Single Event Multilevel Surgery for Crouch Gait in Cerebral Palsy - An Evaluation Using Functional Mobility Score - A Retrospective Analysis

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ABSTRACT

BACKGROUND

Severe crouch gait in children with spastic diplegia causes excessive loading of the patellofemoral joint and may result in gait deterioration, anterior knee pain, and progressive loss of function. We retrospectively evaluated the effect of single-event multilevel surgery (SEMLS) on functional mobility at two years with the help of the Gross Motor Function Classification System (GMFCS).

METHODS

Between the period of 2017 and 2019, 25 children with spastic cerebral diplegia having crouched gait of fewer than 12 years of age underwent SEMLS. The patients were classified according to their GMFCS. The surgical intervention consisted of both soft tissue and bony procedures. Paired-samples t-test was used to compare the values of physical examination findings and walking speed. Two paired sample Wilcoxon signed-rank test was used to compare functional walking scales.

RESULTS

The study group included 15 male and 10 female patients with a mean age of 10.6 years. A total of 105 soft tissue procedures and 25 bony procedures were performed. Majority achieved the ability to walk 500 m at the end of follow-up. The median for FAQ (Functional Assessment Questionnaire) which was 5 before surgery, improved to 6 at 1 year and 7 at 2 years.

CONCLUSIONS

SEMLS for older children and adolescents with crouch gait is effective for improving function and independence. Improvements that were noted at one year were maintained at two years and later.

KEYWORDS

Cerebral Palsy, Crouch Gait, Patellar Tendon Plication, Single-Event Multilevel Surgery

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DOI: 10.18410/jebmh/2020/424

How to Cite This Article:
Mathew J, Karuppal R, Somasundaran S, et al. Single event multilevel surgery for crouch gait in cerebral palsy - an evaluation using functional mobility score: a retrospective analysis. J Evid Based Med Healthc 2020; 7(37), 2043-2047. DOI: 10.18410/jebmh/2020/424

Submission 04-05-2020,
Peer Review 15-05-2020,
Acceptance 02-07-2020,
Published 14-09-2020.

BACKGROUND

Cerebral Palsy (CP) is a major neurodevelopmental disorder, currently estimated to affect approximately 1 in 500 children. As a clinical diagnosis, the aetiology of it is often unknown.[1] Crouch gait is commonly seen in spastic diplegic cerebral palsy. It can develop due to the weakness of antigravity muscles which is inherent in diplegic cerebral palsy.[2] The shortening of hamstrings or psoas muscles, lengthening of the quadriceps muscle-tendon unit, and musculoskeletal deformities like excessive femoral anteversion, fixed flexion deformity of the knee, and pes valgus are the other factors contributing to crouch gait.[3] The development of obesity during adolescence years can also play a role. Non operative options for the management of crouch gaits like muscle stretching and strengthening exercises and floor reaction ankle-foot orthoses, which do not have rewarding results on many occasions. Benefits of SEMLS to correct some or all the factors have also shown improvement in mobility and function.[4] The purpose of the present study is to evaluate the effect of SEMLS on functional mobility at two years or more with the help of the gross motor function classification system (GMFCS).

METHODS

This retrospective cohort study included a sample of 25 patients, who had spastic diplegic cerebral palsy, walked with a crouch gait either independently or with the use of assistive devices, and who underwent surgery between January 2017 and March 2019. The permission from the institutional ethics committee had obtained for our study.
Inclusion criteria for the study group included spastic diplegic cerebral palsy with crouch gait, no other neurological diseases, age group 12 yrs. or less. Exclusion criteria were GMFC score 5, botulinum toxin. A injections, or muscle surgery within the preceding 12 months. All patients were offered a combined SEMLS and rehabilitation program. The surgical steps were decided by the physical examination and gait analysis. The surgical steps and the selection criteria are shown in Table 1.

The routine preoperative radiological evaluation was done in all cases with X-rays of the whole spine, pelvis with hips, knee joint Ap view, and lateral in 30 degrees of flexion and ankle and foot. The soft-tissue surgical procedures were musculotendinous lengthening of the psoas muscle at the pelvic brim,[5] lengthening of the medial hamstrings (semimembranosus and semitendinosus) without lateral hamstrings,[6] patellar tendon plication to shorten the patellar tendon. Quadriceps was always shortened at the patellar tendon level only. A 1-mm diameter stainless steel wire was passed through transverse holes made in the patella and another hole at and in the proximal tibia distal to the tibial tubercle apophysis, which is tightened so that the inferior pole of the patella was at the level of the joint line with the knee extended. The patellar tendon was plicated by the double breasting way without incising the tendon.

