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Clinical and radiological morphometric dependences during the formation of the acetabulum among patients with cerebral palsy

Summary

Relevance. Significant incidence of hip pathology in different groups of patients with cerebral palsy and factors that may affect their formation are the actual object of the study.

The goal of the study. To establish clinical and radiological morphometric dependences influencing the formation of acetabular indices in patients with cerebral palsy.

Materials and methods. The total number of patients was 47 persons (86 joints). We examined patients using our own method (Ukrainian patent №137567), calculated the acetabular angle and Sharp's angle, as well as performed a statistical analysis of factors that may have influenced their formation.

Results. Significant inter-age differences between acetabular angle and Sharp's angle were found. Statistically insignificant differences according to the Gross Motor Function Classification System (GMFCS), gait function, level of injury, congenital hip dysplasia and myotomy of adductors in the medical history were revealed.

Conclusions. Established statistically insignificant differences may indicate that the development of the acetabulum in patients with cerebral palsy occurs independently and correlates only with age, and its pathology is evidenced by true radiographic parameters.

Keywords: cerebral palsy; hip joint; acetabulum; acetabular angle; sharp's angle

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Yatsuliak M, Nemesh M, Martsyniak S, Kabatsii M, Filipchuk V
SI "Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine", Kyiv, Ukraine

Correspondence: Yatsuliak Mykhailo Bogdanovych, postgraduate student, SI "Institute of Traumatology and Orthopedics of NAMS of Ukraine", 27 Bulvarno-Kudriavska St., Kyiv, 01061, Ukraine. Tel +38(097)2655377
E-mail myhail52368@gmail.com

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Introduction

According to the data of medical literature, pediatric orthopedists pay special attention to pathological changes of the hip joint (HJ) in cerebral palsy (CP),[1] because HJ is an important biomechanical link in the musculoskeletal system. During radiological examinations signs of a dysplasia of hip joints come to light 3-4 times more often, than among neurologically healthy children. The final formation of all elements of HJ is directly dependent on the formation of gait function and static-motor function in patients with cerebral palsy. Imbalance of muscle activity leads to decentralization and progressive violation of stability in the hip joint. These features draw the attention of researchers to the disclosure of the etiology and pathogenesis of instability of the hip joint.

Irregular muscle action causes the hips to adduct, flex and rotate internally in the hip joint that in turn leads to a violation of the centering of the femoral head with its displacement upwards and backwards. Most scientists suppose that the acetabulum, under the action of constant pressure of the femoral head that is displaced laterally and upward, is deformed and developmentally delays, due to dystrophic changes, circulatory disorders from pressure and changes in spatial relationships, up to hip subluxation and dislocation.

Some scientists claim that the pathology of the hip joints in patients with cerebral palsy is due to a dysplastic process that is congenital one. The answer to this question is given by radiological examination of a child with cerebral palsy in the first year of life and during the follow-up. But, unfortunately, very few specialists prescribe hip radiography for children with suspected cerebral palsy in the first year of life. This prompted us to study in more detail the factors that may affect the formation of the acetabulum in the frontal plane, namely the acetabular angle and the Sharp's angle, obtained using our own method relative to age norms.[2]

The aim of the study was to establish clinical and radiological morphometric relationships that affect the formation of the acetabulum's indices among the patients with cerebral palsy.

Materials and methods

Our study is based upon the analysis of clinical cases (47 patients, 86 joints) treated in the Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine for pathology of the hip joints in cerebral palsy during the 2018-2020. The gender of the patients was not taken into account, as previous studies did not report significant inter-sex differences.[3] No patient had a history of bone surgery.

We studied various factors that may affect the formation of the acetabulum's parameters: age, Gross Motor Function Classification System (GMFCS),[4] the level of injury (paraparesis, tetraparesis, hemiparesis), ambulatory status (ambulating, non-ambulating), myotomy of adductors and congenital dysplasia in the medical history.

The age of patients ranged between 3-30 years: up to 4 years (5 patients), 4-6 years (10 patients), 7-9 years (10 patients), 10-12 years (8 patients), 13-16 years patients), 30 years (1 patient). According to the GMFCS scale level II was observed in 11 patients, level III – in 16 patients, level IV - in 12 patients. The sample in this study consisted mainly of patients with spastic tetraparesis (30 patients), paraparesis (9 patients) and hemiparesis (8 patients).

