Long-term results after single event multilevel surgery for the correction of gait disorders in spastic diplegic cerebral palsy

PhD dissertation

Dr. Dóra Végvári

Semmelweis University
Clinical Medicine of Doctoral Studies

Consultant: György Szőke MD, DSc

Reviewers: Rita Kiss, PhD, DSc
Zsuzsanna Miklós, MD, PhD
President of examiners' committee: Imre Oláh MD, DSc
Members of examiners' committee: Kinga Karlinger MD, CSc
Jenő Kiss MD, CSc

Budapest

2015

1. Introduction

1.1. Development of knee function after hamstring lengthening as a part of multilevel surgery in children with spastic diplegia

Increased knee flexion in stance phase called flexed knee gait, is one of the most common gait abnormalities in spastic diplegia. There are some factors which lead to a flexed knee gait: hamstring spasticity, external tibial torsion, instability of the foot and quadriceps weakness. Evidence for the effectiveness of hamstring lengthening to correct flexed knee gait in spastic diplegia is scant because of small and inhomogeneous case series, different surgical techniques, and short follow-up. As a result, hamstring lengthening currently is viewed as controversial. A major problem is that, to our knowledge, there have been no long-term studies investigating the effects of hamstring lengthening in skeletally mature patients who were managed in childhood.

1.2. Long-term results after distal rectus femoris transfer as a part of multilevel surgery for the correction of stiff knee gait in spastic diplegic cerebral palsy

Stiff knee gait is a common gait disorders in children with cerebral palsy. It is characterized by decreased knee flexion during swing phase, leading to foot clearance problems, reduced gait velocity and reduced step length. The most common cause of it is the spasticity of the rectus femoris muscle. The standard surgical technique is the distal rectus femoris transfer (DRFT) to the tendons of medial or lateral or to the iliotibial tract. Various studies described good initial results after DRFT, however other authors have noted no significant changes of peak knee flexion in swing, but an increase of total knee motion. Hence the results are inconsistent after DRFT in cerebral palsy patients with stiff knee gait. Only a few studies have addressed longer-term outcomes after distal rectus femoris transfer.

1.3. Does proximal rectus femoris release influence kinematics in patients with cerebral palsy and stiff knee gait?

Stiff gait resulting from rectus femoris dysfunction in cerebral palsy commonly is treated by distal rectus femoris transfer (DRFT), but varying outcomes have been reported. The proximal part of the rectus femoris is believed to play an important role in pelvic tilt and hip flexion. To treat hip flexor contracture and increased anterior pelvic tilt, proximal rectus femoris release can be considered. Proximal rectus femoris release was found to be less effective compared with distal rectus femoris transfer in treating stiff knee gait. No study to our knowledge has investigated the effects of the combination of both procedures on gait.

1.4. Long-term effects after conversion of biarticular to monoarticular muscles compared with musculotendinous lengthening in children with spastic diplegia

Adverse effects such as increased anterior pelvic tilt are reported after muscle-tendon lengthening (MTL) for the correction of flexed knee gait in cerebral palsy. The conversion of biarticular muscles to monoarticular muscles to monoarticular muscles (CBM) represents an alternative treatment, but only few short-term results have been published, without comparison with muscle-tendon lengthening.

2. Purpose

2.1. Development of knee function after hamstring lengthening as a part of multilevel surgery in children with spastic diplegia

The long-term results in adolescents and adults who had had hamstring lengthening as a part of multilevel surgery in childhood were investigated. Our hypothesis was that correction of flexed knee gait seen at short-term follow-up is not maintained in the long term.

2.2. Long-term results after distal rectus femoris transfer as a part of multilevel surgery for the correction of stiff knee gait in spastic diplegic cerebral palsy

The purpose of this study was the evaluation of long-term results in adolescents and adults with diplegic cerebral palsy who were treated with distal rectus femoris transfer. The indication for distal rectus femoris transfer differed between patients with decreased peak knee flexion in swing (C-DRFT) and those with normal or increased peak knee flexion in swing, in which the distal rectus femoris transfer was done as a prophylactic

procedure (P-DRFT) to preserve peak knee flexion in swing after the correction of severe flexed knee contracture in stance phase, these two groups were analysed separately.