The osseous procedures were distal femur extension osteotomy with internal fixation, calcaneal lengthening[7] for the correction of the planovalgus foot.[8] Calcaneal osteotomies were fixed with bone staples. A first-generation cephalosporin was given at the time of induction of anaesthesia and was continued for 48 hours postoperatively. In all patients, non-steroidal antiinflammatory drugs were used for postoperative pain control.

Plaster of Paris cast was used to immobilize the knee joint in a fully extended position. Patients who underwent the bony procedure at the foot had casts with distal extension up to toes. Physical therapy began on 10 days (after suture removal) when the pain subsided and co-operated to passive and active movements. Casts were removed 3 weeks after surgery. Radiographs of all osteotomy sites were made. Partial weight-bearing was started as early with appropriate weight receiving devices and full weight-bearing was encouraged when healing at the osteotomy sites was demonstrated radiologically. Range-of-motion exercises were started immediately after POP cast removal. Knee immobilizers were used at night only for the subsequent 6-month period to reduce the risk of recurrence of knee flexion deformity. The patients who underwent bony surgeries in the foot were used custom made moulded foot orthoses at the time of weight-bearing.

All patients were managed with an individually tailored rehabilitation program at our center for a period of 6 weeks. We had taught all our patients and parents about the necessary rehabilitation methods which they had followed at home. Strengthening exercises were mainly for gluteus maximus, quadriceps, gastrosoleus, and hamstrings. To improve endurance, patients were encouraged to walk and to do the cycling. The frequency of physical therapy sessions was reduced after 12 months.

All patients were reviewed at 3, 6, 9, 12, 18, and 24 months after surgery. Appropriate changes to orthoses, assistive devices, and the physical therapy program to optimize each subject's rehabilitation process were made. A two-dimensional video recording of the gait was performed at 1 and 2 years.

A standardized physical examination was conducted preoperatively and at every follow-up. Radiological evaluations were performed preoperatively and in the early postoperative period. The parameters relevant to the present study were the measurement of fixed flexion deformity at the hip and knee, the measurement of the hamstring length by the popliteal angle.[9] The functional assessment questionnaire (FAQ)[10] and the GMFCS[11] were used to measure functional mobility. The FAQ is a valid scale specific to the task of walking in children with chronic neuromuscular conditions and assists in the documentation of functional changes. It is a 10-level, walking scale encompassing a range of walking abilities from non-ambulatory (level 1) to ambulatory in all community settings and terrains (level 10). In contrast, GMFCS is best suited to stratify patients with cerebral palsy based on broad functional levels. It is considered to be stable over time and nonresponsive to intervention.[12]

Statistical Analysis

All parameters were measured preoperatively, at 1 year and finally at 2 years. The paired sample t-test was used to compare the preoperative and postoperative physical examination findings, walking speed. The two-sample paired Wilcoxon signed-rank test was used to compare FAQ and GMFCS. The significance level was set at $P < 0.05$.

RESULTS

Twenty-five patients fulfilled the eligibility criteria for the 2-year study period. The study group included 15 male and 10 female patients with a mean age of 10.6 years (range, 5 - 12 years) at the time of surgery. Six out of 25 subjects had previous surgeries. Four underwent bilateral hamstrings lengthening. Two patients had surgery to lengthen the gastrosoleus complex of whom one underwent bilateral tendo - Achillis lengthening and one underwent the bilateral Vulpius procedure.

A total of 105 soft tissue procedures and 25 bony procedures were performed in 25 patients (45 hamstring lengthening, 15 Psoas lengthening, 45 Patellar tendon plication, 10 Supracondylar femur osteotomies, and 10 lateral column lengthening). Values of the FAQ, and GMFCS are described in Table II.

The best improvement was seen in GMFCS. No person was able to walk the 500 m distance before surgery; however, the majority achieved the ability to walk 500 m at the end of follow-up. The median for FAQ which was 5 before surgery, improved to 6 at 1 year and 7 at 2 years. Values for three physical examination parameters at Preoperative, 1 year, and 2 years postoperative are described in Table III. Data from both sides are added. Fixed flexion deformity of the hip and knee and the popliteal angle was markedly reduced from the preoperative period. Improvement at 1 year and at 2 years are statistically significant with a probability of less than 0.05. We had a few complications like superficial surgical site infection in 2 patients (8%) and encirclage wire breakage at 1 year in one patient.

Procedure	Evaluation Criteria
Psoas Lengthening	Fixed Flexion Deformity of Hip Joint of more than 20 Degrees
Medial Hamstring Lengthening	Popliteal Angle more than 50 Degrees Under Anaesthesia
Patellar Tendon Plication	Patella Alta by Insall-Salvati Ratio
Distal Femoral Extension Osteotomy	Popliteal Angle more than 70 degrees under Anaesthesia, which may not get Corrected by Hamstring Release alone.