Each acetabulum was evaluated separately, in patients with hemiparesis only the affected side was taken into account. 33 of our patients were ambulating, and 14 patients did not ambulate at the time of the examination, but were considered promising in terms of verticalization, or gait function was lost due to spastic hip dislocation. In 8 patients myotomy of adductors was performed according to

the medical history. Hip radiographs were preserved in 15 patients at the age 3 months: 8 patients were diagnosed with developmental dysplasia of the hip (DDH), 7 patients were born with healthy hips.

Data on whether DDH was treated before the age of one year were not taken into account due to their absence. In order to avoid irradiation of healthy children, the norms were taken from Kutsenok Ya.B. (Table 1).[5] In this study, we analyzed two parameters of the acetabulum: the acetabular angle and the angle of acetabular inclination (Sharp's angle).

Table 1 Normal indicators of acetabular angle and angle of acetabular inclination (Sharp's angle) relative to age according to Kutsenok Ya.B

Age	Up to 4	4-6	7-9	10-12	13-16
Acetabular angle	17.2±0.45	17.3±0.27	16.45±-0.47	14.23±0.76	14.23±0.76
Angle of acetabular inclination (Sharp's angle)	46.88±0.61	45.76±0.31	44.79±-0.81	47.51±0.43	49.31±0.57

All patients underwent a radiograph (posterior anterior view) of the hip joints using our own method, when the true parameters of the hip joint were received.[2] The absence of significant differences in the acetabular parameters (p>0.05) is described in our previous works (Figure 1).[6]

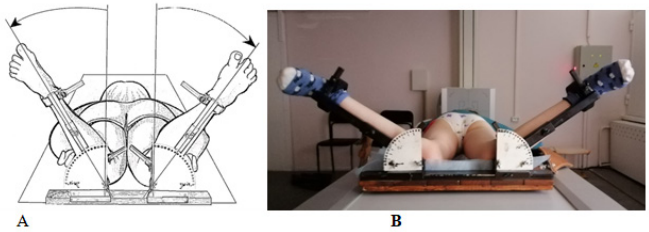

Figure 1 (A, B) The method of determining the clinical and radiographic parameters of the hip joint in patients with pathology of the abovementioned joint[7] (positioning the patient and fixation with an orthopedic console.[8,9]).

The study presents the results of the analysis in the form of distributions of clinical parameters (%), arithmetic mean and standard deviation (M ± SD). Comparison between groups was performed by analysis of variance (ANOVA). The statistical package STATA 14 was used for analysis.

Results and discussion

Conditionally radiographic indices of HJ can be divided into those that characterize in isolation the acetabulum (acetabular angle and Sharp's angle), thigh (femoral neck-shaft angle and torsion of the thigh) and indices that characterize the relationship between the thigh and acetabulum (Reimer's migration index and Wiberg angle). The subject of this study was the parameters of the hip joint in patients with cerebral palsy. We analyzed the acetabular and Sharpe's angle depending on various factors to demonstrate how they affect their development. Most patients had stable hips and were able to ambulate. 30 thighs had a migration rate >33%.

In the comparison of groups of patients by age the acetabular angle in 41 joints (47.67%) the average values of M=14.3±6.0 were within normal limits, 45 joints (52.33%) had M=24.5±6.2 and there was an increase of acetabular angle. In non-increased and increased acetabular angles (p<0,05) significant inter-age differences were observed (Figure 2). Regarding the Sharp's angle in 31 joints (36.05%), the average values of M=44.9±3.4 were within normal limits, 55 joints (63.95%) had M=52.1±3.2 and there was an increase of Sharp's angle. With non-increased Sharp's angle (p>0.05, p=0.7171) the inter-age difference was statistically insignificant, with increasing angle (p<0.05) there were significant differences between groups (Figure 3).

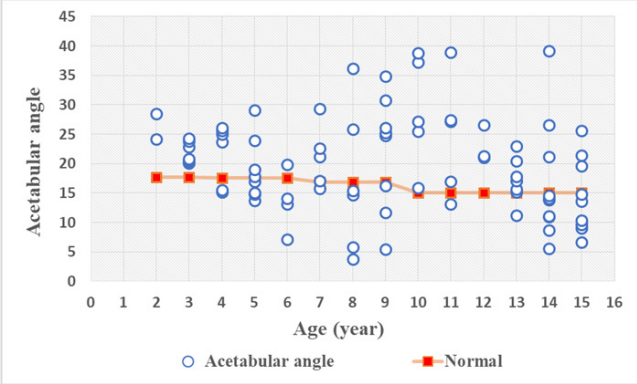

Figure 2 Dot plot of acetabular angle and age in patients with cerebral palsy. In 47.67% of patients the angles were within the age norms.

