen earlier than, or simultaneously with, the increased AI (Table 3).

In 16 of the 56 hips (29%) with $AI \geq 27^\circ$ and in 29 of the 81 hips (36%) with $MP \geq 30\%$ the values decreased below the threshold value without operative treatment. In hips with $AI \geq 30^\circ$ only 2 of 31 hips (6%) and in hips with $MP \geq 40\%$ only 5 of 44 hips (11%) decreased below the threshold values without operative treatment (Fig. 3). Of the 16 hips with $AI \geq 27^\circ$ that decreased without operation, the decrease from the highest measured AI to the last examination (before closure of the triradiate growth plate) was on average 7.8° (range 4–14°). Of the 29 hips with $MP \geq 30\%$ that decreased without operation, the decrease from the highest measured MP to the last examination was in average 10.8% (range 3–15%).

Nonoperative treatment included intensified positioning in abduction and extension, and intensified standing in standing shells. Nonoperative treatment also included management of other problems resulting in increased spasticity as under nourishment, gastric reflux, or constipation. Sixteen children were treated with botulinum toxin of the adductor muscles. The indication for treatment was scissoring resulting in gait, sitting, or nursing problems. The numbers of treatments were one in 11 children, 1 in 2 children, four in 2 children and seven in one child. Of the 16 children, 10 had $MP < 30\%$. The MP was $\geq 30\%$ in six hips; four of these showed a decreasing lateral displacement and two increased and were operated with preventive surgery. The child with seven treatments had an $MP < 30\%$.

Discussion

The findings are based on a total population of children with CP followed until 6.5–13.5 years of age. Most of the

Table 2 Number of children with migration percentage (MP) and acetabular index (AI) above different threshold values

Threshold	Total number	AI $\geq 27^\circ$	AI $\geq 30^\circ$
MP $\geq 30\%$	81	49	31
MP $\geq 33\%$	71	45	30
MP $\geq 40\%$	44	34	25

Table 3 Time relation between MP and AI for different threshold values

	AI first	AI = MP	MP first	Total
AI $\geq 27^\circ$ and MP $\geq 30\%$	4	17	28	49
AI $\geq 27^\circ$ and MP $\geq 33\%$	5	18	22	45
AI $\geq 27^\circ$ and MP $\geq 40\%$	11	11	12	34
AI $\geq 30^\circ$ and MP $\geq 30\%$	2	10	19	31
AI $\geq 30^\circ$ and MP $\geq 33\%$	3	10	17	30
AI $\geq 30^\circ$ and MP $\geq 40\%$	6	7	12	25

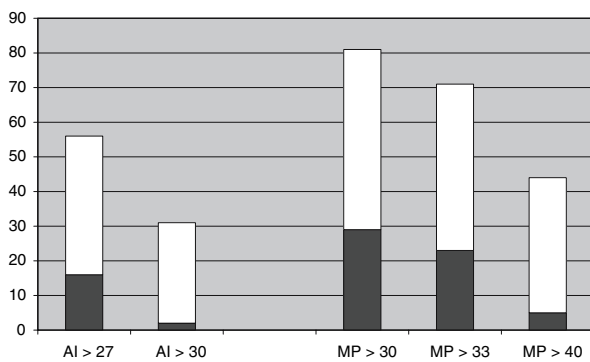


Fig. 3 Number of children with decreased AI or MP below threshold value without operative treatment. *White*: total number above the threshold value. *Black*: decreased without surgery

children had not completed growth. However, the risk of hip dislocation is highest before seven years of age [3].

Parrot et al. [13] demonstrated that an experienced rater would be expected to measure MP within 5.8% of the true value, and AI within 2.6°. Faraj et al. [14] analysed the error in the measurement of MP with less-experienced observers. The median intra-observer difference was 3.2–3.6%, and the median inter-observer difference was 3.3–5%. The upper 95% confidence interval for intra-examiner measurement was 13%, and for inter-examiner value was 22%. These two studies show that the measurement should be done by an experienced examiner and radiographs should be compared and measured by the same examiner.

