Amplification Of Regional Differences In Ulnar Nerve Kinematics By Nerve Tethering

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Disclosures:

Introduction: Towards an understanding of structural, mechanical and functional impacts of nerve tethering, we tested the hypothesis that nerve entrapment increases nerve deformation at the region of tethering during joint movement, thereby amplifying nerve strain. In addition, we performed a high-resolution immuno-histomorphometric study of regional differences in ulnar nerve architecture surrounding the elbow. Such studies have not yet examined this variation, and will enable us to better understand regional architecture underlying the ability of a nerve to accommodate strain, and thus also, structures that may encounter an altered biomechanical environment following tethering.

Methods: The ulnar nerve was dissected out of 4 cadaver arms with the shoulder maintained within its soft tissue bed. Epineurial optical markers were placed using suture, and the elbow and wrist were ranged through configurations that placed increasing tension on the ulnar nerve. Images were taken in each configuration to assess nerve strain and excursion relative to neutral configuration. The procedure was repeated with the ulnar nerve tethered with a suture at Osborne’s ligament to simulate cubital tunnel entrapment. The ulnar nerve was then excised. Sections of ulnar nerve in regions proximal, at, and distal to the elbow joint prior to any branching were taken. Sections were treated using histologic and immunohistomorphometric measures to assess for regional differences in connective tissue density, axonal number and density, fascicular density, and fascicular packing. We defined structures separated by a thick connective tissue barrier, presumably perineurium, as discrete fascicles. We calculated spacing between adjacent fascicles as a measure of packing density.

Results: Untethered nerves translated distally with elbow flexion, presumably due to nerve rotation away from the epicondyle axis. Tethering necessarily suppressed translation. ANOVA revealed significant effects of region and tethering on nerve strain following elbow flexion and wrist extension. Post hoc analysis (Tukey’s HSD) indicated differences in regional strain in both native and entrapped conditions. Regions of the nerve near the elbow joint experienced higher strains (~20-25%) than distal or proximal regions (~8-10%). Tethering induced additional increases in regional strain. Strains distal to the tether were significantly increased, with strains in the vicinity of tethering especially pronounced and increased as much as 20% above normal. Strains proximal to the tether were unaffected.

Immuno-histological analysis revealed differences in fascicle number and fascicle packing along the length of the ulnar nerve. The ulnar nerve proximal to the elbow contained fewer fascicles that were moderately compacted. The region of the nerve at the elbow joint contained a moderate number of fascicles that were loosely packed, suggesting more compliance during nerve stretch. Finally, the distal region of the ulnar nerve contained the most fascicles and highest compaction (Figures 1-3). Axonal density and number were not significantly different along the length of the nerve. Interestingly, fat also appears to vary regionally along the length of the nerve, with increased deposition at the elbow.

Discussion: While regional differences in the kinematic profile of the ulnar nerve have been previously observed it was not known that tethering would affect areas preferentially. This may explain why with advanced cubital tunnel syndromes even small movements may cause such pronounced symptoms, as strain is focused at the region of the joint as opposed to equal load sharing along the length of the nerve. Because this study shows that alterations in the biomechanical environment are an important factor in the treatment of ulnar compressive neuropathy, kinematics should be taken into account with any treatment of an entrapment neuropathy. These regional differences in strain also correlate with architectural differences along the nerve and there are multiple factors that could account for these differences, including the way axons and fascicles are bundled together, to allow for movement.

This study also demonstrates the feasibility of our methods of evaluating nerve kinematics in a live patient. Future directions include plans to differentiate the kinematic profiles of various surgeries that alleviate entrapment and quantify the biomechanical advantages conferred by them. This has especially strong implications in the treatment of cubital tunnel syndromes with ulnar nerve transposition versus simple decompression, where there continues to be controversy over the benefits offered by each surgery.

Significance: Significance: Cubital tunnel syndrome is the second most common entrapment neuropathy after carpal tunnel syndrome and resulted in 50,000 decompression procedures in 2008, a number that continues to rise. While neuropathic symptoms have been commonly attributed to compression, increased nerve strain due to tethering at the compression site has also been hypothesized to alter conduction and cause further progression of pathology.