Aponeurotic release of semimembranosus: A technical note to increase correction gained with hamstring lengthening surgery in cerebral palsy

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ABSTRACT

Objective: The aim of this study was to determine the intraoperative corrective effect of the aponeurotic release of semimembranosus (SM) as a single procedure or an adjunct procedure to distal myotendinous release of semitendinosus (ST) and myofascial release of SM lengthening in the correction of knee flexion deformity in cerebral palsy (CP).

Methods: In this prospective study, 46 knees of 23 consecutive ambulatory patients (15 boys and 8 girls; mean age=8.33 years; age range=5–12 years) with spastic diplegic CP with a gross motor function classification system level (GMFCS) II or III were included. The patients were then divided into 2 groups. In group I, there were 10 patients (4 boys, 6 girls; mean age=8.6±2), and combined release of ST in the myotendinous junction and SM in the myofascial junction, followed by aponeurotic release of SM were carried out. In group II, there were 13 patients (2 girls, 11 boys; mean age=8.2±3), and aponeurotic release of SM was done first and followed by the combined release of ST in the myotendinous junction and the myofascial release of SM. Intraoperative popliteal angle (PA) measurements were recorded in each group.

Results: PA was reduced from 58.1°±7.6° (range=46°–75°) to 41.2°±8.8° (range=20°–54°) in group 1 and from 59.1°±11.3° (range=40°–87°) to 42.7°±10.8° (range=24°–64°) in group 2. No significant difference was observed between the groups in terms of reduction in PA (p=0.867). In group 1, adding the aponeurotic release of SM further reduced the PA to 31.7°±8.5° (range=24°–54°) in group 2. No significant difference between the final PA values in the 2 groups (p=0.662). There was no difference in terms of early complications.

Conclusion: Aponeurotic release of SM is equally effective to reduce the intraoperative PA with combined myotendinous release of ST and myofascial release of SM. Combining all the 3 procedures provides a better correction without forceful manipulation or lengthening of the lateral hamstrings during the correction of knee flexion deformity in CP.

Introduction

Cerebral palsy (CP) may cause a wide variety of gait disturbance patterns. Increased knee flexion during the stance phase of a gait is a common manifestation in patients with ambulatory spastic diplegia (1). Underlying etiology is multifactorial, but contracted, short, and spastic hamstrings are considered a major cause of the knee flexion deformity (2). Hamstring lengthening surgery (HLS) is widely used as a standard procedure to correct the increased knee flexion. The muscles can be lengthened through the muscle-tendon unit or at the tendon level (3-5). Previous studies have reported improvement in passive range of motion and knee extension throughout the stance phase of gait after HLS (6-8), however, outcomes have been hampered by high rates of recurrence and complications. Recurrence of the hamstring contracture may occur in up to 17% of patients (9). If both medial and lateral hamstrings are over lengthened, increased anterior pelvic tilt and genu recurvatum may occur (10-14). A common approach to avoid overlengthening is to release the medial hamstrings at the myotendinous junction of semitendinosus (ST) and the myofascial junction of semimembranosus (SM), avoiding lateral hamstring lengthening altogether. Lengthening at the muscle-tendon junction is thought to be the least disruptive option to preserve muscle function; however, with this technique, minimal acute length gain and incomplete correction of the knee flexion deformity may occur. In an attempt to improve correction without resorting to forceful intraoperative manipulation or lengthening the lateral hamstrings, the release of the aponeurotic band of SM can be used in addition to the release of ST in the myotendinous junction and myofascial release of SM (15). We designed this study to compare the intraoperative corrective effect of the aponeurotic release of SM with the combined myotendinous release of ST and myofascial release of SM, as a single procedure alone or its contribution to correction when all 3 techniques are combined.

