Multiplanar Humeral Shape Changes from Infancy to Adulthood in Patients with Birth-Related Brachial Plexus Palsy

Euan Forrest[1], Paige Lind[1], Michael L Pearl[2], Katharine Elizabeth Alter[3], Frances T Sheehan[4]
[1]Rehabilitation Medicine Department, [2]Quaternion Applications Inc., [3]Rehabilitation Medicine Department, National Institutes of Health, [4]Rehabilitation Medicine Department, National Institues of Health

INTRODUCTION:

Birth-Related Brachial Plexus Palsy (BRBPP), a peripheral nerve injury to an infant's brachial plexus during the birth process, is relatively common (incidence of 0.38-5.1 per 1,000 births) with potentially drastic effects on quality of life for both patients and caregivers. Infants with weakness persisting beyond the first few months of life often lack full shoulder, arm, and/or hand function. As no study has ever quantified the 3D effects of BRBPP on humeral shape and size throughout development, the purpose of this study is to evaluate the temporal patterns of humeral morphology resulting from unilateral BRBPP in patients from infancy to young adulthood. Understanding 3D anatomy in these individuals is imperative for surgical planning, providing insights into the timing and extent of necessary interventions or treatment, and guiding the initial evaluation and follow-up care processes.

METHODS:

3D GRE axial MR images of both arms were acquired from individuals with unilateral BRBPP (20/12 females/males, age 0.6-18.8 years, 11/21 L/R involvement). 3D bone models were made from manual segmentation of MR images (Figure 1), from which bone size, humeral head version, and humeral head inclination were quantified (Figures 2 and 3). Differences between sides (pathology) was tested using a paired Student's t or Wilcoxon test. The relationship between pathology and age was determined using a Pearson's or Spearman's correlation. The test used was based on data normality.

RESULTS:

Bone growth inhibition was seen across the entire population and increased with age (Table 1). The involved humeral head was anteverted relative to the uninvolved and anteversion increased with age (Table 2). Inclination was not different between groups but did decrease with age (Table 2). Sub-group analysis (Figure 4) revealed that bone growth inhibition and anteversion are present early on and continue to increase with age, while humeral head declination is only consistently present in individuals 9+ years old. Version and epicondylar width were variable across patients in the 6 months to 2-year range and then was typically seen in all patients greater than 2 years old.

DISCUSSION AND CONCLUSION:

This study confirms the presence of increasing humeral morphological pathology throughout development in children with BRBPP. The nerve injury fosters humeral growth inhibition within 6 months of birth, which increases throughout growth and development. The lack of humeral head declination in younger patients compared to older patients suggests that pathology is not consistently present until later stages of growth and development. Morphological changes are likely caused by weakened and imbalanced muscle forces, decreasing the level of coordinated movements and forces on the bone. This then leads to size and shape changes that further worsen these imbalances, creating a pathological feedback loop. Increasing pathology with development indicates early intervention is best to limit physical and functional deficits, but if missed, later intervention can still prevent further worsening levels of pathology. These affects not only hinder functional movements but may also have emotional and social impacts on developing children that may also be increasing with age.

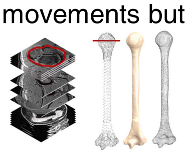

Figure 1: Bone Models
MRI scans were manually segmented around the bone cortex and cartilage (head) to create a 3D point cloud that was meshed to form a 3D model and aligned to its principal axes.

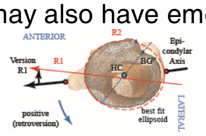

Fig 2: R1, primary radii of best-fit ellipsoid to the humeral head. VerR1: angle subtended by vector R1 and the epicondylar axis.

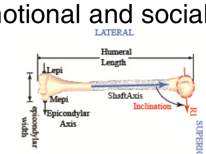

Figure 3: Humeral length: most superior to interior point distance. Shaft axis: central axis of the best-fit cylinder to the humeral shaft. Lepi (Mepi): the most lateral (medial) elbow points.

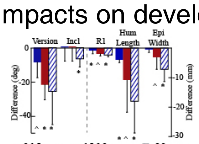

Figure 4: Group Pathology Levels: Average side-to-side differences (pathology), standard deviation. Significance: ^ = p<0.05 and * = p<0.001. Incl, hum, epi = inclination, humeral, epicondylar.

Table 1	Bone Size: Side-to-Side Differences (mm)		
	R1	Hum Length	Epi Width
Involved	17.3±4.4	193.8±76.3	35.7±12.8
Non-involved	19.0±5.1	205.0±82.5	39.5±15.5
Difference	-1.8±1.0	-11.2±9.2	-3.8±4.4
ρ (w/ age)	-0.73	-0.65	-0.72

Negative differences indicate bone growth inhibition. All differences (Wilcoxon signed rank) and correlations (Spearman's): p<0.001

Table 2	Bone Shape: Side-to-Side Differences (deg)	
	Version	Inclination
Involved	9.9°±24.8°	91.3±9.2°
Non-involved	21.0°±14.6°	93.2±6.1°
Difference	-11.1±16.8°	NS
r (w/ age)	-0.59	-0.43

Negative differences indicate humeral head anteversion and declination. Differences (Student's Paired t-test) and correlations (Pearson's) were significant for version (both p<0.001). Inclination difference was not significant, but its correlation was (p=0.015).