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# Long term outcome of single event multilevel surgery in spastic diplegia with flexed knee gait

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ABSTRACT

Distal hamstring lengthening (DHL) is a commonly performed procedure in flexed knee gait. However, the necessity of this procedure has been challenged due to the concerns on adverse effects in long-term follow-up. This retrospective study was undertaken to investigate the long-term outcome of single event multilevel surgery (SEMLS), including bilateral DHL, in ambulatory patients with cerebral palsy using 3D gait analysis. Twenty-nine ambulatory patients with spastic diplegic cerebral palsy who had undergone SEMLS including bilateral DHL were included. 3D gait analysis was performed preoperatively, 1 year postoperatively and over 10 years postoperatively. Preoperative temporal parameters, kinematics and GDI were compared with values obtained 1 and 10 year follow-up visits. The mean age of patients at time of first surgery was 8.3 years (range, 5.4–16.3 years), and mean time from first surgery to last 3D gait analysis was 11.8 years (range, 10.0–13.3 years). Mean pelvic tilt was not changed significantly after SEMLS including DHL. Mean knee flexion at initial contact decreased from 31.1° preoperatively to 26.0° at 1 year postoperatively ($p = 0.065$), and then decreased significantly to 23.6° at 10 years postoperatively ($p = 0.038$) versus the preoperative value. Mean GDI score significantly improved from 69.4 preoperatively to 77.9 at 1 year postoperatively ($p = 0.003$) and continuously improved to 82.2 at 10 years postoperatively ($p = 0.017$). Single event multilevel surgery including DHL provides a favorable outcome 10 years postoperatively in patients with spastic diplegic cerebral palsy.



## 1. Introduction

Single event multilevel surgery (SEMLS) has become the standard treatment to improve gait in ambulatory patients with spastic diplegic cerebral palsy. SEMLS reduces total hospitalization times, subsequent surgeries, and the recurrences of deformities and increases the efficiency of postoperative rehabilitation [1].

Distal hamstring lengthening (DHL) is one of the most common operations performed in patients with cerebral palsy, and previous reports have shown that DHL is effective at reducing knee flexion and improving knee motion [2–10]. However, concerns have been raised that this procedure might aggravate anterior pelvic tilt, lumbar hyperlordosis, genu recurvatum, and eventually induce crouch gait [6–8]. In addition, the need for DHL has been challenged because hamstring length is not shorter in patients with a crouched gait, and because the procedure can increase the lengths of already long muscles [11]. Furthermore, there is a concern that growth spurt in patients of cerebral palsy might result in crouch gait in patients that have undergone DHL at an early age [2].

Few studies have addressed the long-term effects of SEMLS with DHL in spastic diplegia [12,13], and the controversy regarding the merits of DHL continues. In addition, it is questionable whether functional improvements after surgery are maintained into adulthood and how long improvements last. Long-term follow-up studies are necessary to help surgeons predict the outcome of surgery undertaken to improve gait.

Therefore, this study was performed to investigate the long-term outcome of SEMLS including DHL in patients with cerebral palsy (GMFCS level I–III), and we focused on the kinematic changes of patients in this study.

## 2. Materials and methods

This retrospective study was approved by the institutional review board (IRB protocol number, B-0809/061-101) of our hospital, a tertiary referral center for cerebral palsy. The study inclusion criteria were as follows: (1) ambulatory patients

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with cerebral palsy and spastic diplegia (GMFCS level I-III), (2) patients who underwent single event multilevel surgery, including bilateral distal hamstring lengthening (DHL) between 1995 and 2000, and (3) patients who had preoperative 3D gait analysis and postoperative 3D gait analysis at 1 year and at 10 years or more. Patients with a concurrent neuromuscular disease, other than cerebral palsy, or with a history of gait correcting surgery or selective dorsal rhizotomy were excluded. Gender and age at the time of surgery and details of surgical procedures were obtained from medical records. Relevant parameters from preoperative gait analysis were compared with those from over 1 and 10 years postoperative gait analysis.

### 2.1. Operative protocols

Single-event multilevel surgeries were performed by one pediatric orthopaedic surgeon between 1995 and 2000. Preoperative 3D gait analysis was used to plan procedures and indications for individual procedures were consistent with medical understanding at the time of treatment. Surgical procedures were performed based on considerations of both clinical and gait analysis findings (Table 1). All patients underwent bilateral DHL, which was composed of gracilis lengthening, semitendinosus tendon transfer to the adductor magnus, and aponeurotic lengthening of the semimembranosus [14]. Following surgery, each patient received standard postsurgical care, which included casting or bracing, to maintain deformity correction. All patients were placed in a knee immobilizer and patients that underwent tendo-Achilles lengthening (TAL) or bony surgery in the foot were placed in a short leg cast. All patients had a non-weight bearing period of 3–6 weeks after surgery. Standing and weight bearing were resumed with or without leaf-spring type ankle foot orthoses, which were worn for 3 months. Subsequently, patients were referred back to a local rehabilitation center to continue muscle-strengthening exercises and gait training. During this period, ankle foot orthoses were recommended at night only to prevent the recurrence of Achilles tightness.

