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Reconstruction surgery for dislocated hips in children with cerebral palsy

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Introduction The article is a literature review focusing on reconstruction surgery for dislocated hips in children with cerebral palsy (CP). **Material and methods** Publications in Scopus, PubMed, RSCI indexed journals over the past 20 years were reviewed for hip dislocation in children with CP. **Results and discussion** The article discusses the prevalence of the orthopaedic complication of cerebral palsy, pathogenesis, diagnosis, indications to surgery, choice of surgical technique, early rehabilitation and long-term outcomes. A report made for the first educational meeting of the European Pediatric Orthopaedic Society held in Russia at the Ilizarov Center in 2021 was used for the contribution. **Conclusion** Surgical treatment is indicated for hip dislocation in children with CP using holistic approach and principles of single-event multilevel surgery that suggest hip reconstruction, addressing contractures and deformities of the subjacent segments and creating conditions for postoperative postural management. Standardized indications, patient selection and optimal time for intervention are to be carefully considered for the procedure with the use of customized orthopaedic implants and techniques.
Keywords: cerebral palsy, hip dislocation, hip reconstruction, multilevel surgery

Cerebral palsy (CP) is the most common cause of motor disorders that appear in early childhood and is a lifelong condition occurring in approximately 1 in 500 liveborn infants. Around the world, more than 17 million people are living with this disability [1]. Hip dislocation in CP patients is the most severe orthopaedic complication that affects the child's quality of life, the family and caregivers [2–4]. Hip dislocation can result in asymmetric posture, serious difficulties with postural management, difficulties with personal hygiene, pain with hip mobilization and a risk of early onset scoliosis [4–8].

The incidence of hip displacement in CP patients

An overall incidence of hip displacement for the entire birth cohort reported is ≤ 35 % [2], and it shows a linear relationship with the level of gross motor function graded according to the Gross Motor Function Classification System (GMFCS) [9]. The incidence of hip subluxation (Reimers migration index 30–33 %) [10] was shown to increase with the increase in the GMFCS level in the study groups of children and was reported to develop in 41 % [2], 46 % [11], 50 % [12], 39 % [13] of patients GMFCS level III; in 69 % [2], 59 % [11], 62 % [12], 45 % [13] of patients GMFCS level IV; in 90 % [2], 76 % [11], 68 % [12], 72 % [13] of patients GMFCS level V.

Pathogenesis of hip dislocation in CP patients

At birth, the hip joints appear to develop according to the gestational age in children who later develop cerebral palsy, similar to children without neurological disorders [14]. Abnormal forces created by hip adductor muscles (primarily m. adductor longus), followed by the influence of the m. gracilis and m.iliopsoas combined with excessive femoral anteversion and coxa valga and reduced weight-bearing been suggested as the etiology of hip subluxation and dislocation in children with CP [15–20]. The reduced activity of the gluteal muscles results in persistent excessive femoral anteversion [21]. With no treatment performed, the risk of hip dislocation is highest before seven years of age [22, 23]. Terjesen [13] reported that the majority of hip subluxations had already occurred before the age of 5 years at a mean age of 4 years 5 months with 81 % in children with GMFCS levels IV or V.

The annual migration percentage progression of 4 % reported by Terjesen [13], 6–7 % reported by Soo et al. [2] and Connelly et al. [11], 7–9 % [24] are considered unfavorable and are accompanied by hip subluxation. Hip subluxation is considered the onset of an orthopaedic complication [5] with the migration index (Reimers index) 30–33 % [5, 12, 25]. Secondary acetabular dysplasia localized posterolaterally or laterally is caused by the head pressing against the acetabular edge in a pathologically forced posture with adducted and flexed hip due to retraction and spasticity of the adductor muscles and the iliopsoas [2, 3, 18, 26–28]. Total acetabular dysplasia normally develops with hip dislocation [24, 28–30].

A severe deformity of the acetabulum and the head develops with a wide area of lost articular cartilage and a bone defect of the head on the lateral and superior-lateral aspects of the femoral head in untreated children at 10 years [6, 14, 19, 31] with severe pain and no posibility for hip reconstruction [30, 32–34].

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The incidence of severe pain in older children with subluxations and dislocations of the hip is 50–73.7 % [6, 33, 35]. Postural management, passive vertical posture with an axial symmetrical loading on the lower limbs facilitate formation and development of the hip joint, prevention of hip dislocation [36, 37]. Passive vertical posture is useful for the functioning of internal organs improving the involvement and socialization of the patient [38–41]. The axial loading on the limbs reduces the risks of pathological osteoporosis related fractures up to 4-fold [42]. Passive verticalization cannot be provided for children GMFCS levels IV–V due to contractures or dislocations of the hip joint, flexion contractures of the knee joint and severe feet deformities [43–45]. Postural problems with dislocated hip are also recognized as the cause of secondary pathological conditions including additional loss of motor capacity, greater need for assistance, cardiovascular and respiratory disorders, secondary osteoporosis and a risk of pathological fractures, trophic disorders of soft tissues due to unchanging posture [42, 46–48].

