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Long-term development of overcorrection after femoral derotation osteotomy in children with cerebral palsy

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ABSTRACT

Background: Recent studies showed rates of recurrence of internal rotation gait (IRG) after femoral derotation osteotomy (FDO) up to 40%. Some surgeons even advice overcorrection during FDO to avoid a later recurrence.
Research question: Evaluation of the long-term development of limbs with initial overcorrection after FDO.
Methods: 29 limbs of 20 children (9.9 ± 3.2 years at surgery) with IRG, cerebral palsy (CP) and more than 5° external hip rotation postoperatively were included retrospectively. A gait analysis and clinical examination were performed preoperatively (less than one year, E0), postoperatively (9–23 months, E1) and at the long-term follow-up (at least five years postoperatively, E2). Differences between those children that remained overcorrected at E2 and those with a hip rotation within normal range at E2 were evaluated.
Results: At E2 41% of these limbs remained overcorrected, 52% showed a hip rotation within normal range and 7% showed recurrence of IRG. A comparison of those limbs that remained overcorrected and those ending within normal range revealed neither a difference in age at surgery nor in static and dynamic torsional parameters at E0 and E1 except for pelvic rotation. A significantly larger pelvic internal rotation at E1 for those with remaining overcorrection could be identified.
Significance: A general overcorrection during FDO in children with CP to avoid recurrence of IRG cannot be recommended, as 41% remain overcorrected. Preoperative predictors for long-term development couldn't be identified. If pelvic mal-rotation is corrected, hip rotation may change into normal range over the time in combination with the development of a flexed knee gait.

1. Introduction

Internal rotation gait (IRG) is one of the most common gait abnormalities in children with cerebral palsy (CP) and has a prevalence of about 60–70% [1].

The femoral derotation osteotomy (FDO) is the gold standard treatment for patients with CP and IRG [2,3]. The osteotomy can be performed either at supracondylar level or intertrochanterically with comparable results in children with CP [4–6].

Numerous studies could show the effectiveness of the FDO for improving the IRG [2,3,5,7–13]. Nevertheless, in the literature high rates of over- (and under-correction) up to 40% [3,8,10,14], which mainly occur on the less involved limb, as well as rates of recurrence between 9% and 40% [2,10,15–19] are reported.

Factors associated with recurrence could be identified: preoperative equinus deformity, low preoperative hip abduction moments [15], high level of spasticity and slow walking speed [10]. The influence of age at surgery is evaluated differently. While some papers suggest younger age at surgery [15,18,20–22] as risk factor, others don't [19,23]. Ounpuu et al. [19] suggested in a recently published study a distally performed osteotomy to be more likely leading to recurrence than a proximal one. Although factors contributing to recurrence are known, a preoperative prediction which child might be at risk to receive recurrence and might need a different treatment, is not possible yet.

Kim et al. [17] suggested to perform the FDO with a slight overcorrection to avoid recurrence, if surgery has to be performed at an age younger than 10 years without a clear evidence. In contrast, according to Brunner et al. [24] a FDO should always lead to a remaining slight internal rotation gait, because if the limb bends unintendedly due to the neurological deficit, the internal rotated leg will bend under the center of mass and stabilize itself. Further Gage et al. [25] describe the lever-arm dysfunction due to an increased (external) foot progression angle, which might even induce crouch gait. The long-term development of initially overcorrected internal rotation gait is not known.

The objective of the study was to assess the long-term development of hip rotation in children with cerebral palsy and internal rotation gait

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who were initially overcorrected during FDO procedure.

2. Materials and Methods

This is a retrospective cohort study. All ambulatory children with bilateral spastic cerebral palsy that underwent femoral derotation osteotomy (FDO) in the context of single-event multilevel surgery (SEMLS) were collected retrospectively from the gait laboratory database. Inclusion criterion was the availability of 3D gait analysis data less than 12 months before (E0), one year (range: 9–23 months) after (E1) and at least five years after FDO (E2). Exclusion criteria were an additional supramalleolar derotation osteotomy and any gait modifying surgery in the follow-up. 64 children with a mean age of 10.2 ± 2.9 years at surgery matched these criteria. 15 of these children had a unilateral FDO. Thus 113 limbs with FDO could be included.

FDO was performed either distally at supracondylar level or proximally at intertrochanteric level. The primary aim of FDO was to correct increased femoral anteversion. The secondary aims were achieving a neutral clinical mid-point of hip rotation [26] and improve hip function, i.e. mean hip rotation in stance during gait analysis.

