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Clinical and radiographic results of multilevel surgical interventions for hip subluxation and dislocation in children with cerebral palsy

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Introduction The purpose of this work was to study the results of orthopedic correction performed according to the principles of one-stage multilevel surgical intervention in cerebral palsy patients with hip dislocation. **Material and methods** We studied the results of operative orthopedic treatment in 50 children suffering from cerebral palsy (GMFCS levels IV and V, mean age 6.2 ± 1.4 years at the beginning of treatment) who underwent multilevel interventions with the purpose of hip joint reconstruction and correction of other orthopedic complications of cerebral palsy in the knee and foot. The parameters of the orthopedic status were studied as well as such radiographic data as the Reimers index, acetabular index, acetabular frontal depth index, projection neck-to-shaft angle, Wiberg index, tibiotalar angle, angle of the talocalcaneal divergence in the sagittal and frontal planes, coverage of the head of the talus with the navicular bone. The mean follow-up period was 2.8 ± 1.7 years. **Results** Patients underwent 91 reconstructive interventions during the study period involving 461 surgical elements (5.07 per operation on average). The goals of the pathology correction were achieved in all cases. In all patients, by the end of the first year after the operation, hip abduction was more than 30 degrees and flexion was more than 100 degrees. Comfortable sitting posture and correct passive symmetrical verticalization, pain relief in everyday life were reported in all cases. The shape and position of the foot made it possible to use comfortable regular footwear during verticalization, as well as during walking. By the end of the second follow-up year, a decrease in hip abduction to 20 ° was detected in only two patients. In two cases, a partial recurrence of foot valgus was observed which occurred by axial limb loading and required the use of an orthotic appliance. All radiological indicators examined after the treatment remained within the limits of normal values during the follow-up period. But there was a mild tendency to reduction of hypercorrection achieved which was within the normal boundaries. **Conclusion** Multilevel operations in children with severe types of cerebral palsy and hip dislocation as the leading pathology are aimed at achieving correction of all orthopedic problems in the lower limbs. The result of such interventions is not only normal anatomical parameters but also the creation of conditions for rehabilitation measures, especially postural management, which is extremely important for normal hip joint development and prevention of hip subluxation and dislocation recurrence in children.

Keywords: cerebral palsy, hip dislocation, one-stage multilevel orthopedic surgery

INTRODUCTION

By definition of Russman B.S. et al. (1997), cerebral palsy (CP) is a static encephalopathy characterized by impairment of movement and posture control, appearing in early life due to brain damage, diseases or dysfunction but not due to progressive or degenerative brain disorders [1]. Domestic authors use the term "cerebral palsy" for a group of disorders of movements and posture, causing activity limitations which are due to non-progressive lesions of the brain in a developing fetus or child [2].

Cerebral palsy is the most common cause of motor disorders in childhood [3, 4]. Hip dislocation in patients with severe spastic CP types (corresponding to levels IV and V according to the Gross Motor Function Classification System - GMFCS [5]) is one of the most common and very serious complications [4, 6–9]. The incidence of hip dislocation in severe spastic CP types (GMFCS levels IV and V) varies from 33 to 70 % [8, 10, 11]. This condition is accompanied by a decrease in functional abilities, loss of passive verticalization capability, lack of conditions for a comfortable sitting posture, and predisposition to early coxarthrosis accompanied by severe pain [9, 11, 12].

Orthopedic disorders at the level of the hip joint are accompanied by pronounced contractures of the knee and ankle joints, foot deformities that significantly reduce the functional abilities of the child, impede his/her passive verticalization and use of shoes, which in turn worsens the quality of life [4, 13–15]. We believe that the principle of multilevel orthopedic interventions should be used in management of orthopedic pathology in children with severe motor impairment (GMFCS levels IV and V) where the main element is reconstructive surgery on the hip joint, but combined with mandatory correction of concomitant knee and foot orthopedic problems.

The purpose of this study was to analyze the results of correction of orthopedic disorders performed in patients with femur dislocation according to the principles of multilevel one-stage surgical intervention.

