

Results of single-event multilevel orthopedic surgery in children with cerebral palsy

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Abstract

Background: Single-event multilevel orthopedic surgery is a modern approach in the operative treatment of children with cerebral palsy.

Methods: Single-event multilevel orthopedic surgery was carried out in 108 patients with cerebral palsy. Patients' average age was 11.3±1.7 years. Surgical results were analyzed at follow-up after 18 to 24 months, by way of detailed physical examination, functional assessment, imaging, the Edinburgh Visual Gait Score and Gillette Functional Assessment Questionnaire.

Results: In our series, 647 procedures were performed during 141 surgeries. Patients had an average of 4.59 procedures per surgery. Observational gait analysis showed an improvement in stance and swing gait phases in ambulatory children. According to the Gillette Functional Assessment Questionnaire, an increase of functional level was noted in 50 patients but did not change in 32 patients.

Conclusions: For children with cerebral palsy, single-event multilevel surgery is defined as two or more surgical procedures of the soft tissue or bone at two or more anatomical levels during one operative procedure. In cases where a large volume of surgery is required, two separate operations with a short break in between, but requiring only one hospital admission and one rehabilitation period, are also included. This approach requires adapted methods of surgical intervention, and appropriate methods of anesthesia and pain control in the postoperative period to the start of rehabilitation. Compliance with the above principles allowed the necessary correction of orthopedic complications to be achieved in all cases.

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Introduction

Cerebral palsy (CP) is currently the most common cause of motor disorders in young people [1]. The incidence of CP is 3.6 cases per 1000 children in the USA [1], 2.4 per 1000 children in Sweden [2], and in France there are over 1,500 new cases registered every year [3]. In Europe, the total the number of patients under 20 years old with CP is over 240,000 [4]. Of all patients with CP, 83–85% have bilateral or unilateral spastic, dystonic palsy [3, 5] requiring

surgical correction for associated orthopedic complications [6–9].

Currently, the concept of surgical treatment of children with CP implies single-event multilevel orthopedic surgeries (SEMLS) to simultaneously correct orthopedic complications via tendon–muscle procedures and/or procedures involving the bone structures of the limbs [7, 10, 11, 13–16].

The aim of this study was to evaluate the results of SEMLS in the lower limbs of patients with CP during follow-up appointments 18–24 months after surgery.

Methods

The study was carried out between January 2011 and June 2012. The authors performed 214 SEMLS surgeries in patients with CP during this period. Patients included into the study were recipients of SEMLS in the lower extremities. Patients were excluded from the study if: only one anatomic area was operated on, the surgery was performed on the upper limbs, or the period between two consecutive surgeries exceeded six weeks. Overall, 106 cases were excluded.

Along with clinical and radiographic methods of study [17, 18], we used video recordings to assess patients' gait (ability to walk independently with or without walking aids). Recordings were made using two simultaneous cameras positioned in orthogonal projections. Based on the videos, several variables of gait were assessed according to the Edinburgh Visual Gait Score [19]. Gait types of patients able to walk vertically and independently were classified according to Rodda and Graham [20]. Changes related to motor function (ambulation) were evaluated according to the Gillette Functional Assessment Questionnaire (FAQ) [21, 22].

Single-event surgical procedures were carried out under endotracheal narcosis combined with prolonged epidural anesthesia in order to correct orthopedic disorders. Postoperative analgesia was accomplished by continuous infusion of 0.2% naropin solution at the rate of 0.3 mg/kg/hour via a catheter in the epidural space during the first 48 hours.

