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Correction of gait after derotation osteotomies in cerebral palsy: Are the effects predictable?

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ABSTRACT

Derotation osteotomies of the femur and tibia are established procedures to improve transverse plane deformities during walking with inwardly pointing knees and in- and out toeing gait. However, effects of femoral derotation osteotomies on gait were reported to be small, and those for the tibia are not known. Therefore, the aim of the study was to show the relation between the amount of intraoperative rotation and the changes during gait for osteotomies at femur and tibia levels, and predict those for the femur from preoperative clinical and gait data.

Forty-four patients with spastic cerebral palsy between 6 and 19 years were included, 33 limbs received rotation only at the femur, 8 only at the tibia and 12 limbs at both levels. Gait analysis and clinical testing was performed pre- and 21.4 (SD = 1.8) months postoperatively.

The amount of intraoperative derotation of the femur showed no significant correlation with the change in hip rotation during walking ($R = -0.17$, $p = 0.25$), whereas the rotation of the tibia showed an excellent relationship ($R = 0.84$, $p < 0.001$) with the change in knee rotation. Preoperative hip rotation during walking explained only 18% of the variability of the postoperative change in hip rotation during gait. Strength and passive range of motion in hip extension and abduction as well as hip extension or abduction or foot progression during walking did not show any predictive significance.

In conclusion changes of knee rotation during gait is directly predictable from the amount of tibial corrections, contrary the change in hip rotation was not related to the amount of femoral derotation, and prediction was only fair.

1. Introduction

Excessive internal hip rotation during walking, seen as inwardly pointing knees, is common in children with cerebral palsy (CP) and involves 49% of the patients [1]. It can lead to knocking or rubbing of the knees, lever arm dysfunction [2] and is particularly cosmetically unappealing. Internal hip rotation during walking is often associated with in-toeing gait; these children with internal foot progression angle may be particularly prone to tripping and falling. However, normal or external foot progression angle may also present, and need to be accounted for in a successful therapy that aims to achieve normal alignment of the leg during gait.

The primary reason for internal rotation of the hip is increased anteversion of the femur [3–5]. Other cause might be flexion contractures of the hip [4] or weakness of external hip rotators [3]. Internal foot progression angle might be the results of internal hip rotation in the transverse plane and might further increase with internal torsional malalignment of the tiba. Normal or external foot progression angle, in the presence of excessive internal hip rotation, may be caused by external torsional malalignment of the tibia; this combination is referred to as miserable malalignment.

Since primary reasons for leg malalignment are torsional deformities of the bones, external derotation osteotomies of the femur (FDO) and tibial rotation osteotomies (TRO) either internal or external are the common procedures to obtain normal leg alignment. FDO was shown to be effective in correcting intoed gait if passive and dynamic hip rotations are both excessively internal as indicated by physical examination and gait analysis [6–9]. It is not clear why following this recommendation for the correction of femoral anteversion with FDO, 33% of under corrections have been

Abbreviations: FDO, femoral derotation osteotomy; TRO, tibia rotation osteotomy; CP, cerebral palsy; PRoM, passive range of motion.

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observed [10], and only 60% of the intraoperative amount of correction that aim to improve gait was observed postoperatively during walking [11]. In order to solve this problem, slight overcorrection with more external than internal passive range of motion (PRoM) has been suggested [11,12]. However, such overcorrections may lead to outward pointing knees during walking [7]. Furthermore, the hip joint allows a considerable range of motion so that muscular weakness, spasticity and compensatory movements [4] might lead to further internal hip rotation following correction of the anteversion. This makes it difficult to plan the appropriate degrees of derotation in FDO to achieve normal leg alignment during gait. Neither age, GMFCS level nor additional soft tissue surgeries in addition to FDO distinguished good from bad responders to FDO [10]. Regarding TRO there is no information in the literature whether there is a correlation between the intraoperative extent of the derotation and the change of knee rotation during walking in patients with CP. Logically, due to the smaller range of motion in the transverse plane at the knee joint, good correlation can be expected between intraoperative amount of derotation and changes during gait. However this correlation is yet to be shown.

Therefore the aim of this study is first, to show the correlation between intraoperative amount of TRO and FDO and the changes during gait. Second, since weak correlations are expected for FDO, we investigate whether predictors from preoperative clinical and gait assessments were able to predict the improvements during walking.