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MATERIAL AND METHODS

We studied the results of operative orthopedic treatment in 50 children (spastic diplegia, GMFCS levels IV and V, mean age of 6.2 ± 1.37 years at the beginning of treatment). The inclusion criteria were the following:

– Patients with cerebral palsy (GMFCS levels IV and V) operated on for hip dislocation;

– Surgery was carried out in two or more anatomical areas for correction of orthopedic pathology in knee and/or ankle joint and foot;

– Patients not older than 9 years of age;

– Hip joint reconstructive interventions were performed;

– Follow-up not less than 2 years.

Cases that do not meet the above listed criteria were not included in the study.

In assessing the orthopedic status, in addition to clinical findings (contractures in the joints of the lower limbs, foot deformities, ability to acquire comfortable passive sitting and standing postures), the following radiographic parameters were taken into account: the Reimers index, the acetabular index (AI), the index of the frontal acetabular depth (IfAD), the projection NSA, the Wiberg index. Radiography was performed in all patients before and after surgical treatment in standard positions with neutral hip rotation (if possible) and taking into account flexion contractures in the hip joints (if any) [16, 17]. Radiography of the feet under axial loading was performed if surgical interventions in the foot were indicated. The following X-ray parameters were taken into account: the tibiotalar angle (TTA), the angle of the talo-calcaneal divergence in the sagittal and frontal planes (sTCD, fTCD), the degree of coverage of the head of the talus with the navicular bone (%).

The obtained quantitative data were subjected to statistical processing using the AtteStat 13.1 software (Russia). The statistical study included descriptive statistics: mean values (M) and standard deviations (SD). Comparative studies were performed using the Student's and Wilcoxon's tests for paired samples (to test the differences in paired changes between two samples, including the verification of the equality of the means, before treatment and at long-term follow-up). The difference in the measurement of values between the researchers was evaluated using the coefficient of variation. Differences were considered statistically significant for $p \leq 0.05$.

RESULTS

Surgical interventions were carried out in the period between 2012 and 2015. The mean follow-up period was 2.8 ± 1.7 years.

In view of orthopedic complications developed due to cerebral palsy, all patients experienced severe difficulties in achieving a comfortable sitting posture. Passive verticalization under limb loading with the use of front or rear vertical stabilizers was impossible in all patients. Nineteen children (38 %) experienced pain in hip joints during standard manipulations of daily life; 39 patients (78 %) had difficulties to wear shoes.

Table 1 presents orthopedic pathologies in children for which surgical correction was required

The pathology that required surgical correction, as a rule, was bilateral, which predetermined two-stage surgical treatment. In bilateral hip dislocations, surgical intervention was performed sequentially on both extremities; in unilateral hip dislocation, reconstructive intervention was performed on the affected hip joint but corrections on soft tissues and foot were bilateral. Elements of surgical interventions are presented in Table 2.

Table 1

Lower limb orthopaedic disorders

Orthopaedic disorder	Number of cases/segments
Bilateral hip dislocation	31 / 62
Unilateral hip dislocation	19 / 29*
Bilateral flexion adduction contracture of the hip	45 / 90
Adduction contracture in one and abduction contracture in the other hip joint (breeze symptom)	5
Knee flexion contracture	32 / 64
Ankle joint contracture due to triceps/gastrocnemius muscle retraction	23 / 46
Foot flat valgus	34 / 68
First toe valgus more than 25°	12 / 19
Varus equinus foot deformity	8 / 14

Note: * including 10 cases requiring deformity correction of the proximal femur to improve postural management

Table 2

Elements of surgical interventions

Surgical element	Number
Detorsion varus osteotomy	91
San Diego acetabuloplasty	40
Triple osteotomy of the pelvis	2
Lengthening of femoral adductors	95
Lengthening of knee flexors	64
Patella lowering	21
Lengthening of triceps	81
Shortening of the tendon of the posterior tibial muscle	10
Subtalar arthrodesis by Grice	32
Correction of 1st toe valgus	19
Medial release of the foot	6
Total	461

In cases of bilateral dislocation, the interval between the operations was 38.1 ± 25.8 days. In a unilateral subluxation of the femur, but with bilateral valgus deformity and abnormal anteversion of the neck, the derotation-varus osteotomy on the contralateral femur was performed in nine of 19 cases, including 5 cases with a "breech" symptom. The interval between operations in such cases was 9.7 ± 3.3 months. This intervention was performed to improve postural management, even if the Reimers index values were less than 30 %. In another case, the derotation varus osteotomy of the femur was performed one year after the first intervention in connection with the development of subluxation of the initially correctly centered fmur.

