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Original article

GASTROCNEMIUS RECESSION IN AMBULATORY AND NON-AMBULATORY CHILDREN WITH CEREBRAL PALSY

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Abstract

Introduction: Equinus deformity is common in children with cerebral palsy (CP). Persistent fixed restriction after botulinum toxin type A (BoNT-A) treatment may require surgical lengthening. This study compared changes after gastrocnemius recession (GR) between ambulatory and non-ambulatory children with CP previously treated with BoNT-A.

Materials and methods: This retrospective comparative study included 39 children with CP who underwent GR after prior BoNT-A treatment. GMFCS I-III were classified as ambulatory and GMFCS IV-V as non-ambulatory. Passive ankle dorsiflexion with the knee flexed and extended and calf spasticity using the Modified Ashworth Scale (MAS) were assessed preoperatively and postoperatively. Bilateral limb-level dorsiflexion measurements were averaged within each patient for inferential analyses.

Results: Twenty-one children were ambulatory and 18 were non-ambulatory patients. Mean knee-flexed dorsiflexion increased from 6.43° to 16.17° in ambulatory patients and from 5.33° to 10.72° in non-ambulatory patients; mean improvement was 9.74° *versus* 5.39° ($p<0.001$). Knee-extended dorsiflexion increased from 4.83° to 12.52° and from 3.75° to 9.97°, respectively; mean improvement was 7.69° *versus* 6.22° ($p=0.002$). MAS decreased significantly within both groups.

Conclusion: GR was associated with significant improvement in passive ankle dorsiflexion in both groups. Ambulatory patients achieved greater correction, while improvement in non-ambulatory patients remained clinically relevant.

Keywords: cerebral palsy; equinus; gastrocnemius recession; botulinum toxin; dorsiflexion; spasticity; GMFCS

Introduction

Equinus is one of the most frequent lower-limb deformities in children with cerebral palsy (CP). The deformity may initially be dynamic, reflecting excessive plantar-flexor activity, and may progress with growth to fixed musculotendinous shortening and restriction of passive ankle dorsiflexion. The severity and functional consequences of equinus vary substantially across children with CP and are influenced by motor distribution, age, gross motor function, and the presence of fixed contracture[1-4].

Botulinum toxin type A (BoNT-A) is widely used to reduce focal spasticity in children with dynamic equinus. Randomized trials have demonstrated short-term reductions in calf tone and improvements in selected clinical and gait outcomes after injection into the gastrocnemius-

soleus complex[5-8]. A recent systematic review of conservative management also found evidence that BoNT-A can improve gait-related outcomes and, when combined with physical therapy, passive ankle dorsiflexion in ambulatory children with spastic equinus[9-11]. However, BoNT-A primarily addresses excessive muscle activity; it does not directly correct established fixed shortening of the musculotendinous unit.

When equinus becomes fixed, surgical lengthening may be considered. Procedures include gastrocnemius recession, gastro soleus aponeurotic lengthening, and Achilles tendon lengthening. A systematic review of surgical correction of equinus in CP highlighted substantial heterogeneity in patient selection, operative technique, outcome assessment, and follow-up, and emphasized that age and CP phenotype may influence recurrence and overcorrection[2].

Gastrocnemius recession can improve static and dynamic ankle dorsiflexion in appropriately selected ambulatory children. Kay *et al.,* reported significant improvements after GR or Achilles tendon lengthening in ambulatory children undergoing multilevel surgery[4]. El-Sobky subsequently reported significant improvements in passive dorsiflexion, calf spasticity, and clinical gait pattern after distal GR in ambulatory children with spastic CP; the study included only GMFCS I-III patients and specifically excluded previous botulinum toxin treatment[3].

Consequently, less is known about how the clinical response to GR differs between ambulatory and non-ambulatory children who have already received BoNT-A. Gait-based outcomes cannot be applied uniformly to GMFCS IV-V patients, whereas passive ankle dorsiflexion and clinically assessed muscle tone can be measured across the functional spectrum. The purpose of the present study was therefore to compare postoperative changes in passive ankle dorsiflexion and calf spasticity between ambulatory and non-ambulatory children with CP previously treated with BoNT-A. We hypothesized that both groups would improve after GR, but that the magnitude of improvement would differ according to ambulatory status.

