

**Multilevel orthopaedic surgery in children with spastic cerebral palsy****D.A. Popkov<sup>1</sup>, G.M. Chibirov<sup>1</sup>, V.V. Kozhevnikov<sup>2</sup>, N.S. Gvozdev<sup>1</sup>**<sup>1</sup>Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation<sup>2</sup>Federal Center for Traumatology, Orthopedics and Endoprosthetics, Barnaul, Russian Federation

**Introduction** The purpose of the article was to review the modern literature on the role of multilevel single-stage interventions in the surgery of secondary orthopaedic complications in children with cerebral palsy. **Material and methods** The review was done using the databases of the current sources of scientific information including PubMed, Scopus, ResearchGate, RSCI and Elsevier, Springer publishing products. 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.

**Results and discussion** The article discusses terminology, indications, particular techniques and early postoperative period, long-term outcomes of multilevel orthopaedic interventions and aspects of iatrogenic orthopaedic conditions in children with cerebral palsy. **Conclusion** Multilevel intervention is the surgical procedure of choice for the correction of secondary orthopaedic complications in patients with cerebral palsy. The success of the surgery would depend on adequately identified indications and quantitative values of the correction to be performed on the basis of 3D gait analysis, the compliance with specific technical requirements for the procedure and an early rehabilitation program. The strategy of multilevel interventions suggests the greatest possible reduction in the number of orthopaedic surgeries and can be considered successful if the patient undergoes a maximum of two multilevel reconstructive interventions in the childhood.

**Keywords:** cerebral palsy, single-event multilevel orthopaedic surgery

## INTRODUCTION

Cerebral palsy (CP) is the most common cause of motor disorders in childhood [1]. The incidence of CP is 3.6 per 1000 children in the United States [1], 2.4 cases per 1000 children in Sweden [2], which is close to the data for Russia, more than 1 500 new cases are registered annually in France [3], and more than 240 000 CP patients below the age of 20 live in Europe [4]. Bilateral and unilateral spastic, dystonic

CP are most common among other forms of the condition accounting for 83–85 % [3, 5]. Patients with these CP types are likely to develop orthopaedic complications that require surgical correction [6–9]. The purpose of the article was to review the current literature on the role of multilevel single event interventions in the surgery of secondary orthopaedic complications in children with CP.

## MATERIAL AND METHODS

The review was done using the databases of the current sources of scientific information including PubMed, Scopus, ResearchGate, RSCI and Elsevier, Springer publishing products. A report made for the

first educational meeting of the European Pediatric Orthopaedic Society held in Russia in the Ilizarov Center in 2021 was used for the contribution describing different aspects of multilevel interventions.

## RESULTS AND DISCUSSION

*Definition*

Single-event multilevel orthopaedic surgery (SEMLS) is defined as corrections of soft tissue and/or bony deformities at a minimum of two anatomical levels during a single operative event. The advantage of a SEMLS procedure is that only one hospital admission and recovery period are needed for multiple interventions [10–12]. In addition to the medical benefits, the approach facilitates reduced burden of treatment events on the social life of the patient and the family, and also adds to economic advantages for the healthcare system [6, 7, 13–15]. Large scale surgical

intervention can be performed sequentially on two limbs with an interval of 2–4 weeks inbetween during one hospital admission but with a single rehabilitation period that helps maintain the SEMLS principles [16–18]. The advantages of a multi-level approach compared to staged isolated operations in children with cerebral palsy became obvious and were recognized in the 80–90s of the twentieth century [19–21]. Fabry et al. [22] are convinced that 3D gait analysis is useful in evaluating these patients and improves the results of operative treatment, and they have since changed their approach toward multilevel simultaneous corrections.

*Three-dimensional gait analysis, the role in diagnosis and planning SEMLS*

Three-dimensional gait analysis allows synchronous evaluation of the kinematic, kinetic and electroneuromyographic parameters of the gait in CP patients GMFCS levels I–III [23–25]. The basic works on gait analysis identified the main pathological patterns of the gait and movements for individual joints that classified walking disorders and facilitated planning of surgical interventions differentiating equinus gait, jump gait, apparent equinus gait, crouch gait, asymmetric gait, stiff knee gait [8, 23–26].

