A Novel Approach to Document Global Acetabular Deficiency in Patients with Neuromuscular Acetabular Dysplasia

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INTRODUCTION: Neuromuscular hip/acetabular dysplasia is the second most common orthopedic condition in children with cerebral palsy (CP), affecting up to one-third of children with CP. The etiology of neuromuscular acetabular dysplasia is believed to be multifactorial including muscle spasticity, asymmetric muscle forces, and subsequent pathologic proximal femoral anatomy, resulting in acetabular deficiency. Gross Motor Function Classification System (GMFCS) is a method for the classification of the CP severity in children and young adults based on their functional abilities and limitations. Although an anteroposterior (AP) pelvis radiograph is the standard assessment instrument for neuromuscular acetabular dysplasia, the ability to assess the acetabular dysplasia, especially at the posterior, using plain radiographs is challenging due to the 3D nature of the deformity. The purpose of this study was to develop a new technique o quantify global acetabular dysplasia in CP hips with different GMFCS levels and in comparisons to the matched control hips.

METHODS: Over a 12-year period at a single tertiary care institution, a consecutive sample of 285 children with CP were retrospectively identified across all GMFCS levels (age range: 3-22 years, age average: 9.3±3.5 years, 43% females; GMFCS I: n=12, GMFCS II: n=48, GMFCS III: n=55, GMFCS IV: n=92, GMFCS V: n=78). Patients with other neuromuscular conditions or prior hip surgery were excluded. Using a validated automatic segmentation and anatomy measurement program (VirtualHip, Boston Children's Hospital), 3D models of the pelvis were developed, and the acetabular region was isolated (Dice >0.95). An anatomical coordinate system (ISB) was then established using automatic landmark detection. Normal vectors of each element across each acetabular facet (i.e., ilium, ischium, and pubis) were established and averaged to find the regional normal vectors (Figure 1A). Ilium normal angle was measured in the coronal plane as an angle between the normal vector and superior-inferior axis (Figure 1B). Ischium and pubis angles were measured in the axial plane as angles between the ischium/pubis normal and anterior-posterior axis (Figure 1B). The same measurements were conducted on a cohort of 24,112 control asymptomatic hips (age range: 1-25 years, age average: 12±6 years, 48% females). Analysis of variance (ANOVA) with Dunnet posthoc was used to compare the normal angles between the groups (control, GMFCS I-II, GMFCS III, GMFCS IV-V) within 3 age groups of younger than 7 years, between 7 and 12 years old, and older than 12 years. The study was approved by the Boston Children's Hospital IRB.

RESULTS: The acetabular surface normal angles for each facet across all age groups and GMFCS levels, as well as the control group, are presented in Figure 1C. In general, for all acetabular facets, the normal angles of the GMFCS groups are larger than their corresponding age-matched control group (p<0.001). The normal angles increased by increasing GMFCS levels (p<0.001), with larger changes in the superior (ilium) and posterior (ischium) aspects than the anterior region (pubis). The average (over the age groups) of normal angles for pubis (50±5°) was larger than ilium (41±6°) and ischium (11±4°). Increasing the age was associated with decreased normal angle of the control group for all acetabular facets with the most change in the ischium normal angle (from 51±6° for <7 years old to 22±6° for >12 years old group). Except for the large difference between the ischium normal angle of 7 to 12 years old and older than 12 years old (from 49° to 22°), the changes in the normal angle of the control group for different ages were uniform (about 5°).

DISCUSSION: The current result highlights a global pattern in acetabular deficiency in CP patients, which can't be captured using 2D x-ray measurements. We saw strong direct links between CP severity (GMFCS levels) and the acetabular dysplasia as measured by the orientation of the acetabular surface normal vectors, with higher gross motor function deficiency associated with more divergent acetabular facets (lower congruency). We also say consistent reduction in normal angles, with larger reductions in controls than CP hips.

SIGNIFICANCE: Using 3D-model-based measurements to quantify regional acetabular orientation and comparing it with the matched controls provides a more accurate depiction of the acetabular deficiency, which may assist with treatment planning, including surgical correction.

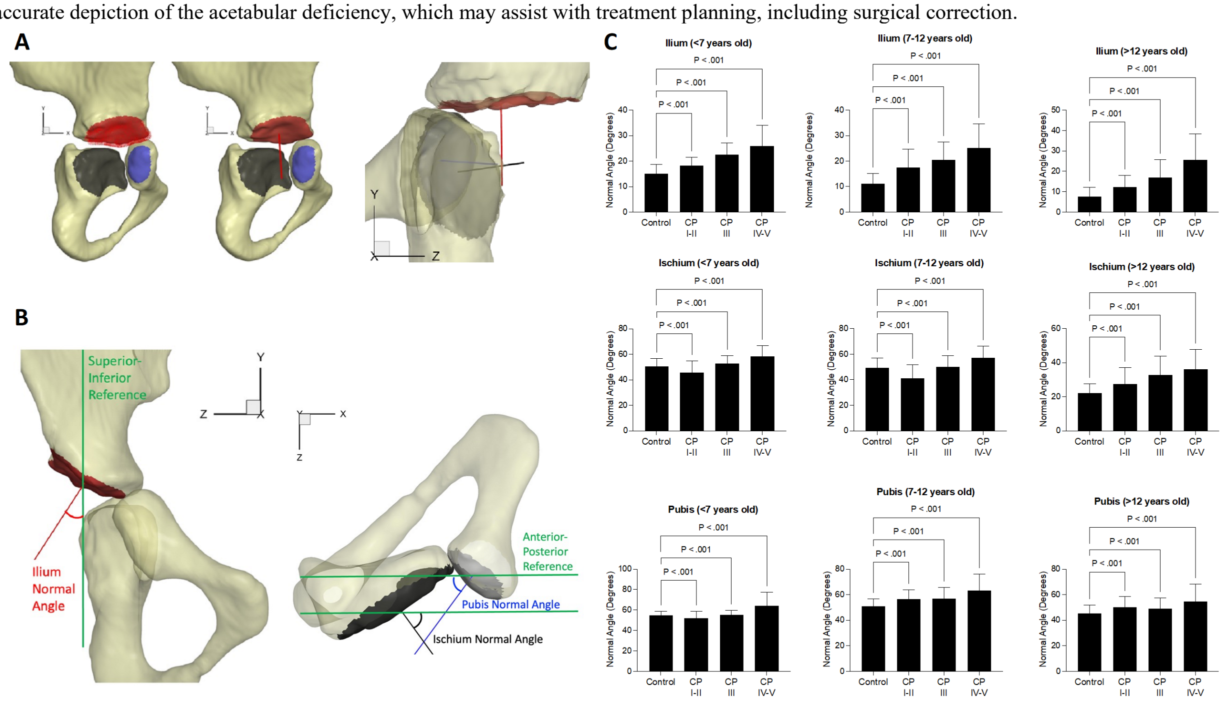

Figure 1. (A) Surface normal for pubis, ilium, and ischium. (B) Measurements of normal angles with respect to the reference lines. (C) Group differences in surface normal measurements compared to controls. A higher angle indicates larger dysplasia.