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Does additional patella tendon shortening influence the effects of multilevel surgery to correct flexed knee gait in cerebral palsy: A randomized controlled trial

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ABSTRACT

Background: The aims of this study were to investigate if patellar tendon shortening (PTS) as a part of SEMLS (single event multilevel surgery) is effective for reduction of flexed knee gait in children with cerebral palsy (CP) and, if PTS leads to stiff knee gait.

Methods: In a randomized controlled study 22 children with flexed knee gait (age: 10.4 ± 2.6 years, GMFCS Level I–III) were randomized and allocated to two groups (1: SEMLS + PTS; 2: SEMLS no PTS): SEMLS was performed for correction of flexed knee gait either with or without additional PTS. Before and after surgery (follow up: 12.7 ± 1.6 months) kinematics (3-D motion analysis) and clinical parameters were compared.

Results: Two children were lost to follow up. Maximum knee extension improved significantly in both groups after SEMLS while the patients with additional PTS showed much more correction (SEMLS + PTS: 37.6° to 11.4°, $p = 0.007$; SEMLS no PTS: 35.1° to 21.8°, $p = 0.016$). After surgery peak knee flexion decreased significantly (14.6°, $p = 0.004$) in the "SEMLS + PTS" group while there was no relevant change in the other group. There was a trend of increase in anterior pelvic tilt after surgery in both groups, but no statistical significant difference. After surgery knee flexion contracture (15.9°, $p < 0.001$) and popliteal angle (27.2, $p = 0.009$) measured on clinical examination only decreased significantly in the "SEMLS + PTS" group.

Conclusion: PTS is effective for correction of flexed knee gait and knee flexion contracture leading to superior stance phase knee extension. However, additional PTS may lead to stiff knee gait and a higher increase of anterior pelvic tilt.

1. Introduction

1.1. Flexed knee gait

In children with cerebral palsy (CP) flexed knee gait is a common gait abnormality [1,2]. In the literature several factors are mentioned contributing to this gait abnormality of which abnormal shortness of the hamstrings and lever-arm dysfunctions are most important [1,3]. Due to a collapse of the moments for hip extension, knee extension and ankle stabilization upright gait is impaired. Hence, flexed knee gait is characterized as increased knee flexion during walking [1,4]. As a consequence of this flexed knee gait energy consumption and stress on the patellofemoral joint including the quadriceps tendon increase [5–8]. Over time elongation of the patellar tendon resulting in patella alta and weakness of the quadriceps muscle often occur [6,8,9]. This may further aggravate this gait deviation [3]. As crouch gait impairs mobility and independence, appropriate treatment of crouch gait is important to improve participation in daily life and to avoid secondary problems like contractures and degeneration of cartilage and soft tissue [10,11].

1.2. Treatment of flexed knee gait

Common procedures for the correction of flexed knee gait are hamstring lengthening (open or percutaneous techniques) [12] and distal femoral extension osteotomy [3,13,14]. In addition to hamstring lengthening or distal femoral extension osteotomy, in patients with active insufficiency of the knee extensors (extensor lag, patella alta) patella advancement is important to re-construct extensor moment in those patients [3,13,15].

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1.3. Patellar tendon shortening

In children a shortening of the patellar tendon seems to be a simple and safe method for treatment of flexed knee gait and patella alta respectively extensor lag [15]. There are reports showing an improvement in power of the quadriceps and knee range of motion after shortening of the patellar tendon [15,16]. Sossai et al. could even show a significant improvement of knee flexion gait after isolated patellar tendon shortening in limbs who had no passive knee extensor lag [15]. In patients with knee flexion contracture, the combination of patellar tendon shortening and distal femoral extension osteotomy led to the same improvement [15]. Nevertheless, those studies are just case series with a low level of evidence.

Therefore, the purpose of this randomized study was to investigate, if patellar tendon shortening improves maximum knee extension and reduces knee flexion contracture in children with flexed knee gait. A further intent was to evaluate, if patellar tendon shortening influences the range of motion of the knee during swing phase respectively leads to stiff knee gait.

2. Patients & methods

2.1. Study design & procedure

The study design was a randomized controlled trial. The approval of this study was granted by the local ethics committee (S-302-2009) and a written informed consent was obtained from each patient or his legal representative before start of the study.

According to specific inclusion criteria (bilateral spastic CP, age 6–18 years, flexed knee gait, ability to ambulate (GMFCS Level I–III), previous 3-D motion analysis) the participants were recruited for the study from the outpatient clinic of the Pediatric Neuroorthopedics unit. Patients were included if they showed a flexed knee gait with mean knee flexion throughout stance phase of more than 20° and maximum knee extension of less than ten degrees during stance in combination with a knee extensor lag of more than ten degrees and/or a patella alta. Patients with jump knee gait patterns, previous surgeries at the lower limbs and previous interventions like Botulinum Toxin A injections (or serial castings) within the last six month were not included in this study.

