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Asymmetric pelvic and hip rotation in children with bilateral cerebral palsy: Uni- or bilateral femoral derotation osteotomy?

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ABSTRACT

Internal rotation gait is common among children with bilateral cerebral palsy. However, despite bilaterally increased femoral anteversion asymmetric internal rotation gait is often found. Femoral derotation osteotomy (FDO) is commonly performed bilaterally. Variable functional outcomes are reported especially in cases with mild internal hip rotation during gait and abnormal preoperative pelvic rotation. A major question is if a unilateral treatment of the more involved side in asymmetric cases leads to a comparable or even superior outcome.

One hundred and nine children with spastic bilateral CP treated with FDO with pre- and 1-year postoperative 3D gait analysis were retrospectively collected. The asymmetry was calculated from the preoperative difference between both limbs in hip rotation obtained by 3D gait analysis. Twenty-eight children with asymmetry larger than 20° were selected and classified into two groups, according to whether they obtained a unilateral or bilateral FDO.

Preoperative clinical examination and pre- and postoperative hip and pelvic rotation in gait analysis on the more and the less involved side did not differ significantly between both groups. Interestingly, in both groups, hip rotation did not change significantly in less-involved limbs, although intraoperative derotation averaged 25°. After unilateral FDO a significant change in pelvic rotation resulted, whereas this was not found after bilateral FDO.

The results of this study suggest that unilateral FDO in children with asymmetric internal rotation gait leads to a comparable functional outcome compared to bilateral treatment. Furthermore, it was shown for the first time that considering the asymmetry has a positive effect on pelvic rotation.

1. Introduction

Internal rotation gait (IRG) is common among children with cerebral palsy (CP) [1]. It is often thought to be a bilateral problem, as it is in the normal population [2], and associated with bilaterally increased femoral anteversion [3]. However, it could be demonstrated, that IRG is predominantly a unilateral phenomenon in patients with bilateral CP [4].

IRG often causes problems with foot clearance in the contralateral leg and tripping. A primary cause of IRG is transverse plane deformity of the pelvis, femur, tibia, and/or foot [4].

Femoral derotation osteotomy (FDO) is seen as the golden standard for the treatment of increased femoral internal rotation [3,5–9]. The osteotomy can be performed either proximally as intertrochanteric osteotomy or distally as supracondylar osteotomy with comparable static and functional results [3,7,9,10]. FDO corrects increased femoral anteversion and is commonly performed bilaterally since the anteversion angle is often increased bilaterally. However, many authors reported variable outcomes after FDO, especially in cases with mild IRG [5,11] and abnormal pelvic rotation preoperatively [3,9,12,13].

A major issue in the treatment is how to identify and address cases with asymmetric internal hip rotation during gait. In patients with asymmetrical forms of bilateral CP the most frequent pattern is an increase in internal hip rotation and pelvic retraction on the more involved side [9,13,14]. Kay et al. [12] reported, that children with bilateral CP and bilateral IRG, who were derotated bilaterally

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tended to be undercorrected on the side with preoperative pelvic retraction and overcorrected on the other side. A correction of pelvic retraction could be achieved after unilateral FDO in patients with unilateral CP [9,13,15], but not after bilateral FDO in patients with bilateral CP [3,13].

Previous investigations could outline that in patients with mild IRG overcorrection is a major problem and considered FDO to be done only if at least 15° of internal rotation are present in gait analysis [5,16]. It remains unresolved if in the patients with asymmetric IRG, where the mild-involved side has 15° or less of hip internal rotation but a bilaterally increased femoral anteversion should undergo bilateral FDO.

The purpose of the current study was therefore to evaluate if unilateral treatment is comparable or even superior to bilateral treatment in patients with asymmetric internal hip rotation during gait.

2. Materials and methods

Standardized 3D gait analysis and clinical examination are routinely performed for all ambulatory patients with CP both before and 1 year after surgery.

For the present cohort study, all ambulatory children with bilateral CP (GMFCS level I–III), increased femoral anteversion, and IRG, who were treated with FDO in the context of single-event multilevel surgery between 2000 and 2011, were selected retrospectively from the gait laboratory database. The amount of intra-operative derotation is routinely measured with derotational K-wires and documented in the surgical report. Patients who underwent additional tibial (de-)rotational osteotomy were excluded from this study. One hundred and eight children with a mean age of 10.7 (±3.2) years [range: 3.8–17.8] matched these criteria.

The asymmetry between both limbs of each subject was calculated from the preoperative difference between the two limbs concerning hip rotation in stance obtained by 3D gait analysis.

All children with bilateral CP and an asymmetry in hip rotation larger than 20° were selected. Twenty-eight children fit these criteria and were retrospectively classified into two groups: one group obtained a unilateral FDO (12 patients); the other group underwent bilateral FDO (16 patients). Accordingly, improvement in asymmetry was calculated as the difference between pre- and postoperative asymmetry.