Osteosynthesis was carried out during corrective osteotomies to provide osteoporotic bone fragments with stability, and to allow early weight bearing and rehabilitation. In proximal femoral varus derotation osteotomies, PHP LCP Synthes (100°, 110°) and/or Surfix (90°) locking plates were applied. In extension supracondylar femoral osteotomies, distal locking femoral plates (Osteosintez, Russia) were used to fix bone fragments. In detorsion osteotomies fixation was obtained using LCP Synthes 5.0 plates. Osteosynthesis of the foot was achieved via threaded wires. Soft tissue operations employed similar techniques determined by strict indications [23, 24]. Aponeurotomy was preferred to lengthening of muscles at the tendon to patients' earlier mobilization. Intraoperatively, local methods of blood

loss prevention were used, and surgery was performed by two surgical teams in order to reduce the duration of the operation.

Statistic assessment was fulfilled using Attestat® software. Mean values of indices and their mean errors were defined for descriptive statistics.

Results

SEMLS results were analyzed in 108 patients with a mean age of 11.3 ± 1.7 years (range: 3–32 years). Gender distribution was 63 males to 45 females.

Cerebral palsy manifested in the following forms: spastic diplegia (70 patients; 64.8%), spastic tetraplegia (8; 7.4%), spastic hemiplegia (20; 18.5%), dystonic type (4; 3.7%), and mixed type (6; 5.6%). According to Gross Motor Function Classification System (GMFCS) criteria, patients were grouped thus: level II, 13 patients (12%); level III, 44 (40.7%); level IV, 41 (38%), and level V, 10 (9.3%).

Overall, 141 surgeries were performed. In 38 cases the operation was bilateral; in 33 patients limb surgeries were performed consecutively within six weeks; and in 37 cases the operation was unilateral but multilevel. Within the 141 surgeries, 647 individual surgical procedures were carried out at an average of 4.59 per surgery (Table 1).

The long-term effects of surgical treatment were assessed 18–24 months after surgery in 82 children (75.9% follow-up rate).

Gait analysis revealed improvements in the majority of 'stance' and 'swing' phase variables, whether the patient walked independently or with aids. Tables 2 presents data corresponding to pre-operative stance and swing gait variables in patients with spastic diplegia, and Table 3 presents data from the same analysis performed at follow-up after 18–24 months. In patients with 'crouch' gait, it was noteworthy that extension of the knee and hip joints increased, excessive dorsal flexion in the ankles practically disappeared, and patients' general position while walking became straighter.

Table 1. Frequency of surgical procedures performed as part of SEMLS treatments

Procedures involved in SEMLS operations	Number
Gastrochemius lengthening	88
Hip adductor lengthening	85
Hamstring lengthening	84
Femoral proximal varus derotation/varus osteotomy	42
Patellar advancement	42
Teno- and aponeurotomy of the psoas major	42
Grice procedure and modifications	36
Triple arthrodesis	34
San Diego acetabuloplasty	33
Tendon transfer in foot	30
Bunion correction	28
Supracondylar femoral osteotomy	28
Proximal tenotomy of the rectus femoris muscle	18
Lateral column lengthening	12
Subtalar fusion	10
Femoral derotation	8
Medial column correction	8
Achilles tendon lengthening	6
Rectus transfer	4
Tibial progressive lengthening	3
Closing lateral wedge valgus intertrochanteric osteotomy with resection hip arthroplasty	2
Resection hip arthroplasty	2
Salter pelvic osteotomy	2

After surgery, a moderate decrease in peak knee flexion of swing prevailed – the gait type changed to ‘stiff knee’ gait, but it was combined with an improvement in functional abilities for those patients with gait types IV or V (‘crouch’ gait) [20].

According to data received from the Gillette FAQ survey, 32 patients (39.02%) saw no improvement in functional motor abilities. In 47 cases (57.32%), mobility was reported to have worsened by one level, and by two levels in three patients (3.66%).