Thus, 91 reconstructive procedures were performed during the observation period, containing 461 surgical elements (on average, 5.07 elements per operation). We should also add that lengthening of the iliopsoas muscle was an obligatory component in the correction of subluxation or dislocation of the femur.

In the early postoperative period, the use of A-shaped plaster immobilization and locking osteosynthesis elements allowed us to perform early postural management: verticalization, a symmetrical posture in standing, sitting, lying, and prone positions. After removal of the plaster bandage (on average, after 6 weeks), we carried out verticalization and postural management using orthotic products (application for invention No. 2017104934 "Abduction rotational system", priority of February 15, 2017, Tomov AD, Popkov D.A., Churakov MV, Volsky GB, Mazaev MS, **Fig. 1**) that are able to keep the lower limbs in the required position.

All surgical interventions ran without complications. Transfusion of erythrocyte mass was performed in 42 cases (46.2 %), during the operation in 7 cases and in the remaining within the first 24 hours after the intervention. Planned goals of surgical interventions to correct orthopedic CP complications in patients of this sample were achieved.

Parameters of radiological examination of hip joints before and after surgery, as well as their dynamics after one and 2 years are presented in Table 3.

In general, all radiologic parameters after surgical treatment remained within the normal values during the follow-up period. But there was a weak tendency to reduction in hypercorrection, not exceeding the limits of the norm (**Fig. 2**).

X-ray dynamics in foot parameters for which the interventions were performed are presented in Table 4.

Thus, all radiographic parameters of both hip joints and feet remained within the normal values for the entire observation period. But there was a weak tendency to reduction of the achieved hypercorrection, not exceeding the limits of the norm.

In all cases, by the end of the first year after surgery, the amplitude of the hip abduction was more than 30º, flexion was more than 100º. Comfortable sitting posture and correct passive symmetrical verticalization, pain relief in everyday life were observed in all cases. The shape and position of the foot made it possible to use comfortable regular footwear at verticalization, as well as during walks.

By the end of the second follow-up year, we detected a decrease in the amplitude of hip abduction to 20° in two patients. In another two cases, a partial relapse of foot valgus was observed, which occurred with axial load of the limbs, which required the use of additional orthotic appliances by passive verticalization (**Fig. 3**).

It should be noted that we observed an external hip torsion in 1 case after a year, which required correction. Intervention (intramedullary elastic reinforcement with titanium rods) was also performed for femoral fracture which occurred at the level of the distal screw of the plate six months after reconstructive intervention. Additional surgical interventions made it possible to fully preserve the treatment outcome.

Fig. 1 Examples of the use of the abduction rotating system: **a** – use of orthosis in the "breeze" symptom, a module that limits the pathological hip abduction; **b** – orthosis for the position in the hip, knee and ankle joints

Table 3

Coxometry parameters

Parameter	Before intervention	After intervention	1-year follow-up	2-year follow-up
Reimers index; %	73.9 ± 15.9	4.2 ± 7.3	3.5 ± 5.8	10.4 ± 8.9
AI; °	29.3 ± 8.9	20.4 ± 6.7	18.2 ± 6.1	20.8 ± 3.8
IfAD	5.4 ± 1.1	4.4 ± 0.25	4.5 ± 0.9	4.6 ± 0.4
NSA; °	160 ± 13.2	118.6 ± 11.4	123.6 ± 8.4	131.1 ± 17.0
Wiberg index; °	–	33.8 ± 6.9	35.7 ± 7.1	31.5 ± 8.6