FDO was performed either distally as supracondylar osteotomy or proximally as intertrochanteric osteotomy. The indication for FDO and the determination of the derotation angle changed over the course of the study. Whereas in the past, the aim of FDO was mainly to correct increased femoral anteversion and to achieve a neutral clinical midpoint [17] between passive internal and external rotation, over time the results of 3D gait analysis became more important for the planning of derotation amount as reported in an earlier study [5]. The amount of derotation was measured intraoperatively by using K-wires placed proximally and distally to the osteotomy. In 10 of the 16 patients with bilateral FDO, derotation was performed with respect to the slight asymmetry in clinical examination and femoral anteversion. The derotation angle differed between 5° and 20° between both sides.

The evaluation of all subjects in this study included a physical examination, videotaping, and instrumented gait analysis according to a standardized protocol. For 3D gait analysis a six-camera Vicon system was used (Oxford Metrics, Oxford, UK) (Vicon 370 until 2002, since then Vicon 612; equivalency of both systems in Heidelberg was meticulously checked). Skin-mounted markers were applied to bony landmarks of the patients according to the protocol of Kadaba et al. [18] and a knee alignment device was used to reduce mistakes in the transversal plane. Two static trials were carried out and, in cases of a more than 5° difference in the frontal plane, an additional third trial was recorded. The patients were asked to walk down a 7 m walkway barefoot at self-determined speed. The examinations were all performed by a physiotherapist and a study nurse, who were specially trained in pediatric neurodevelopmental therapy and had more than 8 years of experience with gait analysis.

Postoperative management consisted of early mobilization with weight-bearing transfers after the first 2–6 weeks and subsequent ambulation, depending on the patient's body weight and concomitant procedures.

2.1. Statistical methods

The outcome variables examined in this study were hip rotation and pelvic rotation in the stance phase of gait, asymmetry and the improvement in asymmetry.

Statistical analysis was performed using IMB SPSS Statistics 19. First, the normal distribution of the outcome variables was confirmed by Shapiro–Wilk test. All tests were two-tailed, and the significance level was set at $p < 0.05$. Then, outcomes were compared between the pre- and postoperative gait analysis parameters for each of both defined groups using Student's *t*-test. Then an analysis of variance (ANOVA) was performed to compare the parameters between both groups.

3. Results

Twelve children were treated with a unilateral FDO; 16 patients with a bilateral FDO. There were no significant differences concerning the age of the patients ($p = 0.588$), the functional level (GMFCS; $p = 0.416$), the proportion of right to left limbs as more involved sides ($p = 0.586$) and the proportion of distal to proximal femoral osteotomies ($p = 0.464$). Concomitant procedures are listed in Table 1.

Neither groups had any significant differences in the preoperative clinical examination including clinical mid-point of hip rotation measured with extended legs [17] (less involved side: $p = 0.175$; more involved side: $p = 0.095$) and anteversion (TPAT [19]) (less involved side: $p = 0.439$; more involved side: $p = 0.973$). Preoperative hip rotation in stance and pelvic rotation did not differ significantly on the more (hip rotation: $p = 0.112$, pelvic rotation: $p = 0.399$) or on the less involved side (hip rotation: $p = 0.831$, pelvic rotation: $p = 0.406$). There was no significant difference in asymmetry between both groups ($p = 0.067$). The derotation angle on the more involved side did not differ significantly as well ($p = 0.103$). The results of preoperative examination are listed in Table 2.

Between the two groups, there were not any significant differences in the postoperative hip rotation ($p = 0.282$) and pelvic rotation ($p = 0.545$) in stance during gait analysis of the more involved limb. Surprisingly, there were no significant differences in the postoperative hip rotation ($p = 0.119$) and pelvic rotation ($p = 0.876$) in stance during gait analysis of the less involved limbs between the group with a unilateral FDO and the group with a bilateral FDO.

Both groups presented a significant improvement in asymmetry (difference between pre- and postoperative asymmetry in hip rotation in stance obtained through gait analysis) (unilateral DO: $p < 0.001$; bilateral DO: $p < 0.001$).

Hip rotation in the stance phase of the limb with less IRG did not change significantly from pre- to postoperatively in either group (unilateral DO: $p = 0.631$; bilateral DO: $p = 0.051$), even though the derotation angle averaged 25.3° ± 7.6° in the group with bilateral FDO.

Although the postoperative asymmetry does not differ ($p = 0.453$), there is a significant difference in postoperative mean hip rotation between both limbs after bilateral FDO ($p = 0.036$). Conversely, these two parameters do not differ significantly in the group with unilateral FDO ($p = 0.493$). For gait analysis graphs please refer to Fig. 1.

The pelvic rotation changed significantly on the more ($p = 0.035$) and less involved side ($p = 0.001$) from pre- to postoperative after unilateral FDO. In contrast there was no significant change on the more ($p = 0.083$) or on the less involved side ($p = 0.234$) after bilateral FDO. The difference between pelvic rotation on the more and less involved side changed from pre- to postoperative significantly in the group with unilateral FDO ($p = 0.038$), whereas a significant change could not be measured in the group with bilateral FDO ($p = 0.941$) (Fig. 2). For gait analysis graphs please refer to Fig. 3.

3.1. Over- and Undercorrection

In the group with bilateral FDO there were seven cases of overcorrection (more than 5° of external rotation in stance phase during gait analysis) on the less involved side and three on the more involved side. Additionally, there were three cases of