Materials and methods

Study design and participants

A retrospective comparative cohort study was performed using clinical records spanning approximately 2 years of children with cerebral palsy who underwent gastrocnemius recession for equinus deformity after previous treatment with botulinum toxin type A at the University Clinic for Orthopedic Surgery, TOARILUC, Clinical Center Mother Teresa, Skopje, Republic of North Macedonia.

The available dataset contained 39 patients and 72 operated limbs. Twenty-one patients were classified as ambulatory (GMFCS I-III) and 18 as non-ambulatory (GMFCS IV-V), based on the Gross Motor Function Classification System. The ambulatory and non-ambulatory groups each contributed 36 operated limbs. Fifteen ambulatory patients and all 18 non-ambulatory patients underwent bilateral procedures.

All patients had spastic cerebral palsy, including spastic quadriplegia, diplegia, and hemiplegia, and all had a positive Silfverskiöld test. Inclusion criteria were: (1) spastic cerebral palsy, (2) equinus deformity with a positive Silfverskiöld test, and (3) previous treatment with botulinum toxin. The exclusion criterion was previous operative treatment for equinus deformity, including previous gastrocnemius recession or Achilles tendon lengthening.

Previous botulinum toxin treatment

All patients had previously been treated with abobotulinumtoxinA (Dysport®). Each patient received three treatment sessions at 3-month intervals. At each session, injections were administered at two sites targeting the medial and lateral heads of the gastrocnemius muscle. The dose was calculated according to body weight and ranged from 5 to 15 U/kg.

Surgical procedure and postoperative management

A longitudinal incision approximately 2-5 cm in length was made over the posterior calf at the level of the gastrocnemius musculotendinous junction. Before incision of the deep fascia, the sural nerve was identified and carefully protected, either superficial or deep to the fascia according to its anatomical course.

A transverse incision was then performed at the level where the gastrocnemius aponeurosis and soleus fascia fuse to form the conjoined tendon.

Following completion of the recession, an above-knee plaster cast was applied for 2 weeks, with the knee maintained in approximately 15° of flexion during immobilization.

Clinical outcome measures

Passive ankle dorsiflexion was recorded in degrees with the knee flexed and with the knee extended. The dataset variables were: DF1KF (preoperative dorsiflexion with knee flexed), DF2KF (postoperative dorsiflexion with knee flexed), DFKE1 (preoperative dorsiflexion with knee extended), and DFKE2 (postoperative dorsiflexion with knee extended). The change in dorsiflexion was calculated as postoperative minus preoperative value, such that a positive value represented increased dorsiflexion.

Calf spasticity was assessed using the Modified Ashworth Scale (MAS), with measurements obtained with the knee flexed and extended. The dataset variables were MAS1KF and MAS2KF for pre- and postoperative knee-flexed assessments, and MAS1KE and MAS2KE for pre- and postoperative knee-extended assessments. A negative change score represented reduced postoperative tone. MAS is an ordinal clinical scale and has known limitations in inter- and intra-rater reliability in children with CP; results were therefore interpreted cautiously [9].

All clinical measurements were performed by the same examiner. Passive ankle dorsiflexion was measured using a standard goniometer. The fulcrum was positioned over the lateral aspect of the lateral malleolus, the stationary arm was aligned parallel to the lateral midline of the fibula toward the head of the fibula, and the moving arm was aligned parallel to the lateral aspect of the shaft of the fifth metatarsal. Measurements were obtained preoperatively and again 2 weeks after removal of the plaster cast.

Statistical analysis

Descriptive statistics were calculated separately for ambulatory and non-ambulatory groups. Because some children underwent bilateral surgery, the two limb-level dorsiflexion measurements were averaged within each bilateral patient before inferential testing; each child therefore contributed one independent patient-level value. Continuous dorsiflexion variables are presented as mean ± standard deviation (SD). Preoperative and postoperative dorsiflexion within each group were compared using paired t-tests. Changes in dorsiflexion between ambulatory and non-ambulatory groups were compared using Welch's independent-samples t-test. Two-sided p values <0.05 were considered statistically significant.

Because MAS is ordinal, within-group pre- to postoperative comparisons were made with the Wilcoxon signed-rank test, and between-group comparisons of change with the Mann-Whitney U test. MAS is summarized primarily as median and interquartile range (IQR), with mean values also provided in the text to aid comparison with prior clinical studies. Age was compared using Welch's t-test and sex using Fisher's exact test. A two-sided p value <0.05 was considered statistically significant. Statistical analyses were performed using Python with the SciPy scientific computing library.