2.3. Does proximal rectus femoris release influence kinematics in patients with cerebral palsy and stiff knee gait?

The purpose of our study was to investigate the effects of an additional proximal rectus release on the knee kinematics when done in combination with DRFT. We sought to determine whether an additional proximal rectus release affects knee and pelvic kinematics when done in combination with DRFT.

2.4. Long-term effects after conversion of biarticular to monoarticular muscles compared with musculotendinous lengthening in children with spastic diplegia

The purpose of this study was to evaluate the long-term effects of conversion of biarticular muscles in comparison with those of muscle-tendon lengthening.

The hypothesis of the present investigation was that conversion of biarticular muscles and muscle-tendon lengthening lead to comparable outcomes concerning knee kinematics, but that conversion of biarticular muscles carries less risk than muscle-tendon lengthening for increased anterior pelvic tilt and recurrence of flexed knee gait.

3. Methods

3.1.Overview

The patients were recruited from cerebral palsy ambulant of Department for Orthopaedic and Trauma Surgery, Heidelberg University Clinics. The ambulatory patients were selected for surgical correction and they regularly receive a standardized evaluation, which includes conventional 3D gait analysis and clinical examination, both before surgery and at regular follow-up examinations.

3.1.1. Clinical examination

The range of motion (ROM) of the hip, knee and ankle joints were examined according to neutral-0°method, to document the muscle shortening. For detecting hip flexion contracture, the Thomas test is used. Furthermore the arbitrary muscular strength according to MRC-scale and the grad of spasticity (modified Ashworth-scale, modified Tardieu-scale, Duncan-Ely test and popliteal angle) were analyzed.

3.1.2. 3D gait analysis

A conventional, marker-based Vicon® 3D-motion captured system was used to track the 3D positions of 25 reflective markers during walking according to Plug-in Gait marker set. The kinetic, kinematic and EMG data were collected simultaneously during level walking over a 7 m walkway. Two force plates were used to collect the kinetic data. For the collection of EMG data an 8-channel device with bipolar surfaces adhesive electrodes according for the SENIAM guidelines was used.

The kinematic, kinetic and EMG data's are transmitted by a charging amplifier to an A/D-converter. For each patient, 10 to 15 trials were recorded. All patients underwent standardized single-event multilevel surgery, including osseous and soft tissue procedures. The surgical procedures were performed according to specific criteria based on clinical examination and gait analysis.

3.1.3. Statistics

Data are presented as *mean* ± *SD, n* represents the number of subjects. Comparisons between two groups were performed with unpaired two-tailed Student's t test

and multiple group comparisons at different time points were performed applying one-way ANOVA followed by Bonferroni- post hoc test. $p<0.05$ was considered to be statistically significant.

Two types of statistical programs were used: PASW Statistics 18 and the Prism 5.

3.2. Development of knee function after hamstring lengthening as a part of multilevel surgery in children with spastic diplegia

Thirty-nine patients who had had a mean age of 10.3 ± 3.5 years at the time of surgery could be re-evaluated and were included in the present study. The patients were examined 4 point in times: before (E0), one year (E1), 2-4 years (E2), and 6-12 years (E3) after surgery. The intraoperative goal of hamstring lengthening for the correction was to achieve a popliteal angle of 20°. If the correction was still insufficient (>20° on the popliteal angle test) after medial hamstring lengthening (MHL), the biceps femoris muscle was lengthened (CHL). Postoperative management consisted of early mobilization with immediate weight-bearing.

3.3. Long-term results after distal rectus femoris transfer as a part of multilevel surgery for the correction of stiff knee gait in spastic diplegic cerebral palsy

This study investigated the long-term results for fifty-three ambulatory patients with spastic diplegic cerebral palsy and stiff-knee gait treated with standardized distal rectus femoris transfer as a part of multilevel surgery. Standardized examinations were carried out before surgery and at one year and nine years after surgery. Patients with decreased peak knee flexion in swing phase who had distal rectus femoris transfer to correct the decreased peak knee flexion in swing phase (C-DRFT) were evaluated separately from those with normal or increased peak knee flexion in swing phase who had distal rectus femoris transfer done as a prophylactic procedure (P-DRFT).

