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Long-term outcomes after multilevel surgery including rectus femoris, hamstring and gastrocnemius procedures in children with cerebral palsy

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ABSTRACT

Background/Aims: Multilevel surgical intervention is a common approach for the correction of gait abnormalities in children with cerebral palsy (CP). The short-term outcomes for the combination of rectus femoris transfer, hamstring lengthening and gastrocnemius lengthening have been well documented using three-dimensional motion analysis. However, the impact of time, growth, and puberty on these short-term outcomes of this combination of procedures is not well understood. The purpose of this study was to evaluate the long-term outcomes of these procedures on gait in patients with CP.
Methods: Twenty-two patients underwent rectus femoris transfers, medial hamstring lengthenings and gastrocnemius lengthenings in combination with a selection of other soft tissue and/or bony procedures of the lower limb. All patients had a pre-operative motion analysis and post-operative analysis one and 11 years following surgery.
Results: Significant changes in both clinical and gait variables from pre to 1 year post surgery confirmed the short-term gait benefits of this combination of surgical procedures. Long-term follow-up data indicated that the passive range of motion gains noted 1 year after surgery were lost at the knee and ankle. However, the improvements in ankle dorsiflexion and knee extension at initial contact were maintained over 11 years. As well, peak ankle dorsiflexion in stance was maintained and peak ankle plantar flexor moments and powers did not show declines long-term. Peak knee flexion showed a decline over the long-term, however, the timing of peak knee flexion in swing was maintained.
Conclusion: When compared to declines in gait kinematics in persons with CP without surgery, these results demonstrate the possible long-term benefits of surgical intervention.

1. Introduction

Single event multilevel surgery (SEMLS) has been shown to improve short-term ambulation and other functions in children with cerebral palsy (CP) [1–5]. The evaluation of long-term outcomes in the pediatric population is particularly relevant as continued growth and weight gain associated with puberty may impact the initial benefits of pre-pubescent surgery. Understanding long-term outcomes will help families and providers establish realistic expectations and treatment goals, and assist in planning for future support. This knowledge will also impact future surgical decision-making in pediatric patients and ultimately improve surgical outcomes.

Mid-term surgical outcomes, 3–5 years post-surgery, have shown that the majority of children with CP demonstrate benefits from SEMLS including improvement in ankle kinematics [6], knee flexion [7,8], mean hip rotation, and foot progression [9], as well as the gait profile score and the Gross Motor Function Measure 66 [10]. However, Saraph et al. reported a reduction in gait function in terms of kinematic, temporal, and stride parameters post-surgery [11]. Although these studies contribute to our understanding of mid-term outcomes, they are limited to 5 years post surgical follow-up, have small samples with wide age ranges, and often include different surgical procedures for each patient.

Dreher et al. used a slightly different approach to study the effects of a specific procedure 9 years post SEMLS. They evaluated the impact of intramuscular recession of the gastrocnemius on ankle outcomes only and found ankle kinematics were maintained 9 years post-surgery; however, there was a loss of passive dorsiflexion range [12]. Dreher et al. also evaluated outcomes of distal rectus femoris transfer on knee flexion in swing [13] and

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hamstring lengthening on knee function in stance [14]. The results of these studies indicated improved knee function were maintained in swing but declined in stance in many patients. It is unclear from these studies how the other procedures, which varied among subjects, included in the SEMLS to address issues at the adjacent joints may have impacted the joint of interest. Since motion at one lower extremity joint impacts motion at adjacent joints, it is critical to include subjects who have similar kinematics prior to surgery, have the same primary surgery and analyze the impact of that surgery at all lower extremity joints.

Increased knee flexion at initial contact and in stance, reduced and/or delayed peak knee flexion in swing, and toe walking are common gait deviations in children with CP [15] and are typically treated with simultaneous gastrocnemius, hamstring and rectus femoris (G/H/RF) procedures. The goal of performing these three procedures simultaneously is to optimize outcomes at the hip, knee, and ankle joints. In a recent study, Adolfsen et al. evaluated the outcomes of these same surgical procedures on patients with CP with either crouch or jump knee and stiff knee in swing and found evidence of short-term improvements in knee and ankle kinematic and kinetic function [1]. It is unclear as to whether these outcomes can be maintained long-term following puberty. Therefore, the purpose of this study was to evaluate long-term outcomes of G/H/RF procedures in children with CP using motion analysis techniques. It is hypothesized that benefits at the knee and ankle seen 1 year post surgery will be maintained 10 years after surgery.

