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# A cohort study of tibialis anterior tendon shortening in combination with calf muscle lengthening in spastic equinus in cerebral palsy

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ABSTRACT

The aim of this study was to evaluate the outcome of combined tibialis anterior tendon shortening (TATS) and calf muscle-tendon lengthening (CMTL) in spastic equinus.

Prospectively collected data was analysed in 26 patients with hemiplegic (n = 13) and diplegic (n = 13) cerebral palsy (CP) (GMFCS level I or II, 14 males, 12 females, age range 10–35 years; mean 16.8 years). All patients had pre-operative 3D gait analysis and a further analysis at a mean of 17.1 months (±5.6 months) after surgery. None was lost to follow-up. Twenty-eight combined TATS and CMTL were undertaken and 19 patients had additional synchronous multilevel surgery. At follow-up 79% of patients had improved foot positioning at initial contact, whilst 68% reported improved fitting or reduced requirement of orthotic support. Statistically significant improvements were seen in the Movement Analysis Profile for ankle dorsi-/plantarflexion (4.15°, p = 0.032), maximum ankle dorsiflexion during swing phase (11.68°, p < 0.001), and Edinburgh Visual Gait Score (EVGS) (4.85, p = 0.014). Diplegic patients had a greater improvement in the EVGS than hemiplegics (6.27 -vs- 2.21, p = 0.024).

The originators of combined TATS and CMTL showed that it improved foot positioning during gait. The present study has independently confirmed favourable outcomes in a similar patient population and added additional outcome measures, the EVGS, foot positioning at initial contact, and maximum ankle dorsiflexion during swing phase. Study limitations include short term follow-up in a heterogeneous population and that 19 patients had additional surgery. TATS combined with CMTL is a recommended option for spastic equinus in ambulatory patients with CP.



## 1. Introduction

Equinus is the commonest deformity in cerebral palsy (CP) [1–3] and lengthening of a shortened gastrocnemius/soleus is commonly undertaken to improve gait. Previous studies have reported recurrent equinus after surgery in approximately 10–30% of patients with hemiplegia [4,5] and overcorrection resulting in a calcaneus heel in 3–30% of patients with spastic diplegia [6–8]. Although central weakness has been suggested by Lin et al. [9], the imbalance of agonist and antagonist muscle lengths across the ankle can also lead to additional functional weakness. In long standing equinus it is thought that the antagonist (tibialis anterior muscle-tendon unit) is elongated and therefore weakened, with the agonist (gastrocnemius/soleus muscle-tendon unit) shortened and also weakened [10–12]. Although the range of dorsiflexion increases as a consequence of calf muscle-tendon lengthening (CMTL), additional therapy is often required to correct gait. It has been proposed that simultaneous tendon shortening of the antagonistic tibialis anterior tendon-muscle unit would help to rebalance muscle strength. Combined shortening of the anterior tibialis tendon-muscle unit and lengthening of the calf tendon-muscle unit in spastic equinus in CP has previously been described by Rutz et al. [13] and has been shown to improve foot positioning during gait.

The Movement Analysis Profile (MAP) [14] has been developed to summarise kinematic data from three-dimensional (3D) instrumented gait analysis. The MAP describes the magnitude of deviation of nine individual variables averaged over the gait cycle. The Gait Profile Score (GPS) [14] reduces the MAP data to a single number that quantifies how much a gait pattern deviates from normal. The GPS is a single index outcome measure that summarises the overall quality of a patient's gait kinematics and

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has been validated for evaluating outcomes [14]. The Edinburgh Visual Gait Score (EVGS) [15] consists of 17 items and is based on the visual observation of gait in the sagittal and coronal planes. It has been validated for use by experienced and inexperienced observers [16], has good concurrent validity with other assessments [17] and is reliable [18]. It has been shown to correlate strongly with the GPS and Gross Motor Function Classification System (GMFCS) [19].

The aim of this study was to evaluate the short-term outcome and the surgical results after tibialis anterior tendon shortening (TATS) in combination with calf muscle-tendon lengthening (CMTL) in spastic equinus in children with CP using the MAP, GPS, EVGS, foot position at initial contact, maximum ankle dorsiflexion during swing and orthoses use or fit. Our hypothesis was that this procedure would improve foot positioning during gait.

## 2. Methods and materials

A retrospective analysis of prospectively collected data of all ambulatory children with CP and spastic equinus undergoing TATS in combination with CMTL was performed. All were performed at a single centre by the same surgeon between August 2011 and September 2014. Exclusion criteria were a diagnosis other than spastic cerebral palsy, dystonia or mixed movement disorder, Botulinum toxin A injections in the previous six months, gait improvement surgery within the preceding 18 months or GMFCS level III–V.

All patients had pre- and post-operative 3D instrumented gait analysis undertaken in a **** accredited laboratory. The clinical assessment included the examination of the passive range of motion, spasticity according to the modified Ashworth/Bohannon scale [20] (scale: 0–4), the manual muscle strength test [21,22] (MRC scale: 0–5) of the ankle dorsi- and plantarflexors, a visual assessment of gait using the EVGS, and the use plus, if appropriate, fit of orthoses. The pre- and post-operative instrumented gait analysis included kinematics and kinetics, using a motion capture system (six camera VICON 460 system, Oxford Metrics Ltd., UK). Patients walked barefoot at a self-selected speed. The Helen Hayes Marker set [23] was used and at least three trials were recorded. Anthropometric data were recorded for appropriate scaling.