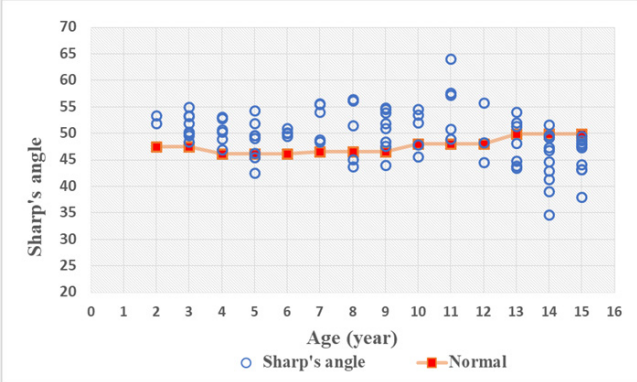

Figure 3 Dot plot of Sharp's angle and age in patients with cerebral palsy. There is an increase of the angle in the younger and middle-aged groups.

In comparison with groups of patients according to GMFCS (II, III, IV) regarding acetabular angle in 35 joints (43.75%) (II level - 20 joints (83.33%), III level - 10 joints (31.25%), IV level - 5 joints (20.83%)) average values of M=14.4±6.5 were within normal limits, in 45 joints (56.25%) (II level - 4 joints (16.67%), III level - 22 joints (68.75%), IV level - 19 joints (79.17%)) average values of M=24.5±6.2 and an increase of acetabular angle was observed. With normal acetabular angle and its increase (p>0.05), the inter-group difference was statistically insignificant. In Sharp's angle in 27 joints (33.75%) (II level - 12 joints (50.0%), III level - 12 joints (37.5%), IV level - 3 joints (12.5%)) average M=44.6±3.5 was within normal limits, in 53 joints (66.25%) (II level - 12 joints (50.0%), III level - 20 joints (62.5%), IV level - 21 joints (87.5%)) M=52.2±3.2 and an increase of the Sharp's angle was observed. In the normal Sharp's angle and in its increase (p>0.05), the difference between the groups was statistically insignificant.

When dividing patients into tetraparetic, paraparetic and hemiparetic ones, regarding acetabular angle in 41 joints (47.67%) (tetraparesis - 25 joints (41.67%), paraparesis - 8 joints (44.44%), hemiparesis - 8 joints (100%)) average values of M=14.3±6,0 were within normal limits, in 45 joints (52.33%) (tetraparesis - 35 joints (58.33%), paraparesis - 10 joints (55.56%), hemiparesis - 0 joints

(0%)) M=24.5±6.2 and an increase of acetabular angle was observed. In non-increased acetabular angle (p>0.05) and in its increase, the difference between the groups was statistically insignificant. Regarding Sharp's angle in 31 joints (36.05%) (tetraparesis - 21 joints (35.0%), paraparesis - 6 joints (33.33%), hemiparesis - 4 joints (50.0%)) average M=44.9±3.4 was within normal limits, in 55 joints (63.95%) (tetraparesis - 39 joints (65.0%), paraparesis - 12 joints (66.67%), hemiparesis - 4 joints (50.0%)) M=52.1±3.2 and an increase of the mentioned angle was observed. In the normal Sharp's angle and in its increase (p>0.05), the difference between the groups was statistically insignificant.

In comparison with groups of patients according to outpatient status (ambulating, non-ambulating) regarding the acetabular angle in 41 joints (48.81%) (ambulating - 36 joints (62.07%), non-ambulating - 5 joints (19.23%)) M=14.3±6.0 was within normal limits, in 43 joints (51.19%) (ambulating - 22 joints (37.93%), non-ambulating - 21 joints (80.77%)) M=24.6±6.4 and an increase of acetabular angle was observed. In non-increased acetabular angle and in its increase (p>0,05) the difference between groups was statistically insignificant. In Sharp's angle of 31 joints (36.90%) (ambulating - 28 joints (48.28%), non-ambulating - 3 joints (11.54%)) M=44.9±3.4 was within normal limits, in 53 joints (63.10%) (ambulating - 30 joints (51.72%), non-ambulating - 23 joints (88.46%)) M =52.1±3.2 and an increase of angle was revealed. In the normal Sharp's angle and in its increase (p>0.05), the difference between the groups was statistically insignificant.

