Detriments in scapular trabecular bone following brachial plexus birth injury despite injury location

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INTRODUCTION: Brachial plexus birth injury (BPBI) affects 1-3 in every 1,000 births, making it the most common nerve injury in children [1]. Sequelae depend on the location of the injury, with nerve rupture (postganglionic) causing muscle weakness, disuse, and contractures [2] and nerve avulsion (preganglionic) leading to muscle weakness and disuse without contracture [3]. Using rat models of these injury locations, we previously showed that postganglionic injury results in more severe gross morphological changes at the glenohumeral joint than preganglionic injury [4]. However, the effect of injury location on bone microstructural changes is unclear. We hypothesized that both injuries would be detrimental to trabecular microstructure, with more severe changes in postganglionic than preganglionic BPBI.

METHODS: All animal work was performed under an approved IACUC protocol. Sprague Dawley rat pups were placed in three groups: sham (n=15), postganglionic (n=26), and preganglionic (n=28) neurectomy. At postnatal day 3-5, neurectomies were performed on one (affected) side, with the contralateral (unaffected) side serving as an additional control. C5 and C6 nerve roots were excised either distal (postganglionic) [2] or proximal (preganglionic) [3] to the dorsal root ganglion. At 8 weeks rats were sacrificed, and affected and unaffected scapulae and humeri were harvested, fixed, and stored at 4°C. Bones were scanned using micro-computed tomography (micro-CT, 10-µm voxels). For the scapula, three volumes of interest were selected near the articulating glenoid surface (Fig. 1) and evaluated for standard trabecular bone metrics, including bone volume fraction (BV/TV), tissue mineral density (TMD), trabecular number (Tb.N), thickness (Tb.Th), and separation (Tb.Sp), and connectivity density (Conn.D) [5]. Affected-to-unaffected ratios were compared between groups using one-way ANOVA with Tukey's posthoc tests (alpha=0.05).

RESULTS: A subset of the scapula data are presented here (n=6-7/group). Zone 1 trabecular bone microstructure was unaltered for post- and preganglionic relative to sham. In zone 2, the only altered metrics were lower BV/TV (-24.5%, p=0.018) and TMD (-23.7%, p=0.008) for preganglionic compared to sham. In zone 3, trabecular bone was significantly deteriorated in most metrics for postganglionic relative to sham, with lower BV/TV (-20.6%, p=0.024), TMD (-20.6%, p=0.026), and Tb.N (-18.8%, p=0.005) (Fig. 2). Postganglionic also tended to have lower Conn.D (-24.2%, p=0.071) and higher Tb.Sp (+24.6%, p=0.13) relative to sham. Similarly, all metrics were deteriorated for preganglionic relative to sham, with lower BV/TV (-36.3%, p=0.0003), TMD (-36.4%, p=0.0003), Conn.D (-34.4%, p=0.01), Tb.N (-30.9%, p<0.0001), and Tb.Th (-9.6%, p=0.016) and higher Tb.Sp (+43.2%, p=0.0007). Compared to postganglionic, the preganglionic group had more deterioration, with lower Tb.Th (-9.4%, 0.019) and higher Tb.Sp (+24.6%, p=0.04), and tended to have lower BV/TV (-19.8%, p=0.091), TMD (-19.9%, p=0.096), and Tb.N (-14.9%, p=0.072).

DISCUSSION: Trabecular mineralization and microstructure were substantially deteriorated following both post- and preganglionic BPBI in the articulating glenoid area of the scapula, specifically within the zone 3 region of the scapular neck. While trabecular structural deterioration was previously reported following postganglionic injury in the proximal humerus [6], our study is the first to report trabecular deterioration in the scapula, which experiences more severe morphological deformities than the humerus [7]. Our data show that preganglionic injury causes similar or worse mineralization and microstructural detriments in the scapula compared to postganglionic injury, despite reduced macrostructural deformity (i.e., glenoid declination) for preganglionic vs. postganglionic in these rats, suggesting separate drivers for micro- and macrostructural changes following BPBI.

SIGNIFICANCE: This study provides important insight into the effect of nerve injury location on the underlying trabecular mineralization and microstructure in the scapula, which contribute to the load-bearing function of the shoulder. Trabecular bone changes with preganglionic injury have not previously been quantified. This work presents new evidence for differences in the macro- and microstructural progression of BPBI. Deepening our understanding of underlying factors driving these differences may inform better treatments to limit the development of deformities following BPBI.

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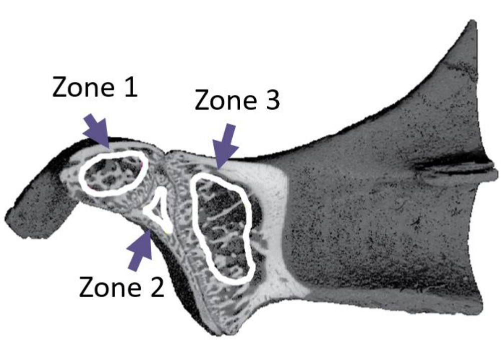

Figure 1. Micro-CT analysis zones in the glenoid fossa region of the scapula.

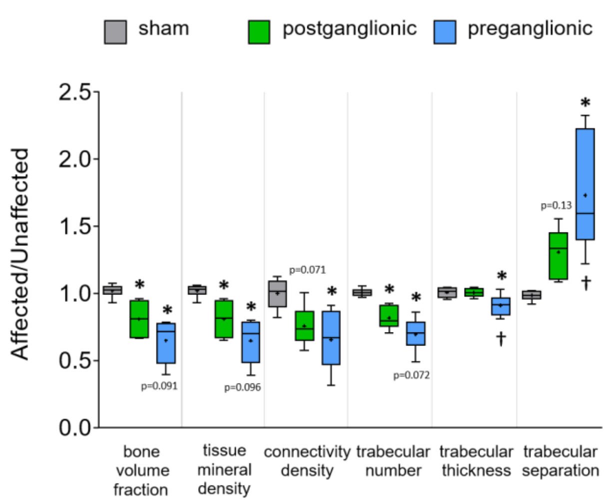

Figure 2. In zone 3, trabecular deterioration occurred in most metrics for post- and preganglionic relative to sham. *p<0.05 vs. sham. †p<0.05 vs. post-ganglionic. + mean value.