It is important to have a horizontal view of the pelvis with the legs in a neutral position. A radiograph with the femur in adduction gives a false high MP; abduction gives a false low value [4]. In- or outward rotation does not influence the measurement to the same extent [4]. In children with contractures or high muscle tone it may be necessary to take the radiograph under fluoroscopic control in order to get measurable pictures.

The AI was less than 27° in 40%, and less than 30° in 60% of the hips with MP ≥ 33%. In most of the hips with both increased MP and AI, the lateralisation of the femoral head preceded the acetabular dysplasia. This is contrary to the findings by Cooke et al. [7], who stated that increased AI is always seen before lateral displacement, and recommended AI for screening purpose.

Vidal et al. [15] and Wheeler et al. [16] both observed only 3–4° correction of the acetabular dysplasia after soft-tissue release. Cornell et al. [17] found poor results in 13 of 15 hips with preoperative AI ≥ 27°. In their sample seven hips were dislocated, and six hips had MP ≥ 60% before treatment. In our sample, 42 of the 56 hips (75%) with AI ≥ 27° improved to <27°; 16 hips improved without operative treatment and 26 improved after operative treatment of which only five included pelvic osteotomy. The highest measured AI in each of these 42 hips was 29.3°

(27–36°). The remaining hips with increased AI are being followed in the prevention programme. Based on our findings, it seems that the dysplasia in most of the hips will decrease if the lateral displacement of the femoral head is corrected.

Of the hips with MP ≥ 33%, one out of three returned to <33% without operative treatment. Of the 44 hips with MP ≥ 40% five hips (11%) returned to <40% without operative treatment. The frequency of hips that decreased below the different threshold values without preventive surgery should be regarded as minimum values for non-operative improvement, as it is not known whether any of those operated on would also have improved without surgery. However, in 10 of the 39 hips with MP ≥ 40% operated on, the MP progressed even after the first operation, and a second operation was needed to regain femoral head coverage. Most of the other hips also showed increasing lateral displacement before operative treatment.

The high number of hips with decreasing AI and MP without surgery has, to our knowledge, not been described earlier. One explanation could be a more-intense nonoperative treatment of the children in the prevention programme. In some children the degree of spasticity spontaneously decreases with increasing age, which may be another explanation. The number of children treated with botulinum toxin was too small to analyse further the significance. In some hips the decrease of MP and AI is within the range of measurement error.

There are a few earlier studies with recommendations of threshold values for preventive surgery. Onimus et al. [6] found the best results in children with MP < 33%, operated at 2–3 years of age. Based on our findings this can be explained by the fact that many of those children would have a good outcome even without preventive surgery.

Cornell et al. [17] showed better results in preventive surgery in hips with MP < 40%. The authors only analysed the results after soft-tissue surgery. Of the 30 hips with MP < 40% in their sample, 26 hips had a MP of 18–33% preoperatively, only four hips had MP between 33 and 40%.

Dobson et al. [1] recommended preventive surgery in those with MP ≥ 40%, AI ≥ 27° and in those with progression of MP of more than 10% in one year.

Some studies have shown better long-term results after preventive surgery at a young age [4, 15]; others did not find any correlation of the results in relation to age at surgery [16–18]. No correlation was seen in the present sample, indicating that the same threshold values can be used regardless of age in the studied period up to 13 years of age.

It seems that MP is the measurement of choice for hip screening in CP. Lateral dislocation is common without acetabular dysplasia, and lateral dislocation often precedes

acetabular dysplasia. Acetabular dysplasia without lateral displacement of the femoral head is uncommon. MP $\geq 33\%$ is recommended as a threshold for reaction or intensified observation. Hips with MP $\geq 40\%$ have a high risk for further displacement, indicating the need for surgical intervention. In children with MP 33–40%, treatment should be based on other clinical signs and the progression of MP over time, which should be evaluated with repeat examinations analysed by the same examiner.

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