In comparison with groups of patients who had a medical history of adductor myotomy and patients who did not have it in 39 joints (46.43%) (myotomy of adductors - 7 joints (43.75%), no myotomy - 32 joints (47.06%)) M=14.7±6.0 was within normal limits, in 45 joints (53.57%) (myotomy of adductors - 9 joints (56.25%), no myotomy - 36 joints (52.94%)) M=24.5±6.2 and an increase of acetabular angle was observed. In non-increased acetabular angle and in its increase (p>0,05) the difference between groups was statistically insignificant. In Sharp's angle of 29 joints (34.52%) (myotomy of adductors - 12 joints (75%), no myotomy - 17 joints (25%)) average values of M=45.0±3.5 were within normal limits, in 55 joints (65.48%) (myotomy of adductors - 4 joints (25%), no myotomy - 51 joint (75%)) M=52.1±3.2 and an increase of angle was observed. In the normal Sharp's angle and in its increase (p>0.05), the difference between the groups was statistically insignificant.

In comparison with groups of patients who have confirmed developmental dysplasia of the hip DDH(developmental dysplasia of the hip or healthy joints at birth) regarding the acetabular angle of 10 joints (36.04%) (DDH - 2 joints (13.33%), healthy persons - 8 joints (66.67%)) M=16.3±2.7 was within normal limits, in 17 joints (62.96%) (DDH - 13 joints (86.67%), healthy persons - 4 joints (33.33%)) M=22.5±3.9 and an increase of acetabular angle was observed. In non-increased acetabular angle and in its increase (p>0,05) the difference between groups was statistically insignificant (Figure 4). In Sharp's angle in 6 joints (22.22%) (DDH - 2 joints (13.33%), healthy persons - 4 joints (33.33%)) M=46.9±2.1 was within normal limits, in 21 joints (77.78%) (DDH - 13 joints (86.67%), healthy - 8 joints (66.67%)) M=51.6±2.6 and an increase of angle was observed. In the normal Sharp's angle and in its increase (p>0.05), the difference between the groups was statistically insignificant (Figure 5).

It should be noted that we did not conduct a total screening of different age groups of patients with cerebral palsy, but performed examination of the hip joints of patients who were admitted to the Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine for specialized care. If in the younger age groups the majority of patients did not ambulate independently, but were considered as promising in terms of verticalization, then in the older age groups the patients who could ambulate independently prevailed. Severe forms of cerebral palsy in patients from older age groups were less prevalent, which may provoke a discussion about the reliability of the interpretation of parametric analysis. In all groups, we presented the hip joints regardless of divisions and influencing factors.

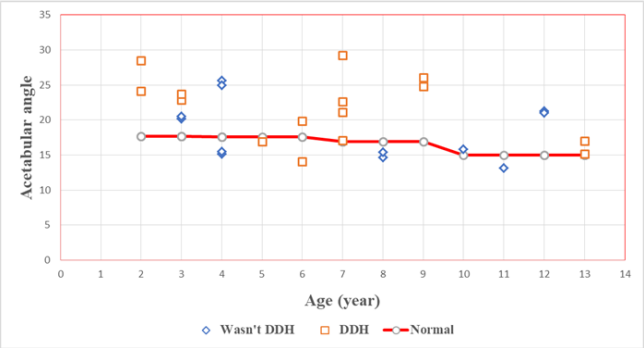

Figure 4 Dot plot of acetabular angle and age in patients with cerebral palsy who underwent radiographs of the hip joints before the age 1 year and it is well known whether they had developmental dysplasia of the hip, or children were born with healthy joints.