Materials and Methods

After institutional review board approval (decision/protocol number: GO 18/983), a prospective study on consecutive ambulatory patients with spastic diplegic...
CP having gross motor function classification system levels (GMFCS) II or III was conducted. Included patients were managed with HLS as part of a single event multilevel surgery (SEMLS) between 2016 and 2018. Our indications for HLS were excessive knee flexion in terminal swing and mid-stance in observational gait analysis and a popliteal angle >60° on the physical examination, which does not change more than 20° with hamstring shift test. The same surgical team performed all the surgical procedures. Patients who underwent concomitant osteotomy, patellar tendon shortening, or tendon transfer around the knee joint were excluded from this study. In the included patients, concomitant soft tissue surgeries included iliopsoas, adductor longus, adductor brevis, gracilis, triceps surae, and tibialis posterior fractional lengthening at the musculotendinous junction. Collected data were age, sex, GMFCS level, concomitant surgical procedures, and intraoperative popliteal angle (PA) measurements. Postoperative complications, including excessive bleeding, neurological complications, and wound healing, were noted.

Patients were divided into 2 groups. In group 1, combined release of ST in the myotendinous junction and SM in the myofascial junction were followed by aponeurotic release of SM. In group 2, aponeurotic release of SM was done first, followed by the combined release of ST in the distal myotendinous junction, and the myofascial release of SM. Eventually, the same procedures were done on each group, and the only difference between groups was the sequence of the muscle lengthening procedures. All soft tissue releases around the hip joint, including iliopsoas, hip adductors, and proximal gracilis, were done before distal HLS. If necessary, distal gracilis lengthening in the myotendinous junction was done after completion of the medial hamstring release (including myotendinous release of ST, myofascial release of SM, and aponeurotic lengthening of SM). Postoperatively, a knee immobilizer was applied to the operated extremity with the knee at full extension and worn for 2 weeks. All the patients were discharged from the hospital on the day after surgery.

**Surgical technique**

The anatomy of the aponeurotic band of SM and its relationship with other important anatomic structures are shown in detail with cadaveric dissection (Figure 1). The release of the thick aponeurosis more distally by splitting the distal SM muscle fibers was previously described by Jones et al. (15). We modified the level of this release by making a transverse stripe about 15 cm proximal to the popliteal skin crease, where the aponeurotic band is sturdy and not covered by SM muscle belly (Figure 1b). Medial hamstring release was done in the supine position with a posterior longitudinal incision over the medial hamstrings, approximately 10 cm proximal to the popliteal skin crease. ST was isolated, overlying sheath opened longitudinally, and 1 transverse stripe using #15 scalpel blade performed at the myotendinous junction, preserving the muscle belly. Myofascial release of SM was also done at the same level with the ST as 1 transverse stripe without damaging the muscle. For the aponeurotic lengthening of SM, the lengthening site was approximately 5 to 8 cm more proximal than the myotendinous release of ST and myofascial release of SM sites using the same incision. Exposing further the interval between ST and SM muscles (Figure 1a), there is a thick aponeurotic band at the anterior aspect of the SM muscle belly that is separate from the myofascial junction in the posterior aspect of SM. This thick band is exposed in the anterior aspect of SM proximally. However, as it traverses distally, it becomes covered circumferentially by the SM muscle belly at the level of myofascial release of SM.

