3-D Characterization of Femoral Head Deformity in Patients with Cerebral Palsy

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INTRODUCTION: Hip disease is the second most common deformity in patients with cerebral palsy (CP). The Gross Motor Function Classification System (GMFCS) score correlates directly with the severity of hip pathology with 66% of GMFCS V patients developing hip instability and displacement by age 7-8 years. Spasticity and neuromuscular imbalances across the hip joint result in varying degrees of hip subluxation or dislocation and acetabular dysplasia with progressive deformity of the femoral head. A categorical hip classification system has been described based on acetabular and proximal femoral radiographic changes in patients with CP. The acetabular morphology of patients with CP has also been studied using three-dimensional (3D) methods. Studies examining proximal femoral shape in CP have focused on changes in femoral anteversion and neck-shaft angle. Morphological changes to the femoral head have been qualitatively described, however, no studies to our knowledge have quantified femoral head deformity in CP. The purpose of this study was to develop a 3D technique to quantify femoral head sphericity, compare it to normal age- and sex-matched controls, and validate this technique to a radiographic two-dimensional (2D) femoral head sphericity measure.

METHODS: A Level 3 case-control study was performed with a retrospective chart review for all non-ambulatory patients with CP (GMFCS level IV or V) who underwent pelvic and/or femoral osteotomies at a single pediatric hospital between 2007 and 2019. Hips of patients with CP who had both a preoperative pelvic computed tomography (CT) scan and corresponding anterior-posterior (AP) and frog leg lateral pelvis radiographs were included. The normal control group consisted of age- and sex-matched hips of patients with abdominal/pelvis CT scans for indications such as abdominal pain (23%) and appendicitis (23%). Normal control group images, radiology reports and medical records were reviewed to ensure there was no evidence of hip disease or neuromuscular disorder prior to inclusion. Normal hips were matched to CP hips at a rate of 2:1 when possible. 3D modelling software was used to generate models from the CT scans. Using the 3D models, root mean square (RMS) was calculated as a 3D sphericity measure using the mean between circumscribed and bounded spheres (0 = perfect sphere). Anteroposterior and lateral radiographs of the hip were used to calculate a 2D sphericity score (0 = perfect sphere)[1]. Intraclass correlation coefficient (ICC) was used to evaluate inter-rater reliability among two observers and was found to be acceptable (3D Sphericity RMS ICC: 0.81, $p<0.001$ and 2D Sphericity score ICC: 0.92, $p<0.001$). Correlation between RMS and 2D sphericity score in the CP and normal control group was determined using Spearman's rho. RMS was compared between CP and normal control hips using Mann-Whitney U.

RESULTS: Twenty-seven children with CP were identified (mean age at surgery: 10.7±4.6 years, 13 male and 14 female) with pre-op radiographs and CT scans. Ten children were GMFCS level 4, and 17 children were GMFCS level 5. RMS was significantly higher in the 54 CP hips than in the 106 controls (3.0±1.4 vs. 1.3±0.5, $p<0.001$). Mean 2D sphericity score for CP hips was also significantly higher, compared to controls (23.0±10.3 vs. 7.2±4.4, $p<0.001$). 3D RMS and 2D sphericity score were significantly correlated in CP ($r_s=0.494$, $p<0.001$) and normal hips ($r_s=0.485$, $p<0.001$).

DISCUSSION:
A methodology was developed to quantify 3D femoral head deformity in children with CP in a manner that correlates with their sphericity score on 2D radiographs. CP hips are quantitatively more aspherical compared to age- and sex-matched controls. Future study will be directed at using this methodology to quantitatively evaluate if hip containment procedures result in improved or maintained femoral head sphericity in children with GMFCS level IV and V CP.

SIGNIFICANCE/CLINICAL RELEVANCE: This methodology quantified greater asphericity of the femoral head in patients with CP compared to controls and further validates the 2D sphericity method, establishing a potential technique to quantify femoral head deformity and further confirming 2D methods which may be used as a lower dose option to monitor femoral head deformity over time.

REFERENCES:
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