The accuracy and informative value of the gait analysis is superior to physical examination in identifying pathological components of movements and the causes. Authors report different coincidence rate of clinical and computerized gait data with the percentage of 66–100 % [25], 50–68 % [27], 22 % [28], 59–90 % [29], 71.7 % [30]. Gait deviations identified by 3D analysis failed to be identified with clinical evaluation in 19.9 % of cases, and gait analysis allowed for ruling out false positive clinical symptoms in 8.4 % of cases [30].

Moissenet M et al. [31] overviewed the management of patients with gait deviations including 3D gait analysis:

- 1) identifying gait deviations;
- 2) establishing the relationship of different types of medical data, such as from clinical gait analysis, physical examination or imaging results;
- 3) choosing the best surgical approach.

The role of 3D analysis implies the measurement of kinematic and spatiotemporal parameters assessing the result of treatment and monitoring the evolution of the patient's capacity to walk after multilevel interventions [11, 32–34].

The authors report general goals and principles of planning multilevel interventions [11, 12, 35–41]. Orthopaedic multilevel single-event interventions are goal-oriented, and planning should be based on the objective analysis of movements and the gait. It is important to understand that surgical orthopaedic intervention does not change the level of GMFCS, but it allows for elimination of secondary orthopaedic complications that interfere with the ambulation potential to be realized by a particular patient.

The fundamental goals of SEMLS are:

- correction of deformities to improve the biomechanics of ambulation including torsion (shoulder lever dysfunction);
- elimination of joint contractures to improve daily motor activity and increase functional capabilities;
- reduction of energy expenditure associated with biomechanical disorders;

- prevention or reduction of pain caused by early arthrosis;

- reduction/elimination of problems with the use of shoes and orthosis.

*General principles of surgical multilevel technique*

The multilevel intervention suggests producing passive movements in the joints of the operated limb with the use of adjustable orthosis and progressive axial loading 2–3 weeks postoperatively initiating early rehabilitation [42]. It is recommended to lengthen muscles through aponeurotomy and produce tendon transfer with anchors rather than suture tendons [43–45]. In addition to that, the elongation of the muscles through the aponeurotic portion without increase in the tendon portion allows for maintaining the contractile capacity and muscle strength of the tissue along with an increased amplitude of passive movements [46, 47]. With correction osteotomies, bone reconstruction procedures, arthrodeses of the feet implants and fixation components made of titanium alloys are practical for primary bone stability to ensure early progressive functional loading on the limbs and a rapid transition from temporary immobilization with a plaster cast to adjustable orthoses [48–54].

The approach suggests reduction of blood loss due to the use of squeezing and hemostatic tourniquets, reduction of the operation time (employing two surgical teams), accurate recording of the angles achieved for passive movements, early postoperative rehabilitation and measures to prevent trophic disorders of soft tissues [16, 18].

*Early rehabilitation following SEMLS*

Early passive and active joint mobilization, verticalization of patients with full axial loading, replacing plaster casts with adjustable orthosis after three to four postoperative weeks post surgery are generally recognized principles of rehabilitation after multi-level interventions [11, 47, 55–58]. Pain is common in the early postoperative period and after the removal of immobilization [59]. Botulinum therapy is indicated postoperatively for pain relief in the mobilized muscles [60]. Rehabilitation suggests getting involved into activities of daily living and school classes from the first postoperative months [61]. Patients can regain initial spatiotemporal parameters of the gait or improve them at one year post surgery [61] with overall improvement in motor functions and the quality of life seen within the second year after surgery [62].

*Outcomes of SEMLS at a long term*

Evaluation of the effectiveness of multilevel interventions at a long term period remains an important issue. The results of treatment evaluated at 1–2 years after surgery and 3–5 years after surgery

provide a balanced representation of the outcomes at a short and medium term [10]. Harvey et al. [63] reported no change in the GMFCS class after SEMLS but steady improvements in the scores on the Functional Mobility Scale. The results of treatment followed up for 10 years and over featured improved kinematic and spatiotemporal parameters. Motor disorders were not seen to slowly deteriorate in the crouch gait patients, but additional interventions were required in 61.5 % of cases during 10 years of follow-up to maintain the result primarily achieved [34].