The impact of hip dislocation on the quality of life

Hip surveillance programs were initiated for children with severe CP for identifying and monitoring the critical early indicators of progressive hip displacement from the first year of life [16, 49]. The programs allowed for early postural management and correction, verticalization with an axial load on the limbs, botulinum therapy, adequate bracing and surgical intervention on soft tissues [5, 16, 25, 49–51].

The frequency of anteroposterior pelvis radiography for severe CP cases would be dependent on the progression of the migration percentage measurements, GMFCS level and hip surveillance program and is normally performed once every 6 to 12 months [5, 16, 25, 49]. Radiographic examination is indicated for a child who cannot take more than 10 steps at the age of 30 months, for adduction contracture of the hip joints, asymmetric abduction or pronounced spasticity at the age of 12–18 months [13, 25]. The Reimers migration index, the acetabular index and the Wiberg's lateral center edge angle are important radiological hip parameters for diagnostic purposes and for evaluating the effectiveness of conservative and surgical treatment [10, 22, 52, 53]. Surveillance program based on radiographic imaging of the hips demonstrated the ability to reduce the amount of reconstructive surgery to be performed prior to the development of acetabular dysplasia and rule out palliative surgery [16, 49, 54].

Surgical orthopaedic treatment

The goals of hip dislocation correction in children with CP are to improve quality of life, prevent early coxarthrosis, relieve pain, improve conditions for mobility, ambulation, care, comfortable sitting posture and reduce dependence on others [55]. Preventive surgery including soft tissue procedures of lengthening the adductor muscles, iliopsoas, knee flexor muscles can be indicated for children with the migration percentage of 30–50 % [25] or less than 40 % [14]. However, the procedure was shown to be ineffective with reoperation rate of 60–74 % after early soft tissue procedures [56, 57].

Reconstruction of the proximal femur necessitates femoral derotational varization osteotomy in combination with or without acetabuloplasty and lengthening of adductors, lengthening (GMFCS III) or excision (GMFCS IV–V) of the iliopsoas muscles [52, 58–60]. A Reimers migration percentage greater than 40 %, the annual increase by 7 % or greater are the threshold values for a decision to perform reconstructive surgery [5, 22, 25]. The optimal age is considered to be 5–7 years, when the of residual growth period is sufficient for the anatomical formation of the hip joint [5, 55, 61, 62]. However, Tomov A.D. et al. [63, 64] and Park H. et al. [65] reported no correlations between the surgeries performed at the age of 8–9 years and less favorable outcomes.

Indications for dysplasia with an acetabular index of less than 30° remain contraversial. Hagglund et al. [16, 22] reported the spontaneous decrease at the baseline acetabular index of less than 30° during residual growth with lateralization of the femoral head addressed in 29 % of cases with intensive conservative treatment. McNerney et al. [58] reported indications for acetabuloplasty with an acetabular index of 25° and greater. Cornell et al. [14] reported poor outcomes in 13 out of 15 cases with a baseline acetabular index of 27° and surgical intervention without correction of acetabular dysplasia.

Acetabuloplasty (Dega, San Diego, Pemberton) is the method of choice for the reconstruction of the pelvic component of the joint [26, 52, 58, 59, 66] providing changes in the acetabular volume and the slope of the articular surface. Biomechanical considerations were shown to facilitate surgical creation of the largest deviation of the posterolateral or lateral aspect of the acetabulum in most spastic CP cases with secondary dysplasia being most pronounced and the femoral head being least covered after varus osteotomy [66–68]. Acetabuloplasty according to San Diego can meet the criteria to a greater extent and to a lesser extent with Dega procedure, and there are less indications for Pemberton acetabuloplasty [18, 44, 52, 61, 69]. A "Method for determining the optimal amount and topography of acetabulum dysplasia correction during acetabuloplasty" was offered to idenytify the topography and the amount of acetabular dysplasia correction required (Application for invention No. 201822180, priority of 15.06.2018) [70]. The method employed CT scans of the hip joints in order to

determine the acetabular index in the frontal plane and the angle of inclination of the acetabulum in the sagittal plane. The amount of acetabular dysplasia correction required could be determined with anatomical angle measurements available to produce acetabuloplasty at the level of the most susceptible edge [63]. Salter osteotomy or triple pelvic osteotomy allows for greater opening of the posterior aspect of acetabulum and are contraindicated in the vast majority of spastic CP cases [14, 26, 58, 65, 69–71].

Bone plates with angular stability made of titanium alloy are considered to be the most reliable bone fixation for osteoporotic bone [53, 72] with a lower risk of secondary dislocations and good conditions for early weight-bearing with no need to immobilize the pelvis [52]. The use of blade plates requires extensive use of plaster casts and is often accompanied by complications associated with unstable fixation of osteoporotic bone in up to 4.5 % [73, 74].

