Abstract

Background: Brachial Plexus Injuries (BPIs) are devastating, life-altering conditions that often result in severe motor impairments, significantly limiting patients' ability to control the affected muscles. Nerve Transfer Surgery (NTS) is a widely adopted intervention designed to reinnervate paralysed muscles by rerouting a donor nerve to the impaired recipient nerve, thereby restoring function. One of the primary target muscles for reinnervation is the Biceps Brachii (BB), as it plays a key role in elbow flexion.

Traditional clinical assessments, such as the Medical Research Council (MRC) Scale and Intramuscular Electromyography (iEMG), provide only qualitative or semi-quantitative evaluations of motor recovery.

Objective: This study evaluated reinnervation outcomes in the BB following NTS, employing High-Density Surface Electromyography (HD-sEMG) and force production metrics.

Methods: The study included adult patients with traumatic brachial plexus injuries affecting the musculocutaneous nerve and requiring surgical reconstruction. Eligible participants were enrolled between January 2023 and December 2024, with surgery performed within 13 months of trauma and follow-up assessments conducted at least 6 months post-operatively. Patients were divided into cross-sectional or longitudinal groups based on whether assessments occurred before or after 24 months from surgery, reflecting the expected timeline for reinnervation. Clinical and demographic data were collected, and muscle recovery was evaluated through outpatient assessments, electromyography, and MRI, with motor function graded using the MRC scale. Both the healthy and affected BB were assessed. HD-sEMG signals and force measurements were recorded during trapezoidal motor tasks performed at 20% and 60% of the maximum voluntary contraction (MVC). The collected data enabled an in-depth analysis of Motor Unit (MU) activation patterns and an evaluation of force control quality using various quantitative metrics.

Results: Reinnervated muscles exhibited notable deficits in precision, stability, and force modulation compared to healthy BBs. This was evidenced by lower Pearson correlation coefficients, higher root mean square errors, and an increased coefficient of variation of force. Additionally, the reduced mean instantaneous discharge rate, increased coefficient of variation of interspike intervals, and higher coherence between force and Cumulative Spike Train (CST) signals in affected BBs suggested a greater reliance on common synaptic inputs. The predominance of low-frequency neural drive components, as shown by the CST power ratio, further indicated compensatory strategies favouring synchronisation over dynamic modulation —likely due to the reduced number of available MUs and the enlargement of reinnervated units.

Discussion: These impairments are likely attributable to disrupted neural pathways and altered synaptic transmission following nerve injury and surgery, which compromise the Central Nervous System's (CNS) ability to deliver consistent and precise input to MUs.

Remarkably, some reinnervated BBs exhibited substantial recovery, approaching the performance of their healthy counterparts, thereby underscoring the interindividual variability in reinnervation outcomes.

Conclusion: These findings highlight the utility of HD-sEMG and force metrics in evaluating neuromuscular recovery. While motor performance in reinnervated BBs was generally reduced compared to healthy muscles, the observed functional activity supports the effectiveness of NTS in restoring motor function following BPI.

Future research should prioritise long-term follow-up, multi-muscle analysis, and advanced assessments of neuroplasticity to further optimise reinnervation strategies and patient outcomes.