Table 2. Gait variables in stance phase in patients with types III, IV, V [20]

		Before surgery (number of pts)	After 8–12 months (number of pts)
Initial contact	Toe contact	20	-
	Flat foot contact	25	21
	Heel contact	-	24
Max ankle dorsiflexion	Excessive >40°	17	-
	Increased 26°-40°	28	14
	Normal	-	31
Knee peak extension	Severe flexion >25°	35	-
	Mod flexion 16°-25°	10	24
	Normal 0°-15°	-	21
Hip peak extension	Severe flexion >15°	19	-
	Mod flexion 1°-15°	26	23
	Normal 0°-20° ext	-	22

As for complications experienced during the surgeries performed, three cases of subcutaneous hematoma were observed after adductor lengthening procedures, whereby the wound edges separated and healed by secondary intention. There were four cases of phlyctena resulting from the compression of soft tissues by the plaster cast bandage, and four cases of transient sciatic nerve palsy following procedures to lengthen the knee flexors, resulting from maneuvers exceeding the extension. All the above-mentioned cases were successfully managed. Two patients (one having had a Grice procedure, and the other correction of the hallux valgus) experienced migration of K-wires requiring their premature removal, but only after bone fragments had already been united. Finally, there was also one case of aseptic necrosis of the femoral head; this was in a 5-year old girl who underwent a procedure to reduce high dislocation of the hip. Conservative treatment was also effective in this case, and after six months, positive signs indicated that the proximal femoral epiphysis was beginning to reconstruct and mineralize following commencement of vertical, weight-bearing activity.

Table 3. Gait variables in swing phase in patients with types III, IV, V [20]

		Before surgery (number of pts)	After 8–12 months (number of pts)
Clearance	None	18	-
	Reduced	27	23
	Full	-	22
Max ankle dorsiflexion	Increased 16°-30°	23	2
	Normal 15°df-5°pf	20	43
	Mod plant flexion 6"-20°	2	-
Terminal knee angle	Severe flexion >30°	33	-
	Mod flexion 16°-30°	12	15
	Normal 5°-15°	-	30
Knee peak flexion	Severely increased >85°	18	-
	Mod increased 71°-85°	23	2
	Normal 50°-70°	4	18
	Mod reduced 35°-49°	-	25
Hip peak flexion	Marked increase >60°	19	-
	Increased flexion 46°-60°	19	12
	Normal 25°-45°	7	26
	Reduced flexion 10°-24°	-	7

Discussion

The gold standard approach to the operative treatment of orthopedic complications in patients with CP is to perform single-event multilevel orthopedic surgeries (SEMLS). This is most often defined as two or more surgical procedures of the soft tissue or bone at two or more anatomical levels during one operative procedure [13]. In some circumstances, for example for surgeries to reconstruct large joints, procedures qualifying as SEMLS may occur 3–6 weeks apart, but involve only one hospital admission, and the period of rehabilitation remains the same for both surgeries [1, 10, 11]. The major advantage of the SEMLS approach is that faulty limb positions and lower limb deformities can be corrected simultaneously, which decreases the number of operations the patient must endure, and requires a single period of rehabilitation. Impairment of the patients' social life is also reduced by such treatment procedures [6, 7, 25, 26].

Both SEMLS variations were applied in our study: in 38 cases (one in 33 patients), the operation was bilateral, having a mean interval of 22.7 days. The mean number of surgical procedures per operation was 4.59, which is close to the data of other authors such as Godwin et al., who reported a mean number of surgical procedures per operation of 5.45 [27].

Initially, SEMLS procedures were only carried out in children able to walk independently, and only after the popularization of quantitative gait analysis [7–9]. Currently, operative treatment in children with motor activity levels IV and V (according to GMFCS) also includes correction of deformities and contractures on several levels in order to facilitate positioning, sitting, patient verticalization, patient's care, and use of auxiliary orthopedic appliances. Correction of these types of problems often require more than one procedure; for example, as well as correction of subluxation and dislocation of the hip, flexion contractures of the knees and correction of foot deformities are also often required [1,10,13]. In our opinion, the principles of SEMLS should include all categories of CP patients requiring surgical treatment regardless of the functional prognosis because, undoubtedly, fewer hospital admissions for surgical treatment is socially significant for every group of patients [14, 27–29].

