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End-To-Side Transfer of the Anterior Interosseous Nerve (Supercharged End-To-Side) In Severe Compressive Neuropathies of the Ulnar Nerve

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Abstract **Original Research Article**

Cubital tunnel syndrome is the second most common compressive neuropathy in the upper extremity after carpal tunnel syndrome. Severe cubital tunnel syndrome is confirmed by axonal loss in electromyography and conduction velocity less than 40 meters/second in the nerve conduction study. As the severity of compressive neuropathy of the ulnar nerve increases, the results of surgical treatment worsen. Axonal regeneration progresses at a rate of 1 to 3 millimeters per day; However, the muscle is irreversibly denervated after 12 to 18 months. Due to the great distance between the location of the compression, the elbow, and the intrinsic muscles of the hand, reinnervation race against time so that irreversible degeneration of the motor plate and subsequent muscle atrophy does not occur. The supercharged end-to-side transfer of the anterior interosseous nerve to the motor fascicle of the ulnar nerve, to treat severe compressive neuropathies, allows earlier neuroregeneration of the intrinsic muscles of the hand, maintaining the viability of the motor plate, while the affected ulnar nerve regenerates throughout its journey.

Keywords: supercharged end-to-side transfer, anterior interosseous nerve, ulnar nerve, compressive neuropathy, cubital tunel.

INTRODUCTION

Cubital tunnel syndrome is the second most common compressive neuropathy in the upper extremity after carpal tunnel syndrome. It represents a diagnostic challenge, since patients frequently do not go to the doctor until a long time after the symptoms appearance, when the nerve is already seriously affected.

Ulnar compressive neuropathy presents as a progressive and predictable spectrum of injury. It goes through different stages: dynamic ischemia, demyelination and axonal loss. These stages can be differentiated by a thorough clinical history, directed clinical examination, and correct interpretation of neurophysiological studies. When the process becomes chronic, axonal loss occurs. In these severe cases the symptoms are constant, the two-point discrimination test is altered, and they are accompanied by weakness and muscle atrophy. Neurophysiological studies show a decrease in conduction velocity, decreased amplitude (reflection of the lower number of functioning fibers), muscle fibrillation in the resting phase (indicates loss of motor axons), presence of action potentials of motor units during the recruitment phase (reinnervation by collateral axonal sprouts from neighboring unaffected motor fibers). The amplitude of the CMAP (compound muscle action potential) decreases in more severe cases. This electromyographic finding helps in surgical decision making because it predicts functional outcomes [3, 4]. Severe cubital tunnel syndrome is confirmed by axonal loss in electromyography and conduction velocity less than 40 meters/second in the nerve conduction study [2].

Conservative treatment of ulnar neuropathy will be indicated in patients with mild or moderate symptoms (dynamic ischemia) in whom sensory alterations are not constant and the motor conduction speed at the elbow is greater than 40 meters/second. It is based on preventive measures, pharmacological treatment and rehabilitative treatment. Depending on the severity of the symptoms and as long as the criteria set out above are maintained, conservative treatment can be prolonged for up to 2 or 3 months before considering surgical decompression.

Severe cases do not respond to conservative treatment, and as the severity of compressive neuropathy increases, the results of surgical treatment worsen [1]. Recovery after surgery in severe cases is much slower.

Surgical treatment is subject to controversy. There is no consensus on whether in situ decompression (open or endoscopic) or associacion with anterior transposition (via epitroclectomy, subcutaneous transposition, transmuscular transposition or submuscular transposition) is the best option. Some authors recommend associating a decompression of the ulnar nerve at the level of Guyon's canal given the frequent association of both syndromes, which would explain the failures after isolated decompression of the ulnar nerve at the elbow [5].

Axonal regeneration progresses at a rate of 1 to 3 millimeters per day; However, the muscle is irreversibly denervated after 12 to 18 months [6, 7]. Due to the great distance between compression location, the elbow, and the intrinsic muscles of the hand, reinnervation goes on a race against the clock so that the motor end plate does not undergo through irrevirsible degeneration and subsequent muscle atrophy does not occur [8].

In chronic neuropathies with severe axonal injury, end-to-side supercharged nerve transfer between the anterior interosseous nerve (AIN) and the motor bundle of the ulnar nerve at the level of the wrist, associated with nerve decompression, seems to be a recommendable procedure to achieve reinnervation of the intrinsic musculature dependent on the ulnar nerve [4, 3].

In 1991, Mackinnon *et al*., described the use of the anterior interosseous nerve to restore intrinsic muscle function in complete injuries of the ulnar nerve, with an end-to-end suture. In 2009, the same authors described the use of an end-to-side transfer, the supercharge transfer, of the anterior interosseous nerve to the motor branch of the ulnar nerve, in severe cubital tunnel syndrome [5-9].

This transfer allows earlier neuroregeneration of the intrinsic muscles of the hand, maintaining the viability of the motor plate, while the affected ulnar nerve regenerates along its path [10, 11].

Power *et al*., suggested that in the first two to three months function improves due to remyelination. In the fourth and fifth months, due to axonal regeneration after decompression of Guyon's canal, and the earliest recovery with the the anterior interosseous nerve transfer will be at 6-7 months [12].

OBJECTIVES

The aim of this study is to perform a narrative revisión of recent literatura on supercharged AIN-to ulnar nerve transfers in the treatment of severe ulnar compressive neuropathies.