Mean hip rotation in stance was derived from 3D gait analysis. 3D gait analysis was performed using a six camera Vicon System (Oxford Metrics, Oxford, UK) (Vicon 370 (50 Hz) until 2002 and a twelve camera Vicon system (Vicon 612 (120 Hz)) since then. Equivalency of both systems was meticulously checked: over a period of two months all patient data were processed with both softwares and the results showed deviations of relevant kinematic parameters of less than 2°. The markers were placed according to the protocol of Kadaba et al. [27] and a knee alignment device was used over the whole course of the study. Always three static trials are carried out. In these trials the lateral knee joint position for the knee alignment device (KAD) is kept constant while the medial position is allowed to vary slightly according to palpation. For all three trials the "thigh rotation offset" is calculated, i.e. the disagreement between orientation of the knee alignment and position of lateral thigh marker is determined. The minimum thigh rotation offset then indicates the most consistent static trial. If the disagreement is large (> 5%) then knee varus/valgus position is monitored in dynamic gait trials performed thereafter and possible cross-talk with knee flexion in swing is carefully checked. If this effect is found significant then more static trials are taken with the KAD at the end of the gait examination. The static trial leading to reasonably small knee varus/valgus motion in swing is then picked for further analysis of dynamic trials.

Limbs were classified as overcorrected, if the mean hip rotation in stance was more than 5° external at E1 according to previous work [3,15]. 29 limbs (16 left, 13 right) of 20 children matched this criterion and were used for further analysis. One child had a unilateral FDO. The distribution of GMFCS level was as follows: GMFCS I: 6 limbs, GMFCS II: 19 limbs, GFMCS III: 2 limbs. The average age at surgery was 9.9 ± 3.2 years. The average age at E2 was 18.4 ± 4.1 years. The average follow-up at E2 were 101 ± 30 months.

Concomitant procedures performed during SEMLS are listed in Table 1:

Primary outcome parameter was mean hip rotation in stance during gait analysis at E2.

Secondary outcome parameters included dynamic rotational parameters and static torsional parameters at E2: mean pelvic rotation in stance, mean foot progression angle in stance, clinically measured anteversion via trochanteric prominence angle test [28] and mid-point of passive hip rotation with hips extended [26].

Mean knee flexion/extension and peak knee flexion in stance phase, mean dorsi-/plantarflexion and peak ankle dorsiflexion in stance phase may be contributing factors to hip internal rotation and were correspondingly assessed at all examination dates.

The outcome at E2 was defined according to previous work [3,15]:

Table 1
Concomitant procedures performed during SEMLS for the 29 limbs that were overcorrected at E1 (all limbs) and separately for the 12 limbs that remained overcorrected at E2 and the 15 limbs within normal range at E2. *Bony foot stabilizations include bony correction of a hallux valgus (subgroup that remained overcorrected), subtalar arthrodesis (3× subgroup within normal range at E2) and chopart arthrodesis (1× subgroup within normal range at E2).

Procedures	all limbs	remained overcorrected at E2	within normal range at E2
Pelvic osteotomy	0	0	0
FDO (proximal)	12	4	7
FDO (distal)	17	8	8
Intramuscular psoas lengthening	3	0	3
Adductor lengthening	1	1	0
Hamstring lengthening	19	8	9
Distal rectus femoris transfer	19	9	9
Patella tendon shortening	0	0	0
Calf muscle lengthening	21	7	13
Bony foot stabilization *	5	1	4
Soft tissue procedures, foot	7	3	3

- remained overcorrection: mean hip rotation in stance at E2 more than 5° external
- recurred internal rotation gait: mean hip rotation in stance at E2 more than 15° internal
- hip rotation within normal range: mean hip rotation in stance at E2 less than 5° external and less than 15° internal

An ANOVA with post-hoc *t*-test with Bonferroni correction was performed to assess differences between E0, E1 and E2 for the torsional parameters.

A mixed linear model with limb as repeated factor and "correction" (either remained overcorrected or developed a hip rotation within normal range) as independent factor was used to analyze differences between those children that remained overcorrected at E2 and those children that had a hip rotation within normal range at E2 after initial overcorrection. This test allows independence of observation of the two limbs of one patient. The evaluated parameters were age at sugery, pre- and postoperative mean hip rotation in stance, mean pelvic rotation in stance, mean foot progression angle in stance, mean knee flexion/extension in stance, mean dorsi-/plantarflexion in stance and postoperative contralateral mean hip rotation in stance.

Significance level was set at $p < 0.005$.

3. Results

At E2 12 limbs (41%) remained overcorrected, 15 limbs (52%) had a hip rotation within normal range and two limbs (7%) were internally rotated.

Analysing all 29 limbs that were overcorrected at E1, mean hip rotation in stance ($p < 0.001$), mean foot progression angle in stance ($p < 0.001$), anteversion ($p < 0.001$) and mid-point of passive hip rotation ($p < 0.001$) revealed significant differences between the three tested time points (E0, E1, E2) and a post-hoc analysis was performed. Mean pelvic rotation in stance didn't ($p = 0.962$) present a significant difference in between the three different time points (E0, E1, E2). (Fig. 1).

Table 2 presents the comparison of different confounding factors between the group of patients that remained overcorrected at E2 and those that developed a hip rotation within normal range at E2 after initial overcorrection into external hip rotation.

In the group that developed a hip rotation within normal range at E2 more calf muscle lengthening procedures, bony foot stabilizations and psoas lengthening procedures were performed compared to the