The advantages of performing SEMLS in patients with CP are widely recognized. Opinions vary only in the timescale within which these operations are carried out: some authors begin these surgeries from the age of 4 years [7, 27]; others from the age of 8 [12, 16, 26, 35]. In our study, the patients' ages ranged from 3–32 years old. We believe that the age at which surgical treatment commences is determined first of all by the development of orthopedic complications.

Other aspects to consider in the use of SEMLS in patients with CP are the methods of surgical treatment used, and the materials used in osteosynthesis to enable early mobilization of the joints of the operated limb [18]. This is achieved by performing aponeurotomy instead of tenotomy, stable osteosynthesis adapted to conditions of osteoporosis (locking plates), early dissection of plaster cast, use of orthosis in early postoperative period. The use of materials to achieve osteosynthesis in SEMLS should

cause minimum trauma, and the duration of procedure should be minimized to increase efficiency of the surgery.

Previous studies have described the advantages of using Surfix-type plates in proximal femur varus derotation osteotomies from the point of view that they decrease intraoperative blood loss and reduce the duration of the surgery [30], thus suppressing the body's resistance and influence on the postoperative period, and negating potential decompensation of associated diseases caused by major surgery [31–34]. In children with severe forms of spastic palsy, this is very important since they are often affected by various chronic diseases. Surgical treatment according to SEMLS principles also implies the use of prophylactics to reduce intraoperative blood loss and decrease of duration of the surgery [10, 13, 24, 26].

According to results from Gillette FAQ assessments, following the above-mentioned principles enabled us to increase the motor abilities of our patients in 61% of cases, particularly in patients with severe forms of 'crouch' gait (GMFCS levels III and IV), whereby knee and hip extension was improved to normal levels, excessive dorsal flexion of the ankles in the stance phase decreased or normalized, and swing phase clearance increased. Authors of other studies have reported similar results from SEMLS procedures, with validation of efficiency seen in the laboratory following quantitative gait analysis [7, 8–10, 19, 20, 22, 35].

Although some authors state that it may be possible [27], we tend to agree with others [12,35] that not even the most successful surgical treatment can alter a patient's functional GMFCS level. Rather, it is more likely to return a child's motor abilities to their original status, i.e. before they were compromised by the development of orthopedic complications.

In children with CP, it is important to carry out objective quantitative assessment of surgical treatment results. Currently, the gold standard is quantitative analysis of kinematic, kinetic and electromyographic variables of gait (laboratory of quantitative gait analysis) [9, 16–18]. Based on a meta-analysis of published literature, McGinley et al. demonstrated that without objective quantitative analysis, authors tend to overestimate the results of

operative treatments in children with CP [13]. The Edinburgh Visual Gait Score was developed for use in countries where orthopedists had no access to quantitative gait analysis, and was verified by comparison with the results of laboratory of quantitative gait analysis [17, 18]. Use of these two scales means we consider our results to be reliable.

A limitation of our study is that we have not assessed the long-term effects of surgical treatment. However, other authors have reported that favorable outcomes of such interventions persist for more than five years [27], and that treatment results were more stable in children operated on in late childhood [12, 16]. Finally, the most significant changes were noted in the initial GMFCS levels II, III, IV [27].

Conclusions

Performing SEMLS in patients with CP implies either: two or more soft tissue or bony surgical procedures at two or more anatomical levels during one operative procedure, or one or more complex operations performed within a short period time (3–6 weeks), requiring only one hospital admission and one period of rehabilitation for both limbs.

This approach demands use of adapted methods of operative intervention, which allow a patient to be rehabilitated much more quickly.

In this study we have shown that use of SEMLS successfully achieved improvement of orthopedic complications in patients with CP. Furthermore, at follow-up after 1.5–2 years, use of SEMLS was found to improve of functional abilities in 50 (61%) of 82 patients with severe CP pathology.

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