Patient Selection

Patient selection is based on neurophysiological studies. Good candidates for this surgical technique are those who present in the EMG a decrease in the amplitudes of the muscle action potential (reflecting a lower number of axons crossing the compression site) and the presence of fibrillations / positive sharp waves that indicate that at least some motor endplates remain available and receptive to reinnervation. These findings suggest denervation of the target muscle, but not a complete loss of the motor endplates, indicating that the muscle can still be reinnervated [12].

Surgical Technique

As the terminal branch of the anterior interosseous nerve enters the pronator quadratus, it is identified and isolated. This point is preferred for transfer due to it’s the proximity with the ulnar nerve and because the function of the pronator quadratus can be compensated by the pronator teres. The motor bundle of the ulnar nerve is isolated approximately 9 cm proximal to the palmar crease of the wrist. At this point the ulnar nerve divides into a dorsal cutaneous branch, a deep motor branch, and a sensory branch [5].

The branches of the AIN to the pronator quadratus contain between 500 and 700 nerve fibers, while the deep motor branch of the ulnar contains about 1200 at this level [5]. Once isolated, the distal branch of the AIN to the pronator quadratus is mobilized to the motor branch of the ulnar nerve. When the necessary length of the AIN is achieved, it is sutured in a end-to-side manner to the ulnar motor bundle through a small epineural window and secured with microsutures and/or fibrin glue [12].

In the postoperative period, when the intrinsic muscles begin to be reinnervated, follow-up by a Rehabilitator familiar with a "donor-centered activation" type approach is important [13].

RESULTS

End-to-side transfer of the anterior interosseous nerve was described by Mackinnon for the treatment of severe ulnar neuropathy. In several recent studies, good results have been obtained with the use of this technique in the treatment of compressive neuropathies of the ulnar, and even in some cases of injury due to nerve section [14-19]. However, In Sallam's study, improvement in ulnar nerve function after nerve transfer was limited. The activity of the adductor hallucis improved, but not that much regarding to the first interosseus [20]. Barteli in his study suggests that in proximal injuries that affect the ulnar nerve, adding the transfer of the motor branch of the opponens pollicis to the terminal branch of the motor branch of the ulnar nerve could be an alternative for reconstruction [21].

Davidge *et al*., carried out a study with this technique in both compressive neuropathy and section injuries. In fifty-five patients, 70% achieved at least grade 3 return of intrinsic function. Most cases were compressive injuries; only five patients had complete ulnar section injuries [22].

Dengler *et al*., presented in a retrospective study that included forty-two patients with severe cubital tunnel syndrome operated on in the last five years. Decompression was associated with supercharge transfer of the anterior interosseous nerve (AIN) to the ulnar nerve. Postoperative first dorsal interosseous muscle strength, pinch strength, and DASH scores improved significantly from baseline. In three patients, the technique was unsuccessful. Apart from age, there were no significant clinical or diagnostic variables that could predict failure. There was no CMAP amplitude threshold below which the technique was unsuccessful [23].

Jarvie *et al*., presented two cases of severe ulnar neuropathy treated with this technique. Nerve conduction studies at the first year showed reinnervation of the ulnar nerve with high amplitude motor unit potentials in the first dorsal interosseous, increased motor amplitudes in the hypothenars and speed Improved conduction through the elbow. However, sensory response remained absent, suggesting lack of sensory recovery, based on electrodiagnostic studies, compared to significant motor recovery. It provides additional evidence that transfer is responsible for the observed motor recovery [24].

Doherty *et al.*, also conducted a study with thirty patients with severe ulnar compressive neuropathy and concluded that this technique demonstrates clinical improvement of intrinsic muscle strength when combined with proximal subcutaneous transposition of the ulnar nerve in patients with severe ulnar neuropathy at the elbow with axonopathy [25].

The motor component is a priority over the sensory component of the ulnar nerve; Traditionally, sensory nerve transfers have been used from the third space median nerve bundle, the median palmar cutaneous nerve, or the lateral antebrachial cutaneous nerve. However, due to the type of end-to-end transfer, they leave a sensory deficit at the donor site [5-26]. Felder *et al*., conducted a study with encouraging results in which they applied a cross palm graft between the median and ulnar nerve for sensory recovery [27]. This technique was applied in 2022 by Medina in one case, with success [28].

Besides compressions in the cubital tunnel, Tanure published a clinical case of a patient with Hirayama disease (cervical myelopathy), affecting the territory of the ulnar nerve, C7, C8 and T1; in which the transfer described in this study was performed, with recovery of motor function in seven months [29].

CONCLUSION

Although good results have been obtained in several articles, more data is required to draw conclusions and provide specific indications. Additionally, the supercharge concept may be applicable to other nerve injuries other than ulnar nerve injuries. If support for the technique continues, additional transfers will probably be devised and used [30].

Another option to explore would be the use of electrical stimulation after decompression. Juckett conducted a review on electrical stimulation in peripheral nerve injuries [18]. After decades of promising animal studies, some recent randomized clinical trials have provided encouraging evidence of electrical stimulation as a clinically applicable therapy that accelerates recovery and improves outcome [31-34]. Several ongoing trials are further exploring the indications for electrical stimulation and its optimal administration protocol to maximize patient benefit [35-40].

End-to-side supercharge transfer is an effective and safe treatment that can restore intrinsic function in patients with proximal nerve injuries [41]. Currently, based on the little bibliographic evidence, supercharge transfer of AIN to ulnar in compressive proximal ulnar neuropathies seems to be a procedure with low morbidity and is a solution to be considered in the algorithm [42], of the treatment of this pathology to avoid motor end plate degeneration, although more studies are needed to support this technique.

Conflict of Interests

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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