2. Methods

2.1. Subjects

At the study institution, the standard of care for ambulatory patients with CP includes motion analysis for surgical treatment decision-making. Following IRB approval, prospective subjects who met the inclusion criteria were identified and contacted. Subjects were included if they were diagnosed with CP, had in the following order; a pre-operative gait analysis, orthopaedic surgery, 1 year post-operative gait analysis and were approximately 10 years out from their surgical intervention. Subjects were excluded if they had any lower extremity orthopaedic surgery following the initial post-operative gait analysis, had a selective dorsal rhizotomy or were diagnosed with other neuromuscular diseases. A subset of subjects who underwent G/H/RF procedures was selected for this analysis.

2.2. Gait analysis

Each subject underwent a pre-operative (P0) and post-operative (P1) gait analysis within 6 months prior to surgery and approximately 1 year after surgery. The analyses included: video, physical examination, surface electromyography (EMG), and motion analysis. A second post-operative gait analysis (P2) was performed using the same data collection procedures as the two previous analyses. Motion analysis data were collected using a VICON 512 motion measurement system (VICON Motion Systems, Inc., Los Angeles, CA). Joint kinematics were computed utilizing standard protocols [16] and angle definitions [17]. Three AMTI (Advanced Mechanical Technology Inc., Watertown, MA) force platforms were used to acquire ground reaction forces and kinetics were calculated using Newtonian mechanics [18]. Dynamic electromyographic data (EMG) were collected on selected muscles using an MA300 EMG system (Motion Lab Systems, Baton Rouge, LA). Workstation and Polygon software (VICON Motion Systems, Los Angeles, CA) and MATLAB (MathWorks Natick, MA) were used for data processing, computation and presentation.

Retro-reflective markers were aligned with specific bony landmarks on the lower extremities, pelvis, and trunk following standard protocols [19]. Each subject walked on a 20 m path until three strides were collected per side including force plate data if possible. All trials were collected barefoot and with braces (when applicable) at the subject's self-selected walking velocity.

2.3. Surgery

All subjects underwent surgical intervention which included rectus femoris transfer or release, intramuscular hamstrings lengthening (medial only or medial and lateral) and gastrocnemius lengthening with the understanding of the treatment indications at the time. Surgical procedures were completed following standard techniques for the gastrocnemius [12] and hamstring lengthenings [20] and distal rectus femoris transfer [13]. The distal rectus femoris release was performed early in this cohort (1987–1988) by isolating the rectus femoris from the underlying vastus intermedius through a horizontal incision approximately 3–4 finger breadths above the patella. A 2 cm tendinous portion of the rectus femoris was then resected. This release was abandoned after initial short-term results showed better outcomes with the rectus femoris transfer. There were two patients who underwent semitendinosis transfers to the distal femur in 1989. The transfer procedure represented surgical practice during the first 2 years of the study period and was subsequently abandoned due to limitations in attaining optimal hip flexion at P1. All subjects were prescribed standard postoperative rehabilitation protocols following surgery.

2.4. Analysis and statistics

A single representative barefoot trial was selected for analysis for each subject based upon visual assessment of multiple trials of kinematic and kinetic data. Statistical analysis was performed using SAS 9.3 (SAS, Cary, North Carolina). A single factor one-way ANOVA with an alpha level of 0.05 was used to compare the selected parameter at each of the evaluations. If a statistically significant change in a parameter of interest were noted, a Tukey HSD post-hoc analysis was performed to determine which of the evaluations was driving the finding. Each parameter was checked to ensure that the normality assumption for an ANOVA model held. Normality was determined through visual inspection of the normal plot of the residuals, as well as with the Shapiro-Wilk normality test. If the Shapiro-Wilk test had a p-value greater than or equal to 0.10 the data were considered normally distributed. If the analyzed parameter was found to violate the normality assumption, the analysis was re-run using a Kruskal–Wallis one-way analysis of variance, with an alpha level of 0.05, which takes into account non-normal data. If the Kruskal–Wallis test resulted in a statistically significant result, a Mann–Whitney post hoc analysis was performed to determine which comparison drove the significant finding.

3. Results

3.1. Subjects

Two hundred and seventy-five children with CP who underwent SEMLS with pre and post-operative motion analyses between 1987 and 1999 were identified (Table 1). Of these subjects, 36 were excluded due to previous selective dorsal rhizotomy and 55 were excluded due to additional lower extremity orthopaedic surgery within 10 years following P1. Of the remaining 184 patients, 70 were successfully contacted. Of these 70 patients, one was not able to find transit, one was not ambulatory and 17 declined to participate leaving 51 who agreed to participate in this study. A