Consecutively, children were assessed for eligibility on the basis of results obtained by 3-D-gait analysis. After recruitment and exclusion of three individuals (Fig. 1) a balanced randomization of the remaining 22 children was conducted: According to the method reported in an another RCT [17] the patients were allocated to the groups by minimization [18]. Each child was allocated both to strata according to age (6–10 years, 10–14 years, 14–18 years) and maximum knee extension in stance ($< 35°$, $> 35°$) as monitored in gait analysis and averaged between right and left leg. The principle of minimization was performed by a computer script developed within our group using Matlab R 2009a (The MathWorks, Inc. Natick, MA, USA).

Along the recruitment process eight children were allocated (per balanced random) to the PTS group and 14 to the NoPTS group, respectively. At a mean follow up period of one year after surgery, the children were reinvited for clinical examination and motion analysis. Two children of the group “SEMLS no PTS” had to be excluded from further analyses (Fig. 1).

Finally, 20 children (40 limbs) with a mean age of 10.4 years (SD = 2.6 years) were enrolled in this study and separated into two groups (Table 1):

SEMLS + PTS: Eight children (16 limbs) with a mean age of 10.9 years (SD = 3.1 years) were planned for SEMLS including a patellar tendon shortening surgery.

SEMLS no PTS: Twelve children (24 limbs) with a mean age of 10.0 years (SD = 2.0 years) were selected for SEMLS without patellar tendon shortening surgery.

2.2. Surgical technique

Patellar tendon shortening was done in a minimal invasive technique using a strong 1.3 mm POLY-P-DIOXANONE cord (PDS, Ethicon Germany, Norderstedt, Germany). Four small 10 mm incisions were done medial and lateral along the tendon. While the knee was held in extension the cord was guided by the needle through the patellar tendon Z-wise from the upper lateral to the upper medial corner and then to the lower lateral and lower medial corner. Last the needle was pushed through the patellar tendon to the upper lateral origin part and a knot was done after the shortening: The patella was pulled distally until one centimeter above the tibial eminentia with a sharp clamp. Afterwards, the suture was tightened with several knots to secure the position. An intraoperative radiographic examination was done to control for patella position. Then, the knee was flexed to 90° knee flexion carefully and another radiograph was taken to ensure that the position of the patella remained in the desired distal position.

In case of knee flexion contracture of more than 10° a distal femoral extension and shortening osteotomy (DFESO) was done. Afterwards, the knee was tested for remaining hamstring shortness indicated by intraoperative modified popliteal angle testing (with the contralateral hip flexed). If there was a modified popliteal angle of 30 or more after DFESO, an additional intramuscular medial hamstring lengthening (M. gracilis, M. semimembranosus and M. semitendinosus) was performed. If there was no knee flexion contracture but an increased modified popliteal angle intraoperatively, an isolated medial hamstring lengthening was done. In case of positive preoperative Duncan Ely’s sign a transposition of the rectus femoris muscle was done. Concomitant surgeries of the SEMLS are listed in Table 1.

After surgery, bilateral shank plaster casts and thermoplastic thigh splints in 20° of knee flexion (day 1–3 after surgery)/knee extension (3 days after surgery) connected with a rod to fix the limbs in 10–15° of external rotation were fitted to each patient. Epidural anesthesia was used for seven days after surgery. Physiotherapists applied early passive and active mobilization of the knee and hip joints starting at the first day after surgery. In case of patellar tendon shortening knee flexion was limited to 30° for the first two weeks and afterwards to 60° for further two weeks. The children began to use full weight bearing four weeks after surgery.

The number of peri- and post-operative complications were extracted from the post-operative medical reports and evaluated according to the Clavien-Dindo system [19].

2.3. 3-D gait analysis

Before (E0) and one year (E1) after surgery gait analysis was performed using a conventional three-dimensional motion capture (Vicon® camera system, Oxford Metrics, Oxford, United Kingdom) as reported before [12]: Skin mounted markers were applied to bony landmarks of the patients according to a standard protocol and kinematics as well as kinetics were calculated according to a standard software procedure (Plugin Gait; Oxford Metrics, Oxford, United Kingdom) based on Kadaba et al. [20]. Pre and post examinations including documentation of the popliteal angle [21] were carried out by the same physiotherapist and study nurse with special education in pediatric neuro-developmental therapy and gait analysis. Patients were asked to walk barefoot along a 7-m walkway at self-selected speed. At least 5 representative strides were averaged for further analysis. Before surgery nine children used four-point crutches or a walker assistance during 3-D motion analysis (GMFCS III, Table 1). Therefore in these patients kinetics could not be recorded.

2.4. Data analysis

An “a priori” power analysis (two tailed, $d = 1.57$, $\alpha = 0.05$, $1-\beta = 0.95$, allocation ratio = 1) was conducted to adjust the sample size