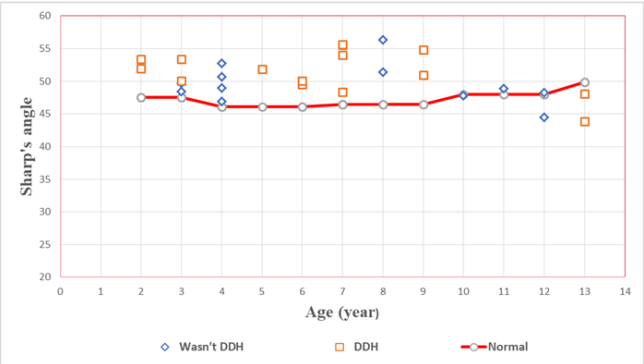

Figure 5 Dot plot of Sharp's angle and age in patients with cerebral palsy who underwent radiographs of the hip joints before the age 1 year and it is well known whether they had developmental dysplasia of the hip, or children were born with healthy joints.

Significant differences between the age groups of increased acetabular angle and Sharp's angle may indicate significant variability of parameters. As the number of examined patients increases, the data will be updated. Increased acetabular angle and Sharp's angle in the studied patients with cerebral palsy were more often observed in younger and middle-aged groups, when, according to the literature, there is a greater risk of spastic dislocation of the femoral head.

No differences were found between groups of patients according to GMFCS (II, III, IV), as well as according to the level of lesion (tetraparesis, paraparesis, hemiparesis) regarding acetabular angle and Sharp's angle. The indices of the acetabulum were either normal or increased. In the comparison of groups of patients according to ambulatory status (ambulating, non-ambulating) no differences were found between groups of patients regarding acetabular angle and Sharp's angle. In our opinion, gait function has a great importance for the formation of hip joints in patients with cerebral palsy, but we did

not find any effect of ambulation upon the acetabular indices in the frontal plane. This may indicate that the ability to move, as well as the severity of the form of cerebral palsy do not affect the formation of the acetabulum.

Analyzing the acetabular angle and Sharp's angle of patients with cerebral palsy who had a history of adductor myotomy and patients who did not have it, we did not find any difference between the groups. The purpose of surgery on the muscular system (in this case, myotomy of adductors in cerebral palsy) is to weaken the abductor muscles and redistribute the forces of antagonists (change the levers' relationship). This can be explained by the decrease in the incidence of spastic hip dislocation among patients with cerebral palsy after performing this surgery. One uses exclusively clinical indications for adductor myotomy, often without taking into account the bone pathology of the hip joint. Our studies show that adductor myotomy does not affect the development of the acetabulum in patients with cerebral palsy.

We found no statistically significant differences when analyzing acetabular angle and Sharp's angle in groups of patients with congenital dysplasia and patients born with healthy hips confirmed by radiographs of the hip joints in infancy. Acetabular angle was within the upper limit of the age norm, or increased in all age groups, and Sharp's angle was increased in the younger and middle-aged groups, and in the older age groups was within the normal range, regardless of whether congenital hip dysplasia was present. These data may provoke discussion due to the small sample size, as well as the lack of data on whether congenital dysplasia was treated before the age of one year.

If we take into account the fact that in half of the studied joints (52.33%) the acetabular angle was increased, and Sharp's angle was above the age-related norm in 63.95%, congenital hip dysplasia in patients with cerebral palsy was much more common than we can prove using radiographs of the hip joints at the age below 1 year, as the analyzed factors do not directly affect the development of the acetabulum. Sharp's angle in the younger age groups has always been increased with a trend to decrease during growth.

Based on studies of the mathematical model of the hip joints, when evaluating a large number of options, problems in spastic hips are caused by two specifically different elements: too much support's reaction force (in the contact zone of the head and cavity) and a force vector in the wrong direction in spastic hip affecting development of the acetabulum.[10] This phenomenon is due to the peculiarities of the position of the spastic hip: flexion, adduction and internal rotation, as well as the inclination of the pelvis. Therefore, the maximum load falls upon the posterior edge of the acetabulum, which is often poorly developed in cerebral palsy.[11] The pathological change in the parameters of the acetabulum in the frontal plane will depend more on congenital dysplasia of the hip joints. Therefore, when choosing therapeutic tactics the exact radiographic parameters should take into account.

Conclusions

The lack of interrelations between clinical data and angles that in isolated ways characterize the acetabular inclination in the frontal plane makes it impossible to use the acetabular and the Sharp's angle as prognostic factors.

Acknowledgments

None.

Conflicts of interest

The authors declare the absence of a conflict of interest during the preparation of this paper.

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