All data were expressed as a percentage of the gait cycle using Polygon software (Oxford Metrics Ltd., UK). The MAP [14], GPS [14] and EVGS [15–17,24] were calculated for all patients pre- and postoperatively.

### 2.1. Surgical technique

Posterior calf muscle lengthening was performed by recessing the proximal gastrocnemius and, if required, soleus aponeuroses. Following this the tibialis anterior tendon was exposed distal to the extensor retinaculum and freed of paratenon (Fig. 1). The ankle was placed into no more than 10° of dorsiflexion. The redundant tendon was then rolled around a pair of Gillies forceps to maximum tension and in such a way that the rolled-up excess tendon lay deep in the wound. The tension in the shortened tibialis anterior tendon was maintained by the assistant whilst a grasping whip stitch (using a pre-tensioned No. 6 Vicryl suture (Ethicon Inc., Johnson and Johnson)) was placed into the tendon. The suture was then anchored to the underlying navicular and medial cuneiform bones at the original insertion of tibialis anterior (Fig. 2). Post-operatively the foot was placed at a plantigrade position and held in a below knee cast which was split immediately. After two weeks the cast was changed to a plantigrade weight-bearing cast and retained for a further four weeks.

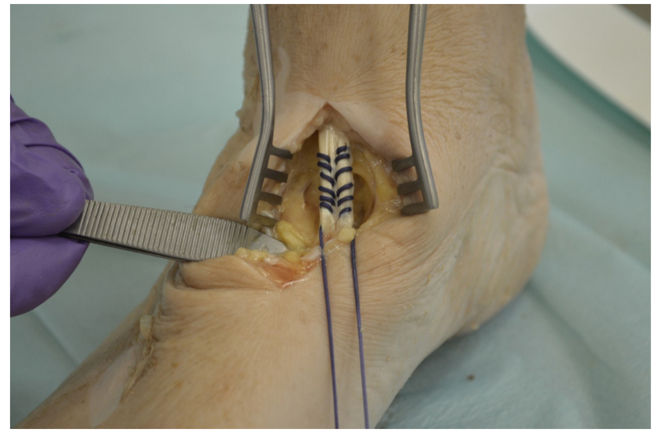

**Fig. 1.** Exposed tibialis tendon tensioned using Gillies forceps and a whip stitch (No. 6 Vicryl, Ethicon Inc., Johnson and Johnson). Cadaveric limb by courtesy of Professor *****, Professor of Translational anatomy, University of ****.

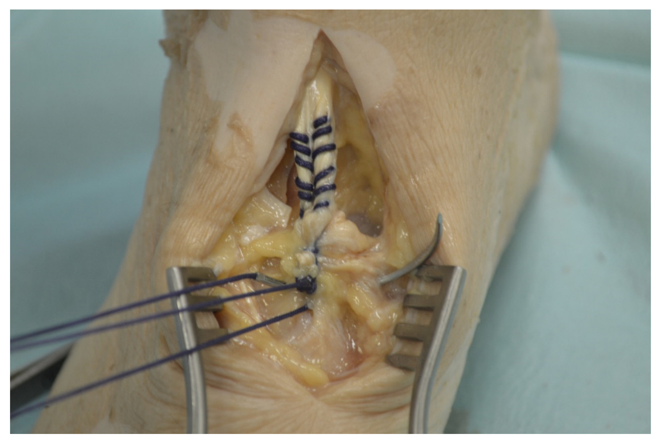

**Fig. 2.** Transosseous fixation of shortened tibialis anterior tendon to the medial cuneiform and navicular bones.

### 2.2. Statistics

Testing for normality of the data was performed using the Shapiro-Wilk test. Paired data were assessed using the paired *t*-test or Wilcoxon's matched-pairs signed ranks test or Chi-squared testing, where appropriate, and sequential data were assessed using repeated analysis of variance (ANOVA) with Bonferroni post hoc analysis (SPSS statistical software version 21.0, SPSS Inc., Chicago, Illinois). A p-value of $<0.05$ was considered to be statistically significant.

## 3. Results

Twenty-six patients had 28 surgical interventions. Group I consisted of 13 patients with hemiplegic CP and group II of 13 patients with diplegic CP. The mean age of the patients was 16.8 years (sd $\pm$ 5.9 years, range 10.3–34.5 years) at the time of surgery. Four patients had undergone previous gait improvement surgery over 18 months prior to the combined TATS and CMTL surgery, and none had previous CMTL surgery. Nine patients were skeletally immature at the time of surgery. Additional, synchronous multilevel surgery was performed in 19 patients. Within the cohort 18 patients were GMFCS level I and eight were GMFCS level II. There were no statistical differences in patient demographics between the hemiplegic and diplegic patients ($p < 0.05$). There was a combined gastro-soleus contracture in eight limbs and an