3.4. Does proximal rectus femoris release influence kinematics in patients with cerebral palsy and stiff knee gait?

Twenty patients with spastic bilateral cerebral palsy treated with DRFT and proximal rectus femoris release were matched with 20 patients in whom only DRFT was performed. Standardized three-dimensional gait analysis was done before surgery, at 1 year after surgery, and at a mean of 9 years after surgery. Basic statistics were done to compare the outcome of both groups.

3.5. Long-term effects after conversion of biarticular to monoarticular muscles compared with musculotendinous lengthening in children with spastuc diplegia

The long-term outcome of 21 diplegic patients treated with conversion of biarticular muscles to monoarticular muscles (CBM) in a prospective study was compared with the results in muscle tendon lengthening patients (MTL) in a matched-pair analysis. The standardized examinations were done before surgery, 1 year, and at 9 years postoperatively.

4. Results

4.1. Development of knee function after hamstring lengthening as a part of multilevel surgery in children with spastic diplegia

Significant improvements in kinematic parameters and the popliteal angle were noted at short-term follow-up ($p < 0.01$), supporting the results of previous studies. Long-term results showed significant deterioration of minimum knee flexion in stance and the popliteal angle ($p < 0.01$), whereas the improvements in the Gross Motor Function Classification System and Gillette Gait Index were maintained. This recurrence of flexed knee gait is partial and measurable. Increased pelvic tilt was found in 49% of the limbs postoperatively, which may represent one factor leading to recurrence of flexed knee gait. Genu recurvatum was seen in eighteen patients (twenty-seven limbs; 35%) one year postoperatively, especially in the patients with a jump knee gait pattern preoperatively. At long-term follow-up, genu recurvatum resolved in many limbs, but 12% of the limbs showed residual genu recurvatum, indicating that overcorrection represents a problem following hamstring lengthening.

4.2. Long-term results after distal rectus femoris transfer as a part of multilevel surgery for the correction of stiff knee gait in spastic diplegic cerebral palsy

A significantly increased peak knee flexion in swing phase was found in the C-DRFT group one year after surgery, while a significant loss (15°) in peak knee flexion in swing phase was noted in the P-DRFT group. A slight but not significant increase in peak knee flexion in swing phase in both groups was noted at the time of the long-term follow-up. A significant improvement in timing of peak knee flexion in swing phase was only found for the C-DRFT group, and was maintained after nine years. Knee motion and knee flexion velocity were significantly increased in both groups and were maintained at long-term follow-up in the C-DRFT group, while the P-DRFT showed a deterioration of knee motion.

4.3. Does proximal rectus femoris release influence kinematics in patients with cerebral palsy and stiff knee gait?

The peak knee flexion in swing was slightly increased in both groups 1 year after surgery, but was not different between groups. Although there was a slight but not significant decrease found the group with DRFT only, there was no significant difference at long-term follow-up between the groups. Timing of peak knee flexion, range of knee flexion, and knee flexion velocity improved significantly in both groups, and in both groups a slight deterioration was seen with time; there were no differences in these parameters between the groups at any point, however. There were no group differences in spatiotemporal parameters at any time. There were no significant differences in the long-term development of anterior pelvic tilt between the groups.

4.4. Long-term effects after conversion of biarticular to monoarticular muscles compared with musculotendinous lengthening in children with spastic diplegia

Mean anterior pelvic tilt increased one year after surgery in both groups. This increase was higher in MTL patients and statistically significant only for this group. Knee flexion at initial contact and minimum knee flexion in stance were significantly decreased in both groups, while in swing the CBM group tended to show more of a decrease in knee flexion but at the cost of reduced peak flexion. Both groups showed deterioration of kinematic knee parameters through to long-term follow-up; the favourable effects of CBM disappeared, and the two groups displayed comparable average pelvic and knee kinematics. Considering individual patterns the prevalence of increased anterior pelvic tilt was lower in the CBM group 1 year after surgery, indicating that sparing the semitendinosus may have a positive effect on pelvic stability. However, after 9 years 30% of the patients in both groups showed increased anterior pelvic tilt indicative of persistent hamstring insufficiency.