### 2.2. Acquisition of kinematic data, temporal data, and gait deviation index

3D Gait analysis was performed a few days before surgery using a Vicon 370 apparatus (Oxford, United Kingdom) equipped with seven CCD cameras and two force plates. Markers were placed as for the Helen Meyer marker set [15] by a single operator with 17 years of experience, who also performed data processing (Fig. 1). Patients were asked to walk barefoot on a 9 m walkway three times with an interval of approximately 30 s, and the mean kinematic data and temporal parameters of the three trials were archived. 3D gait analysis was repeated at more than 1 and 10 years postoperatively. The gait deviation index (GDI) were calculated using pelvic and hip kinematic data in all three planes, knee and ankle data in the sagittal plane, and foot progression with control data as described by Schwartz [16]. A GDI score of >100 denotes a non-pathological gait, and each 10-point decrement below 100 indicates 1SD deviation from normal kinematics. Relevant kinematic parameters, including the mean pelvic tilt, minimum hip flexion, maximum hip flexion in early stance, maximum hip flexion in late swing, mean hip adduction, mean hip rotation, knee flexion at initial contact, minimum knee flexion in stance, peak knee flexion in swing, knee range of motion, knee flexion in terminal swing, ankle dorsiflexion at initial contact, peak ankle dorsiflexion in stance, peak ankle dorsiflexion in swing, and the mean foot progression in stance, temporal parameters, and GDI values, were considered as the outcome measures.

### 2.3. Statistical methods

To achieve statistical independence, only data from one limb per patient was included in the statistical analysis [17]. Preoperative temporal parameters, kinematics, and GDI were compared with values obtained at 1 and 10 years postoperatively using repeated measures analysis of variance (ANOVA) with a Bonferroni post hoc test. Statistical analyses were conducted using SPSS for Windows (version 18.0; SPSS, Chicago, Illinois), and $p$ values $< 0.05$ were considered significant.

## 3. Results

Between 1995 and 2000, 104 children with spastic diplegia underwent SEMLS with bilateral DHL at our institution. Of these, 88 patients had preoperative 3D gait analysis and postoperative 3D gait analysis at 1 year. Of the 88 patients, 29 had also over 10 year postoperative 3D gait analysis and were finally included in this study.

Mean age of 29 patients at time of first surgery was $8.3 \pm 2.6$ years (range, 5.4–16.3 years), and there were 18 males and 11 females. The mean age of the 15 patients at the time of second surgery was $12.3 \pm 4.4$ years. Mean time from first surgery to last 3D gait analysis was $11.8 \pm 1.1$ years. The total number of surgical procedures performed at first operation was 213 (7.3 per patient), 49 at second operation (15 patients, 1.7 per patient) and 5 at third operations (2 patients, 0.2 per patient). Eight patients (15 limbs) underwent repeated distal hamstring lengthening at the second operation. Rectus femoris transfer (RFT) was performed in 29 limbs of 16 patients at first operation and in 11 limbs of 6 patients at second operation (Table 2).

### 3.1. Temporal parameters

Stride length significantly increased from 78.9 cm/s preoperatively to 87.8 cm/s at 1 year postoperatively ($p = 0.01$) and continually increased to 103.0 cm/s at 10 year postoperatively ($p < 0.001$). Walking speed unchanged at 1 year postoperatively, but increased significantly from 72.3 cm/s at 1 year postoperatively to 87.0 cm/s at 10 years postoperatively ($p = 0.001$). However, cadence was not changed significantly ($p = 0.136$) (Table 3).

### 3.2. Kinematic parameters

Mean pelvic tilt did not change significantly after SEMLS ($p = 0.393$) and was 17.8 preoperatively, 18.6 at 1 year postoperatively, and 16.8 at 10 years postoperatively. Mean knee flexion at initial contact and knee flexion during terminal swing decreased from 31.1° and 31.4° preoperatively, respectively to 26.0° and 25.9° at 1 year postoperatively, respectively ($p = 0.065$ and 0.088). But it decreased significantly to 23.6° and 23.0° 10 years postoperatively ($p = 0.038$ and 0.015, respectively) versus preoperative values (Table 3).

Mean ankle dorsiflexion at initial contact and mean peak ankle dorsiflexion in the swing phase increased slightly from 1.8° and 9.8° preoperatively to 7.1° and 14.5° at 1 year postoperatively ($p = 0.059$ and 0.469). But it decreased significantly to 1.2° and 7.1° at 10 year postoperatively versus preoperative values ($p = 0.011$ and 0.017, respectively) (Table 3).

Mean hip rotation decreased from 10.1° preoperatively to 4.4° at 1 year postoperatively ($p = 0.484$), and further decreased to −1.0° at 10 years postoperatively ($p = 0.01$) versus the preoperative value. Mean foot progression in stance improved from −0.2° preoperatively to −8.9° at 1 year postoperatively ($p = 0.011$) and this improvement was maintained at −9.7° at 10 years postoperatively ($p = 1.0$) (Table 3).

**Table 1**
Surgical principles of major procedures included in single event multilevel surgery at Seoul National University Bundang Hospital (SNUBH).

| Procedure | Clinical criteria | Gait analysis criteria |
|---|---|---|
| Intramuscular psoas lengthening | Flexion contracture > 15° | Decreased hip extension |
| Adductor tenotomy | Hip abduction < 20° | Decreased hip abduction |
| Distal hamstring lengthening | Increased popliteal angle | Increased knee flexion at initial contact/terminal swing |
| Rectus femoris transfer | Duncan-Ely test (+) | Decreased/delayed peak knee flexion |
| Tendo achilles lengthening | Equinus deformity with Silfverskiöld test (−) | Decreased dorsiflexion in stance, abnormal rocker, and foot drop in swing |
| Strayer procedure | Equinus deformity with Silfverskiöld test (+) | Decreased dorsiflexion in stance and abnormal rocker |
| Femoral derotation osteotomy | Increased femoral anteversion | Internal foot progression with increased hip internal rotation |