**Evaluation of the popliteal angle**

The effect of HLS in the correction of knee flexion deformity was assessed with intraoperative PA measurement. The PA was evaluated with the patient supine and under general anesthesia. The examined limb was brought to 90° of hip and knee flexion with the contralateral limb in full extension. The angle formed by the tested tibia and an imaginary vertical line at the moment of knee extension that initiated pelvic rotation was measured as PA (16-18). Photographs were then obtained from the lateral side of the patient at a standard distance and height from the patient (1-meter distance, at the level of the knee joint) (Figure 2). PA measurements were performed on digital photographs using a software program (Surgimap®, a Nemaris Inc.™). First, the baseline PA was measured in all the patients in both groups. In group 1, PA was then measured again after myotendinous lengthening of ST and myofascial lengthening of SM, followed by a third measurement after the aponeurotic release of SM. In group 2, PA was measured again after the aponeurotic release of SM, which was followed by a third measurement after myotendinous lengthening of ST and myofascial lengthening of SM. A total of 2 independent observers blinded to each other did all the measurements separately.
Results
The study included 46 knees of 23 patients (15 boys and 8 girls) with an average age of 8.33±2.2 (range 5–12) years. Of these, 7 patients were at GMFCS level II and 16 at level III. No patients had previously undergone orthopedic surgery. No patients had fixed knee flexion contractures. Most patients underwent additional concomitant muscle lengthening procedures as a part of SEMLS (Table 1). There were 10 patients (20 knees) in group I and 13 patients (26 knees) in group II. The baseline characteristics of the patients are shown in Table 2. There were no significant differences between the groups in terms of age at surgery, GMFCS level, or baseline PA. Male predominance was noted in group 2 but not in group 1 (p=0.039). Mean baseline PA was reduced from 58.1°±7.6° (range 46°–75°) to 41.2°±8.8° (range 20°–54°) with the myotendinous release of ST and myofascial release of SM in group 1. In group 2, baseline PA was reduced from 59.1°±11.3° (range 40°–87°) to 42.7°±10.8° (range 24°–64°) with the aponeurotic lengthening of SM only. Reductions obtained in PA with the myotendinous release of ST and myofascial release of SM in group 1 and by the aponeurotic release of SM in group 2 were both statistically significant (p<0.001). There was no significant difference between reductions obtained in the PA with the first surgical steps in each group (p=0.867). Moreover, in group 1, adding the aponeurotic release of SM further reduced the PA to 31.7°±8.5° (range 14°–47°) (p=0.002), and in group 2, adding the myotendinous release of ST and myofascial release of SM further reduced the PA to 32.9°±7.2° (range 16°–44°) (p=0.004). There was no significant difference between the 2 groups in terms of final PA measurements (p=0.662). The interobserver reliability test revealed excellent reliability with an ICC value of 0.946. We did not encounter any complications, such as excessive bleeding, nerve palsy, significant pain, or infection.

Discussion
Surgical lengthening of contracted hamstrings is an integral component in the surgical treatment of knee flexion deformity in patients with CP. A delicate balance between recurrence and over-correction exists, and any excessive surgical attempt may provoke iatrogenic hamstring insufficiency. Outcomes have been inconsistent after hamstring lengthening: some patients have significant improvement, but others experience little benefit or even deterioration (13, 19). Therefore, fine-tuning the surgical dose is essential. Classical teaching for surgical lengthening of the muscle-tendon unit in children with CP has emphasized complete acute correction of the myostatic deformity. Reduction of the intraoperative PA below 30° is recommended by some authors after HLS (16, 20). However, it is not always possible to achieve the desired amount of correction with myofascial medial hamstring lengthening alone. Additional lengthening can be achieved with forceful manipulation and postoperative immobilization of the knee at maximum extension (6, 7, 21). However, intraoperative manipulation may permanently damage the underlying muscle fibers, causing iatrogenic hamstring weakness or even iatrogenic sciatic nerve injury (8, 9). Alternatively, lateral hamstrings can be addressed. The consequence of excessive lengthening of both medial and lateral hamstrings may cause an overcorrection that could manifest as increased anterior pelvic tilt or genu recurvatum (10-13). Another strategy is to perform only single stripes in the musculotendinous junction of the medial hamstrings without acute intraoperative stretching and to allow spontaneous separa-

Table 1. List of concomitant soft tissue release procedures

| Concomitant procedure | Number of procedures |
|-----------------------|----------------------|
| Patas FL              | 22                   |
| Adductor release      | 16                   |
| Gracilis release (proximal) | 10         |
| Gracilis release (distal) | 14       |
| Gastrocnemious FL     | 32                   |
| Tibialis posterior FL | 4                    |