Table I. Surgical Steps and Selection Criteria

	Pre-Op	1 - Year Post Op	2 Years Post Op
FAQ	6	7^{+}	8^{++}
GMFCS	4	3	2

Table II. Pre-Operative, 1- and 2-Year Values for Functional Scales

The values are given as median. + The values at 1-year post operatively was significantly different from the preoperative value ($p < 0.05$). ++ The value at 2 years postoperatively was significantly different from the preoperative value ($p < 0.05$).

	Pre-Op	1 – Year Post Op	2 Years Post Op
Fixed Flexion Deformity of the Hip	18.2 ± 6.2	8.1 ± 3.8	4.8 ± 3.0
Fixed Flexion Deformity of the Knee	22.8 ± 8.9	2.7 ± 1.6	$2.0 \pm 1.66^{++}$
Popliteal Angle	60.1 ± 12.3	$28.6 \pm 8.4^{+}$	$34.2 \pm 8.2^{++}$

Table III. Pre-Operative, 1- and 2-Year Physical Examination Findings

The values are given as median and standard deviation. + The values at 1-year post operatively was significantly different from the preoperative value ($p < 0.05$). ++ The value at 2 years post - operatively was significantly different from the preoperative value ($p < 0.05$)

DISCUSSION

There is only limited information available about post-SEMLS rehabilitation.[13] Evidence was found for large improvements in gait with more equivocal evidence for changes in gross motor function[13] The crouch being highly energy-consuming gait, the improvement in energy consumption by returning to normal or near-normal gait suggests benefits to the patients.

Orthopaedic surgery results in weakness, loss of independence, and decreased gross motor function, which makes rehabilitation after SEMLS challenging.[14] After surgery, the walking speed improved at 1 and 2 years. An improvement in the speed can be partly attributed to the increase in the height of the person as in the present study.[15] In our study, we observed that the pattern of change differed according to the functional level preoperatively. Children with GMFCS II walked without assistive devices at household distances and therefore had improved statistically significantly at greater distances. Children with GMFCS levels III and IV had improved more at short distances and the greatest change was at 10 m. Our patients reached the preoperative level at 3 - 4 months postoperatively. This agrees with other studies. The world's first randomized controlled trial of SEMLS was published from the Royal Children's Hospital in Melbourne.[16] This randomized clinical trial reported a 57% improvement in gait according to the Gillette Gait Index and a 4.9% improvement in gross motor function according to the GMFM-66.[16] Multilevel orthopaedic surgery in thirty-four ambulatory children with spastic diplegia was previously studied to analyze the studied gait improvements.[17] They evaluated the functional level using the functional mobility scale(FMS) and found the same results, when compared with our study at 1 year. Moreover, 5-year postoperatively, children at GMFCS level III showed improvements at FMS 500 m.[17]

Even if SEMLS is aimed at correcting all existing deviations in gait, additional surgery is sometimes necessary. It was found a need for such surgery already at the 1-year follow-up.[18] Preoperative and 2-years postoperative values of three gait laboratory parameters, namely, stride length, crouch angle at the initial stance, and peak knee flexion in mid-swing, showed improvement and

was statistical significance. A significant increase in the paediatric evaluation of disability, the mobility questionnaire at 6 months, and 1 year and 2 years were reported before,[19] which agrees with our results. In a previous study there[20] found that ambulatory children aged 10 years and 7 months with GMFCS levels I, II, and III undergoing multilevel surgery showed a decrease (improvement) in preoperative gait profile score from 16.3° to 11.3° at short-term follow-up and improvement of 5° at long-term follow-up. We consider the relatively small sample size as important limitations. The generalisability of the findings would also have been improved with a larger study sample and a longer follow-up period.

During rehabilitation, the emphasis was on strengthening exercises and endurance training for walking. Strengthening exercises are beneficial for a person with crouch gait.[21] We had taught all our patients and parents about the necessary rehabilitation methods which they had followed at home. The tailored parental rehabilitation training was found to be very useful for those coming from remote areas where they don't have the adequate facility and those cannot financially afford it. We believe, proper rehabilitation may have positively influenced results in our series. The various considerations to prevent the progression of crouch gait are the use of orthosis and strengthening exercises, deciding the right stage for surgical intervention, and a search for appropriate surgical management. It includes hamstring lengthening to be carried out and whether to carry out patellar tendon shortening, how much shortening should be carried out.

CONCLUSIONS

Single-event multilevel surgery for crouch gait in spastic diplegia cerebral palsy for older children and adolescents is effective for relieving stress on the knee extensor mechanism, reducing knee pain, and improving function and independence. The tailored parental rehabilitation training was found to be very useful for those who don't have access to it anymore. Factors like the use of appropriate orthosis and strengthening exercises, opting for the right stage and the right choice for surgical intervention are mandatory to prevent / correct the progression of crouch gait.

Financial or Other Competing Interests: None.

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