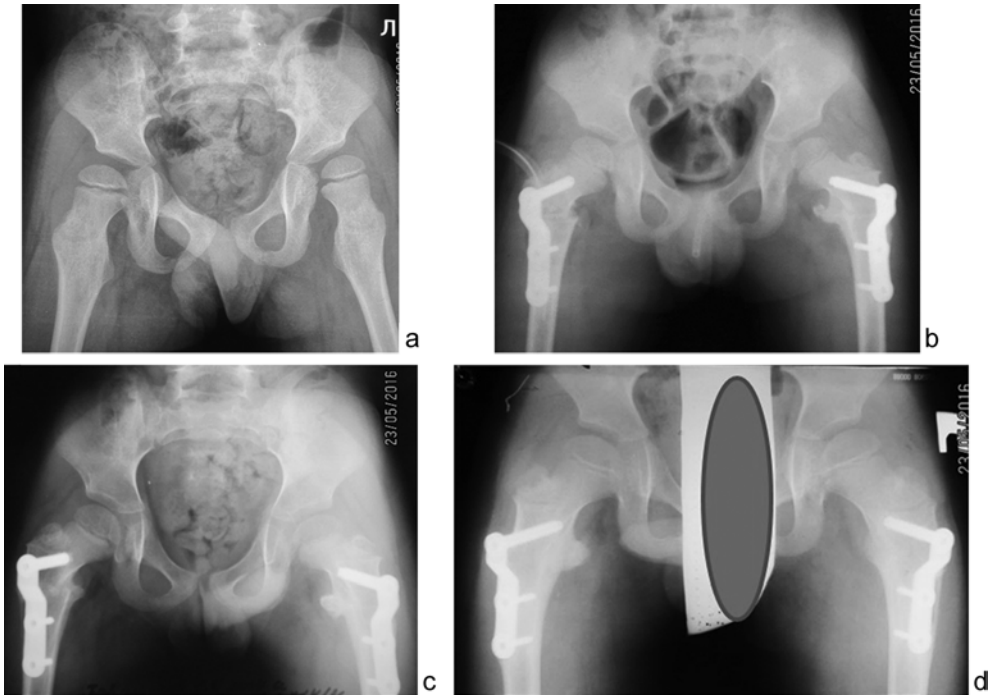

Fig. 2 Radiographies of the pelvis: **a** – before surgery (Reimers index 44 % (right), 52 % (left); AI 29° (right), 28° (left); NSA 162° (right), 170 ° (left); **b** – after derotation-varus osteotomies (Reimers index 12 % (right), 14 % (left); AI .29° (right), 28° (left); NSA 127° (right), 128° (left); Wiberg index 31° (right), 23° (left); **c** – after 1 year (Reimers index 25 % (right), 14 % (left); AI 28° (right), 29° (left); NSA 133° (right), 134° (left); Wiberg index 24 (right), 22° (left); **d** – after 2 years (Reimers index 25 % (right), 22 % (left); AI 24° (right), 26° (left); NSA137° (right), 133° (left), Wiberg index 22° (right), 21° (left)

Table 4

Radiographic foot parameters (M ± SD)

Parameter	Before surgery	After surgery	After 1 year	After 2 years
TTA; °	128 ± 8.4	102.3 ± 6.8	99.8 ± 5.5	96.8 ± 6.3
sTCD; °	37.3 ± 6.3	20.0 ± 5.1	19.5 ± 3.2	18.2 ± 5.4
fTCD; °	41.7 ± 5.9	26.3 ± 4.0	25.5 ± 4.3	25.8 ± 3.4
% talar head coverage	59.5 ± 5.6	94.5 ± 4.8	90.8 ± 2.2	87.7 ± 3.9

Fig. 3 Patient P., 8-year old at the beginning of treatment, GMFCS level IV: **a** – standing posture before treatment, asymmetric; **b** – hip abduction before treatment, less than 30°; **c** – foot shape before treatment, valgus of the posterior part; **d** – radiograph of the pelvis before treatment (Reimers index 52 % (right), 75 % (left), AI 28° (right), 35° (left), NSD 150° (right), 154° (left); **e** – after derotation varus osteotomies and acetabuloplasty (Reimers index 24 % (right), 18 % (left), AI 26° (right), 22° (left), NSA 119° (right), 122° (left); Wiberg index 14° (right), 24° (left); **f** – after 1 year (Reimers index 14 % (right), 13 % (left), AI 23° (right), 23° (left), NSA 115° (right), 129° (left), Wiberg index 17° (right), 23° (left); **g** – after 2 years (Reimers index 8 % (right), 5 % (left), AI 18° (right), 20° (left), BSA 124° (right), 132° (left), Wiberg index 27° (right), 33° (left)