Development of hip joints in the long-term period after surgery

McNerney et al. [58], Reidy K. et al. [52] reported changes in the migration percentage from 63.6–66 % at the baseline to 2.7–5 % after the intervention with a slight increase to 9.7–11 % at a long term. Tomov A.D. et al. reported the postoperative migration percentage of 0.4–2.0 % with 57.6–72.3 % at the baseline followed by an annual increase of no greater than 3 % with derotational varus osteotomy (DVO) and no greater than 2 % with a combined DVO and acetabuloplasty [64].

An increase in the neck-to-shaft angle (NSA) is reported at a long term period [52, 59, 75]. Miller [18] recommended creating a NSA of 100° in unambulated patients, and 120° in ambulated patients. Mazur et al. [75] recommended a NSA of 100–110° in GMFCS IV–V patients aged 4–12 years, assuming a 20° spontaneous increase in NSA during subsequent growth, and a NSA of a 110–120° in older patients with nearly completed spontaneous growth. Tomov A.D. et al. reported the annual increase in the NSA of not greater than 1–2° [64].

Recurrent hip subluxations and dislocations can occur as complications of reconstructive interventions with the incidence ranging from 4.1 to 27.9 % [52, 76, 82]. Jozwiak et al. [59] reported 1 dislocation and 6 subluxations (23 %) after 30 reconstructive surgeries at a long term. Rutz et al. [77] reported 2 recurrent hip dislocations at a long term following 168 interventions. McNerney et al. [58] reported 6 hip joints with a migration percentage of greater than 33 % among 61 hips at a long term. The authors attribute all cases of recurrent subluxation to surgery related events including failure to achieve muscle balance. Tomov A.D. et al. reported an annual increase in the Reimers index of 10 % and greater in 3 patients out of 124 due to the absence of postural management and verticalization in the postoperative period that required a serious change in the rehabilitation program and surgical intervention to restore muscle balance (n = 2) and reoperation (n = 1) [63, 64].

The mean annual increase in the migration index of 2–3.5 % after reconstructive interventions can demostrate the favorable development of the hip joint and serve as prognostic factor for a good outcome [64, 78]. An annual increase in the migration index of 7 % or greater is considered unfavorable and is associated with a risk of redislocation [52, 64]. In addition to the successful hip reconstruction, the overall success of treatment largely relies on maintaining conditions for the favorable development of the hip joint including postural management, verticalization, passive and active mobilization of joints, rational orthosis facilitating to the potential of residual growth and remodeling of the articular ends of the hip.

Flexion contractures of the knee and ankle joints and feet deformities are thought to be addressed simultaneously with hip dislocation to ensure favorable conditions for postoperative rehabilitation, early adequate verticalization and ease of using orthotic products [79]. No recurrent hip subluxations/dislocations were reported in patients who underwent procedures performed according to the principles of multi-level one-event orthopaedic interventions providing muscle balance and a proper long-term postoperative management [58, 64, 80, 81].

Strategy for bilateral and unilateral hip dislocation

Either a sequential correction of the hip dislocation with a short interval of 3 to 6 weeks or simultaneous intervention on both joints can be indicated for bilateral involvement [52, 58, 59, 82]. An approach to unilateral hip dislocation includes DVO and intervention on the involved muscle groups only on the side of dislocation [83, 84] with subluxation observed on the contralateral limb in 11.8–44.4 % of cases at a long term after reconstruction of the opposiing joint [64, 85, 86]. A more balanced approach is to perform reconstructive intervention on the displaced hip only with the bilateral muscle balance restored supported by healthcare programme for children with CP including adequate postural management [79, 87, 88].

Evaluation of outcomes

In addition to orthopaedic and radiological grading systems outcomes were evaluated with pain intensity, symmetry of posture, ease and care scales [62, 89]. Pain was fully relieved in 82–100 % of cases at a long term [52, 82, 90]. Krebs et al. [55] reported sitting symmetry with no changes in 77 % of cases, improvements in 14 % and deteriorations in 9 %. An improvement in lying symmetry was observed in

35 % of the patients, and an improvement in sitting symmetry was observed in 43 % of cases. Outcomes are recommended to be evaluated no earlier than 1 year after the intervention. Stasikelis et al. [91] reported the return of preoperative passive and active ambulation levels at a mean of 7 to 10 months after osteotomy. Multi-level interventions including reconstructive hip surgery performed for children with severe CP facilitate improved quality of life, physical and psychosocial functioning. However, an improved motor activity can occur in patients GMFCS IV only with improved technical means of rehabilitation, and walking can become the main way of ambulation in patients GMFCS III only [63].

Surgical treatment is indicated for hip dislocation in children with CP using holistic approach and principles of single-event multilevel surgery that suggest hip reconstruction, addressing contractures and deformities of the subjacent segments and creating conditions for postoperative postural management. Standardized indications, patient selection and optimal time for intervention are to be carefully considered for the procedure with the use of customized orthopaedic implants and techniques.

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