Results

Cohort characteristics

The cohort included 39 children, 21 ambulatory and 18 non-ambulatory patients. Mean age was 7.19±2.93 years in the ambulatory group and 5.72±1.84 years in the non-ambulatory group (p=0.066). The ambulatory group included 10 males and 11 females, and the non-ambulatory group included 8 males and 10 females (p=1.000). Seventy-two operated limbs were recorded, with 36 limbs in each group.

Table 1. Baseline characteristics

Characteristic	Ambulatory (n=21)	Non-ambulatory (n=18)	p value
Age, years, mean ± SD	7.19±2.93	5.72±1.84	0.066
Male / female, n	10/11	8/10	1.000
GMFCS I, n	5	0	-
GMFCS II, n	7	0	-
GMFCS III, n	9	0	-
GMFCS IV, n	0	9	-
GMFCS V, n	0	9	-
Bilateral procedures, n	15	18	-
Unilateral procedures, n	6	0	-
Operated limbs, n	36	36	-

GMFCS-Gross Motor Function Classification System, SD-standard deviation. Age compared using Welch's t-test, sex compared using Fisher's exact test

Passive ankle dorsiflexion

Both groups demonstrated significant increases in passive dorsiflexion after GR. With the knee flexed, patient-level mean dorsiflexion increased from 6.43±1.98° to 16.17±2.90° in ambulatory patients (mean change 9.74°, 95% CI 8.83-10.64; p<0.001) and from 5.33±1.46° to 10.72±1.05° in non-ambulatory patients (mean change 5.39°, 95% CI 4.80-5.98; p<0.001). Improvement was significantly greater in ambulatory patients (p<0.001).

With the knee extended, patient-level mean dorsiflexion increased from 4.83±1.24° to 12.52±2.03° in ambulatory patients (mean change 7.69°, 95% CI 6.94-8.44; p<0.001) and from 3.75 ± 0.97° to 9.97±1.17° in non-ambulatory patients (mean change 6.22°, 95% CI 5.65-6.80; p<0.001). The improvement was significantly greater in the ambulatory group (p=0.002).

Table 2. Passive ankle dorsiflexion before and after gastrocnemius recession

Outcome	Group	Preoperative, mean ± SD	Postoperative, mean ± SD	Mean change (95% CI)	Within-group p	Between-group p*
Dorsiflexion, knee flexed	Ambulatory	6.43±1.98°	16.17±2.90°	+9.74°(8.83 to 10.64)	<0.001	<0.001
	Non-ambulatory	5.33±1.46°	10.72±1.05°	+5.39°(4.80 to 5.98)	<0.001	
Dorsiflexion, knee extended	Ambulatory	4.83±1.24°	12.52±2.03°	+7.69°(6.94 to 8.44)	<0.001	0.002
	Non-ambulatory	3.75±0.97°	9.97±1.17°	+6.22°(5.65 to 6.80)	<0.001	

*Between-group p value compares postoperative change between ambulatory and non-ambulatory groups using Welch's t-test. CI-confidence interval, SD-standard deviation

Calf spasticity

Calf spasticity decreased after surgery in both groups. With the knee flexed, median MAS decreased from 2 [IQR 1-2] to 1 [0-1] in the ambulatory group (Wilcoxon p=0.001) and from 3 [2-3] to 2 [2-2] in the non-ambulatory group (p=0.003). Mean MAS change was -0.90

and -0.50 points, respectively. The between-group difference in change was not statistically significant (Mann-Whitney U p=0.133).

With the knee extended, median MAS decreased from 2 [2-2] to 1 [0-2] in ambulatory patients (p=0.001) and from 3 [3-3] to 3 [2-3] in non-ambulatory patients (p=0.025). Mean MAS change was -0.90 and -0.28 points, respectively. The change differed significantly between groups (Mann-Whitney U p=0.016), with a larger reduction among ambulatory patients.