2. Methodology

2.1. Patients and surgical interventions

Forty-four patients with spastic cerebral palsy GMFCS I-III, with uni- and bilateral involvement between 6 and 19 years volunteered to participate in the study. Participants provided written consent, as approved by the local ethics committee. Of these patients 53 limbs received FDO and/or TRO between 2010 and 2013; patient's details are shown in Table 2. FDO was performed at the distal supracondylar level of the femur using a condylar blade plate fixation. TRO was performed supramalleolar at the tibia using a dynamic compression plate fixation. Patients that received intertrochanteric femur osteotomies were excluded, since they were typically done in combination with hip reconstruction surgeries that might have affected the muscular situation at the hip.

Indication for FDO and TRO was based on physical examination and gait analysis as follows: Patients that obtained FDO showed internal hip rotation during walking and internal clinical midpoint of hip rotation both above one standard deviation of TD controls. The therapeutic goal for FDO was to achieve 10° more external than internal passive rotation or symmetry for internal and external rotation when the remaining internal rotation was less than 30°.

Patients that obtained TRO showed internal/external knee rotation during walking and tibial torsion both outside one standard deviation of TD controls. The treatment goal for TRO was that the second toe was in line with the tibial tuberosity with extended knees in plantigrade foot position.

Detailed patients descriptions including procedures in addition with the index procedures (TRO and FDO) were shown in Table 2. Sixty limbs of 30 typically developed (TD) peers between 6 and 19 years served as reference for normal gait; mean age was 12.4 years (SD = 3.2).

2.2. Data collection and evaluation

Instrumented gait analysis and clinical assessment was performed before and after surgery. Mean follow up time was 21.4 months (SD = 1.8) range: (17–23). Kinematic and kinetic data were collected using the Vicon Plug-in-Gait marker set on an 8-cameraVicon system (Vicon, Oxford, UK) and two force plates (AMTI, Watertown, MA, USA) In addition medial ankle and knee markers were used during the standing trial to improve the accuracy of the joint rotations in the transverse plane [12,13].

The subjects were asked to walk at comfortable speed down the 15 m walkway until 5 gait cycles with valid kinetics for both legs were captured. All participants were ambulating barefoot. Subsequent to gait analysis, participants underwent full clinical examination. For this study strength and range of passive hip abduction and extension and the midpoint between passive hip internal and external rotation and the tibial torsion were evaluated. Hip internal and external rotation as well as tibial torsion was measured with the patient prone and the knees flexed to 90 degrees [14]. The derotation angle was monitored intra-operatively by two 2.5–3 mm K-wires inserted proximally and distally to the osteotomy site and was documented after the plate was fixed.

Gait parameters hip rotation, extension and abduction, knee rotation and foot progression angles were calculated as the average over the stance phase of gait for each gait cycle and were then averaged over 5 gait cycles for each subject.

The amount of derotation of femur and tibia measured intraoperatively, were correlated to the changes on hip rotation and knee rotation during gait respectively. For 45 legs that received FDO, in addition a predictor analysis was performed to predict the amount of hip rotation during gait relative to the amount of intraoperative derotation. The eight possible predictors derived from preoperative clinical and gait measurements were: 1–6 hip extension and abduction PRoM, strength and deviation between TD peers during gait; 7–8 hip transverse plane rotation and foot progression difference during gait between patients and TD controls. For those patients that received FDO and TRO the amount of intraoperative TRO was added to the foot progression angle.

Stepwise multilinear regression of the response value performed on the predictor parameters. Henze–Zirkler's multivariate normality test was used to test the requirements for the multiple regression analysis [15]. The calculation was carried out using the function 'stepwisefit' of the MatLab 6.2 statistics toolbox (The Mathworks Inc., Natick, USA). The maximum p-value for a term to be added was $p = 0.05$. The minimum p-value for a term to be removed was $p = 0.10$ clinical significance was defined according to [16].

Since recurrence due to growth might also have affected the efficacy of derotation osteotomies, the length changes of thigh and shank between preoperative and postoperative measures were correlated to the effects on gait. The segment lengths were determined during a standing trial captured with the Vicon system. Thigh and shank lengths were calculated as the distance between hip and knee joint center and knee and ankle joint center respectively.

Most of the surgeries mentioned previously performed in addition to TRO and FDO aim to improve crouch gait. Some authors dispute the beneficial effects of additional surgeries on the outcome on FDO [10]. However, since changes in hip and knee extension might affect the moment arms of the hip muscles, the relation between improvement in knee and hip extension and outcome of FDO was analyzed to verify this observation.

3. Results

3.1. Surgical outcome during gait and correlation to the intraoperative derotation

The average external FDO measured intraoperatively was 29.3° (SD = 5.2) [20°, 40°] Functional improvement in mean hip rotation