Table 2. Summary of patient demographic data

| Parameter         | Group I [n=10] | Group II [n=13] | P   |
|-------------------|----------------|-----------------|-----|
| Sex               | Men            | Women           | 0.039*|
|                   | 4              | 6               |     |
| Age (years)       | 8.6±2          | 8±2.35          | 0.522|
| GMFCS level       | 3              | 4               | 0.66 |
| II                |                |                 |     |
| III               | 7              | 9               |     |
| Baseline PA (°)   | 58.1°±7.6°     | 59.1°±11.3°     | 0.731|
| 1st lengthening   | 41.2°±8.8°     | 42.7°±10.8°     | 0.867|
| 2nd lengthening   | 31.7°±8.5°     | 32.9°±7.2°      | 0.662|

*For group 1, myotendinous lengthening of ST and the myofascial lengthening of SM. For group 2, aponeurotic release of SM.

Statistical analyses were performed using Statistical Package for the Social Sciences version 22 (IBM SPSS Corp.; Armonk, NY, USA), and statistical significance was defined as p<0.05. Normality of the variables was examined using Shapiro–Wilk test. Accordingly, it was seen that all scales displayed a normal distribution. Descriptive statistics were presented as mean ± standard deviation. Student’s t-test was used to compare the differences between groups. Repeated measure two-way analysis of variance (ANOVA) was used to compare between pre-and postoperative PA values. The intra-class correlation coefficient (ICC) was used to determine the inter-observer reliability of all PA measurements. Power analysis in this study were determined on the primary outcome measure between the 2 treatment groups in terms of reduction in the PA. A post-hoc statistical power was calculated as 88%, using n=46, α=0.19, and α=0.05.

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tion with postoperative gradual stretching through physiotherapy (22). Although this approach would be less disruptive to the muscle; however, it may result in minimal acute length gain and incomplete correction of the knee flexion deformity. According to our results, a combination of the aponeurotic band of SM with the myotendinous lengthening of ST and the myofascial lengthening of SM may be an alternative to forceful manipulation or lateral hamstring lengthening. Proximal release of SM from the ischial origin was a standard procedure in the 80s but lost its popularity with time. Previous studies have reported that proximal hamstring release effectively addresses the knee flexion deformity (23-25). To our knowledge, there is no previous study comparing proximal versus distal hamstring lengthening. Release of the aponeurotic band of SM in CP-related knee flexion deformity was first described by Jones et al. (15). In their study, the authors undertook cadaveric dissection to define SM muscle anatomy and evaluated the clinical impact of the release of its proximal aponeurotic band on PA correction. The authors anatomically described the aponeurosis as a constant band separate from the well-known myofascial junction. Division of this aponeurotic band after myotendinous release of ST and myofascial release of SM provided further correction of the PA. However, the efficacy of this technique was not supported by any further study.

The main limitation of our study is the absence of postoperative kinematic analysis that could objectively assess the clinical implications of the procedure. We assessed the correction achieved by the procedure with intraoperative PA measurements, which is known to have low inter-observer reliability and poor correlation with kinematic parameters, making it unreliable for decision-making in HLD (26, 27). However, PA is the only objective tool for assessing knee flexion deformity intraoperatively. Per our results, the release of the aponeurotic release of the SM makes a significant contribution to intraoperative PA correction without causing early complications such as excessive blood loss or nerve injury. As our next step, we are planning to conduct another study to evaluate the possible implications of the aponeurotic release of SM in the sagittal kinematic parameters of the pelvis and knee using instrumented gait analysis.

In conclusion, the aponeurotic release of SM provides equal intraoperative PA correction compared with the combined myotendinous release of ST and myofascial release of SM. Combining all 3 procedures resulted in a better overall correction without forceful manipulation or lengthening of the lateral hamstrings.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethical Committee of Hacettepe University (decision/protocol number: GO 18/983).

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