Table 3. Modified Ashworth Scale before and after gastrocnemius recession

Outcome	Group	Preoperative median [IQR]	Postoperative median [IQR]	Median change [IQR]	Within-group p	Between-group p*
MAS, knee flexed	Ambulatory	2[1-2]	1[0-1]	-1[-2 to 0]	0.001	0.133
	Non-ambulatory	3[2-3]	2[2-2]	-0.5[-1 to 0]	0.003	
MAS, knee extended	Ambulatory	2[2-2]	1[0-2]	-1[-1 to 0]	0.001	0.016
	Non-ambulatory	3[3-3]	3[2-3]	0[-0.75 to 0]	0.025	

*Within-group p values from Wilcoxon signed-rank tests, between-group p values from Mann-Whitney U tests comparing change. IQR-interquartile range, MAS-Modified Ashworth Scale

Discussion

The main finding of this study is that passive ankle dorsiflexion improved significantly after gastrocnemius recession in both ambulatory and non-ambulatory children with CP who had previously received BoNT-A. Ambulatory children achieved a larger correction, particularly with the knee flexed. On patient-level analysis, the mean gain was 9.74° *versus* 5.39° with the knee flexed and 7.69° *versus* 6.22° with the knee extended. Thus, ambulatory status was associated with the magnitude of postoperative correction, but meaningful improvement was present in both groups.

These findings should not be interpreted as evidence that GR is ineffective in non-ambulatory patients. The non-ambulatory group demonstrated statistically significant improvement in passive dorsiflexion in both knee positions. In children who do not walk, the objectives of treatment differ from gait-oriented goals. Correction of equinus and a more plantigrade foot position may be clinically useful for hygiene and daily care, positioning of the feet and lower limbs in the wheelchair, dressing, and accommodation of footwear or orthoses. The direction of the dorsiflexion findings is consistent with previous studies of surgical calf lengthening in ambulatory CP. Kay *et al*., found significant postoperative improvement in static and dynamic dorsiflexion after both GR and Achilles tendon lengthening in selected ambulatory children[4]. El-Sobky reported significant gains in passive dorsiflexion and reduced calf spasticity after distal GR, with no significant change in static ankle strength[3]. Wren *et al.,* also demonstrated that gastrocnemius recession alters muscle-tendon behavior and ankle mechanics in children with CP and equinus gait[5].

The present study differs from much of the published surgical literature in two clinically relevant respects. First, it includes GMFCS IV-V children, for whom gait-based measures cannot serve as a universal endpoint. Second, all patients had previously been treated with BoNT-A. Randomized studies support BoNT-A for short-term reduction of plantar-flexor tone in dynamic equinus[6-8], and a systematic review supports its role among conservative strategies for ambulatory spastic equinus[11].

Spasticity decreased after GR in both groups, but the between-group pattern was less uniform than for dorsiflexion. With the knee flexed, the difference in MAS change between

groups was not statistically significant. With the knee extended, the ambulatory group demonstrated a greater reduction. This finding may reflect differences in baseline tone, fixed contracture, or the relative contribution of the gastrocnemius across knee positions. However, MAS measures resistance to passive movement rather than spasticity in isolation and has only moderate and variable reliability in children with CP[9]. The MAS findings should therefore be viewed as supportive secondary outcomes rather than as a direct physiological measure of the operative effect.

An important methodological feature of the present analysis was accounting for bilateral procedures. Although 72 operated limbs were recorded, 33 of 39 children underwent bilateral surgery. Treating all limbs as statistically independent would underestimate within-patient correlation. Therefore, bilateral dorsiflexion measurements were averaged within each patient for inferential analyses, leaving the patient as the independent statistical unit. Future studies with larger samples could retain limb-level data using mixed-effects or generalized estimating equation models.

Clinical implications

For ambulatory children, improvement in dorsiflexion may contribute to better foot positioning and facilitate gait-related goals, although gait outcomes were not measured in the present study. For non-ambulatory children, treatment goals are different and should not be judged by walking ability. A more correctable and better-positioned foot may facilitate hygiene, dressing, wheelchair foot placement, orthotic or footwear accommodation, and everyday caregiving.

Conclusion

Gastrocnemius recession was associated with significant improvement in passive ankle dorsiflexion in both ambulatory and non-ambulatory children with cerebral palsy previously treated with botulinum toxin. Ambulatory patients demonstrated a greater magnitude of correction, but non-ambulatory patients also achieved significant improvement. In non-ambulatory children, the clinical value of correcting equinus should extend beyond gait and may include easier hygiene and daily care, improved positioning of the feet and lower limbs in the wheelchair, and improved accommodation of footwear or orthoses.

Conflict of interest statement. None declared.

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