Haumont et al. [64] reported a sample group of 97 children with spastic CP who walked with a flexed-knee gait (crouch gait pattern or its debut) and underwent SEMLS, showed an overall improvement in gait at 10 years follow-up. In this study, 69 % of children underwent one or two surgical events including initial surgery and 31 % had undergone three or more in a 10 year period, and 68 % were considered as candidates for additional surgical intervention at the age of 18. Dreher T. et al. [65] reported a multi-center study including 331 children with bilateral spastic CP evaluated at long term (9.1 years) follow-up, and 177 (76.6 %) children could maintain their improvement in GPS (Gait Profile Score). Thirty-nine per cent of children required additional surgery during follow-up.

All the authors of the above series with a follow-up period of 9 years or more consider the term SEMLS to be changed to the more realistic term 'multilevel surgery' (MLS), because more than a third of cases require additional interventions over a course of long-term follow-up to maintain the result achieved. No more than two reconstructive interventions can be produced for CP patients before skeletal maturity for the successful planning and surgical treatment [64]. Maintaining the spatiotemporal and kinematic parameters of gait in the long-term period is accompanied by higher quality of life which correlate with the GMFCS level [64, 66].

*Iatrogenic complications, procedures to be not recommended*

In addition to the natural development of the crouch gait pattern, an iatrogenic crouch gait pattern

can develop after unreasonable fibromyotomies and isolated Achilles lengthening performed at an early age [67, 68]. The subsequent inevitable weakening of the tibial triceps can lead to a lost function of the soleus muscle and the eccentric contraction, absorption of the kinetic energy of the supporting limb and pathological knee flexion in the supporting phase [25, 69–72]. As mentioned above, only an aponeurotomy of the gastrocnemius muscle allows for maintaining the pushing force during plantar flexion of the foot and prevents the development of triceps weakness [46]. Gatamov O.I. et al. reported [73] the adverse event occurring in the group of iatrogenic gait disorders at an earlier age as compared with patients who develop the condition as a natural course. Iatrogenic crouch gait is typical for GMFCS level II patients, while GMFCS level III is common for patients without previous surgical treatment [73]. In addition to that, there is a negative effect from early interventions performed for plantar flexors (Ulzibat fibromyotomy, open Achilles lengthening in children with spastic diplegia [67, 72, 74, 75]) that can result in the early development of the pathological crouch gait pattern in children with CP GMFCS levels I and II and without torsion deformities.

There is a risk of trauma and premature closure of the anterior portion of the physis of the proximal tibia and associated genu recurvatum deformity when the patella is brought down, the patellar tendon mobilized (in isolation or with a fragment of the underlying bone), and the periosteum is fixed with circlage and Kirschner wires in a traumatic manner [76]. Hachache et al. [77] evaluated the effectiveness and safety of percutaneous proximal gracilis tenotomy in children with CP and identified iatrogenic lesions including an injury of the anterior branch of the obturator nerve, considerable bleeding with hematoma formation considering the deep location of the proximal tendon of the m. gracilis in the soft tissues. Percutaneous medial hamstring myofascial lengthening is often associated with an abusive injury of the muscle itself as compared to open procedure [78]. Therefore, percutaneous lengthening of the retracted muscles is highly discouraged at the above sites.

## CONCLUSION

Multilevel intervention is the surgical procedure of choice for the correction of secondary orthopaedic complications in patients with cerebral palsy who can improve the ambulation capacity and the quality of life. The success of the surgery would depend on adequately identified indications and quantitative values of the correction to be performed on the basis of 3D gait analysis,

the compliance with specific technical requirements for the procedure and an early rehabilitation program. The strategy of multilevel interventions suggests the greatest possible reduction in the number of orthopaedic surgeries and can be considered successful if the patient undergoes a maximum of two multilevel reconstructive interventions in the childhood.



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#### **Information about the authors:**

1. Dmitry A. Popkov, M.D., Ph.D., Professor of RAS, correspondent member French Academy of Medical Sciences, Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation, ORCID: 0000-0002-8996-867X, Email: dpopkov@mail.ru
2. Georgy M. Chibirov, M.D., Ph.D., Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation, Email: georgii\_chibirov@mail.ru
3. Vadim V. Kozhevnikov, M.D., Ph.D., Federal Center for Traumatology, Orthopedics and Endoprosthetics, Barnaul, , Russian Federation
4. Nikita S. Gvozdev, Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation, Email: gvozdev\_n.s@mail.ru