5. Conclusions

1. According to our long-term results the hamstring lengthening to correct flexed knee gait is a not suggested technique, because of the recurrence of flexed knee gait.
2. The conversion of biarticular muscles to monoarticular muscles is a significantly more extensive procedure and has no long-term advantage over muscle tendon lengthening.
3. Patients with jump-knee gait had to be discouraged from hamstring lengthening, because of the high prevalence of lasting genu recurvatum.
4. Patients with preoperatively diminished maximal knee flexion in swing benefited from DRFT in long-term outcome.
5. The prophylactic DRFT on flexed knee gait patients had to be discouraged because of impairing the knee extension after DRFT.
6. The influences of proximal rectus femoris release on DRFT effects on the knee joint are negligible.

6. Bibliography of the candidate's publications

6.1.Publication related to the PhD thesis

1) Dreher T., **Vegvari D.**, Wolf S., Geisbüsch A., Simone Gantz, Wenz W. and Braatz F.: Development of knee function following hamstring lengthening in children with spastic diplegia – a long-term outcome study. *J Bone Joint Surg Am. 2012 Jan 18;94(2):121-30.* **(IF: 3.234)**
2) Dreher T, Wolf SI, Maier M, Hagmann S, **Vegvari D**, Gantz S, Heitzmann D, Wenz W, Braatz F: Long-term results after distal rectus femoris transfer as a part of multilevel surgery for the correction of stiff-knee gait in spastic diplegic cerebral palsy. *J Bone Joint Surg Am. 2012 Oct 2;94(19):e 142(1-10)* **(IF: 3.234)**
3) Dreher T, **Vegvari D**, Wolf SI, Klotz M, Müller S, Metaxiotis D, Wenz W, Döderlein L, Braatz F: Long-term effects after conversion of biarticular to monoarticular muscles compared with musculotendineus lengthening in children with spastic diplegia. *Gait Posture. 2013 Mar;37(3):430-5* **(IF: 2.299)**
4) **Vegvari D**, Wolf SI, Heitzman D, Klotz MC, Dreher T: Does proximal rectus femoris release influence kinematics in patients with cerebral palsy and stiff knee gait? *Clin Orthop Relat Res. 2013 Oct;471(10):3293-300* **(IF: 2.882)**

6.2.Publication not related to the PhD thesis

1) Dreher T, Brunner R, **Vegvari D**, Heitzmann D, Gantz S, Maier MW., Braatz F, Wolf SI: The effects of muscle-tendon surgery on dynamic electromyographic patterns and muscle tone in children with cerebral palsy. *Gait Posture. 2013 Jun;38(2):215-20* **(IF: 2.299)**

6.3.Citable abstracts

1) Szakály N, Tamás P, Terebessy T, **Végvári D**, Marschalkó P, Basch L: Internet database of scoliosis screening. *Biomechanica Hungarica VI: 2013 (1) 103-110*
2) Lukáts Á, Szabó A, Halász G, Berta ÁI, Röhlich P, Doma V, **Végvári D**, Szél Á: Photopigment coexpression in the

mammalian retina. *XIX. International Symposium of Morphological sciences, Budapest, Hungary, 2007. augusztus 19-24./(Abstr) Acta Biol. Segediensis, 51 (suppl) 2007, 26*

3) Doma V, Halász G, Szabó A, Berta ÁI, **Végvári D**, Röhlich P, Szél Á, Lukáts Á: The effect of thyroid hormone substitution on M/L-cone development in in vitro organotypic retinal culture. *XIX. International Symposium of Morphological sciences, Budapest, Hungary, 2007. augusztus 19-24./ (Abstr) Acta Biol. Segediensis, 51 (suppl) 2007, 10*

4) **Végvári D**, Szabó A, Deák G, Lukáts Á, Berta ÁI, Szél Á: The expression of erythropoietin and its receptor in the developing rat retina. *XIX. International Symposium of Morphological sciences, Budapest, Hungary, 2007. augusztus 19-24./ (Abstr) Acta Biol. Segediensis, 51 (suppl) 2007, 52*