Continuation Fig. 3 Patient P., 8-year old at the beginning of treatment, GMFCS level IV: **h** – radiography of the feet before surgery, TTA 112° (right), 120° (left), sTCD 50° (right), 54° (left); **i** X-ray of the feet after the intervention, TTA 105° (right), 116° (left), sTCD 35° (right), 36° (left); **j** – 1 year after treatment, TTA 108° (right), 94° (left), sTCD 26° (right), 34° (left); **k** – 2 years after treatment, TTA 87° (right), 105° (left), sTCD 27° (right), 36° (left); **l** – standing posture, symmetrical, comfortable; **m** – abduction in the hip more than 30°; **n** – no foot deformity

DISCUSSION

Interventions for hip dislocation in CP children are aimed at elimination of mal-position in the hip joint, increase in the range of motions, facilitation of hygienic procedures, need to prevent the development of early coxarthrosis with severe pain due to spasticity and, thus, to achieve the ability to sit alone or with somebody's assistance, possibility of verticalization and axial load on the lower limbs in order to prevent the progression of osteoporosis, and, in some cases, the ability to walk with the help of support aids [18–20].

The optimal age for reconstructive interventions is the age between 5 to 7 years, when the potential for remodeling the acetabulum and proximal femur after femoral head reduction is still high, and the progression of the reduction in the amplitude of joint movements is not yet so rapid [19–22]. In the case of subluxation and hip dislocation, an early (at age of 3–9 years) reconstructive surgery performed on soft tissues [23–25] or corrective osteotomy of the femur combined with an intervention on the tendons and muscles with different variants of osteotomy of the pelvic bones [19, 26–31], remains effective. It was this tactic selected for treatment of CP patients with the pathology of hip joints included in the study.

However, due to the systemic nature of the lesions in cerebral palsy, hip joint pathology is a serious but not the only its component [14, 15, 32, 33]. Interventions are also required in the area of the knee joint, ankle joint, and foot for the purposes of improving the sitting posture, verticalization, foot loading and the possibility to use comfortable footwear during verticalization and walks in the wheelchair [14, 15, 34, 35]. In our study, all patients required interventions in two or more anatomical areas, including the reconstruction of the hip joint: 91 reconstructive procedures were performed, containing 461 surgical elements (an average of 5.07 per operation).

It is known that hip dislocation in CP children is accompanied by contractures and pain [36], sitting posture disorders and the inability of active and passive standing postures [37]. Jung N.H. et al. [38] showed a direct correlation between the degree of lateralization of the femoral head (Reimers index) and the deterioration in the quality of life in CP children studied with the Caregiver Priorities and Child Health Index of Life with Disabilities [39]. It has been shown that reconstructive hip joint interventions in severe CP types improve the quality of life of children in regard to pain and conditions for mobility, movement, and care [19].

The results of our study confirm the findings of the previous studies that showed that reduction of hip dislocation improves the conditions for verticalization of patients and increases the range of movements in the hip joint. Nevertheless, we find it important and necessary to simultaneously eliminate flexion contractures of the knee joint and foot deformities for both restoring favorable conditions to achieve passive symmetrical verticalization with axial loading on the lower limbs and for improving the quality of life of such patients. Compliance with the principle of simultaneous multilevel interventions in children suffering from severe CP types with hip dislocation is preferable [24, 25]. It is these conditions that ensure correct, comfortable postural management, kinesiotherapy and create favorable conditions for the development of the hip joint in the process of child's growth. In all our cases, the radiographic parameters of the coxometry remained within the limits of normal values allowing a sufficient range of motion in the hip joint.

CONCLUSIONS

Multilevel operations in children with severe CP where the leading sign of the pathology is hip dislocation are aimed at achieving correction of all orthopedic problems in the lower limbs. Such interventions should result not only in the achievement of normal anatomical parameters, but also in creation of conditions for the implementation of rehabilitation measures, especially postural management, which is extremely important for the normal development of the hip joint and prevention of recurrent hip subluxation and dislocation.

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