*Case report*

# END-TO-SIDE NEURORRHAPHY TECHNIQUES: EXPLORING NEURONAL REGENERATION TO RESTORE NERVE FUNCTION - CASE REPORT


## ABSTRACT

**Aims:** To report the case of a pediatric patient with total left brachial plexopathy, exhibiting partially restored motor function and impaired sensitivity, that was treated with the end-to-side neurorrhaphy (ETSN) technique.

**Presentation of case:** A 13-year-old right-handed female with no comorbidities underwent a car accident. After clinical and imaging evaluation, the diagnostic hypothesis was total left brachial plexopathy with partially restored function and loss of protective sensitivity in the pincer region. A surgical intervention was recommended. When analyzing the characteristics, end-to-side neurorrhaphy appeared to be the most appropriate technique in scenarios where a donor is unavailable, being the procedure performed.

**Discussion:** ETSN is based on the suture of the distal end of a transected nerve to the lateral side of a healthy donor nerve, aiming to restore neurons through peripheral plasticity. Generally, ETSN cannot replicate model technique's efficacy, such as in brachial plexus repair, but remains valid in select cases. In many situations, the traditional technique is effective, however, in certain challenging scenarios involving nerve injuries exceeding 3-4 cm or in the absence of donor nerves, it becomes necessary to resort to alternative methods. Therefore, ETSN technique stands as an excellent choice and deserves consideration.

**Conclusion:** The patient progressed with a good prognosis and recovered protective sensitivity in the pincer region. ETSN technique is efficient for peripheral nerve injuries with inaccessible proximal trunks or long nerve defects. The discussion surrounding ETSN remains controversial, making this study essential for expanding scientific knowledge.



*Keywords: Neurorrhaphy, Sensory, Trauma, Pediatrics, Case report.*



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## 1. INTRODUCTION

Peripheral nerve injuries affect 2-2.8% of polytrauma patients, being associated with significant impairment to the functioning of the upper and lower extremities [1]. Variables such as the technique applied, the type of nerve reconstruction and the period between the injury and surgery impact clinical results, being a challenge for reconstructive surgeons [2]. The end-to-end epineural nerve suture, considered the gold standard technique for microsurgical nerve reconstruction, has imperfections, sometimes not being feasible for many reasons, such as when significant gaps between the stumps exist, limited amount of obtainable graft tissue, unavailability of the proximal nerve stump and morbidity at the donor site [2, 3, 4]. In this context, the literature discusses the End-to-Side neurorrhaphy (ETSN) technique as a potential strategy for treating nerve lesions [3, 4, 5].

ETSN was initially described in the “Traité des Sections Nerveuses" by Létiévant in 1873, however, the technique was rapidly abandoned due to unsatisfactory outcomes, probably related to the utilization of non microsurgical instruments and techniques [4]. Decades later, Viterbo´s experimental work, exhibiting histologic evidence of axonal growth into the distal recipient nerve and electrophysiologic evidence of reinnervation, shifted the attention of the scientific community back to ETSN [5].

ETSN involves coaptation of the distal stump of a transected nerve to the trunk of an adjacent donor nerve, allowing the patient to regain nerve function after damage [5]. This technique is based on the concept that axons regenerate through terminal and collateral sprouting from the donor nerve, however, the mechanisms of neural regeneration remain not entirely understood, with discrepancies among study findings [6].

Usually, ETSN is recommended for situations where end-to-end neurorrhaphy cannot be performed or when the proximal stump is unavailable, as observed in global brachial plexus avulsion injuries [7]. When compared to other classic procedures, ETSN needs less time and dissection [1]. From this perspective, this study reports the case of a pediatric patient with total left brachial plexopathy, exhibiting partially restored motor function and impaired sensitivity. ETSN was performed from the lateral cutaneous nerve to the median nerve to restore protective sensation in the pincer region.

## 2. PRESENTATION OF CASE

Patient WK, a 13-year-old right-handed female with no comorbidities, underwent a car accident. She was admitted to the neurosurgery department of a leading trauma hospital in Brazil and, after clinical stabilization, had lost motility of the left upper limb. The clinical investigation showed no intracranial lesions and fractures. The patient was then followed up as an outpatient, undergoing post-trauma motor physiotherapy, which led to partial recovery of the movements of the affected limb after two months.

A new physical examination revealed restored motor function in the musculocutaneous, median and axillary nerves. However, motor function of the ulnar and radial nerves was compromised. Also, painful sensitivity was preserved in the C5, hypoaesthetic in C6 and T1 and anesthetic in C7 and C8, with an electroneuromyography (ENMG) performed for further evaluation.

ENMG and magnetic resonance imaging (MRI) of the brachial plexus identified left axonal brachial plexopathy, mainly affecting upper and middle trunks, pre and postganglionic. The evaluation exhibited absent or reduced reinnervation signs in the biceps, extensor digitorum communis and extensor indicis muscles.

The MRI indicated avulsion of left C7 and C8 roots in the intradural portion, with no other alterations. Right plexus appeared normal. The left plexus showed heterogeneous appearance with prominent edema in the retroclavicular region, outside the scalene triangle. Diffuse muscle edema was present in the supraspinatus, infraspinatus, subscapularis and deltoid muscles, indicating denervation. Spinal cord signal alteration was noted from C3 to C6-C7 transition, related to traumatic myelopathy.

The diagnostic hypothesis was total left brachial plexopathy with partially restored function and loss of protective sensitivity in the pincer region. Surgical intervention was recommended. When analyzing the characteristics of the lesion in WK's case, which had nerve defects of over 3 cm associated with the absence of potential proximal donor nerve trunks, end-to-side neurorrhaphy appeared to be the most appropriate technique, being the procedure performed, involving neurorrhaphy of the lateral cutaneous nerve as the donor to the median nerve as the recipient.

The patient presented a good prognosis and recovered protective sensitivity in the pincer region. Below are a series of pictures of the procedure.

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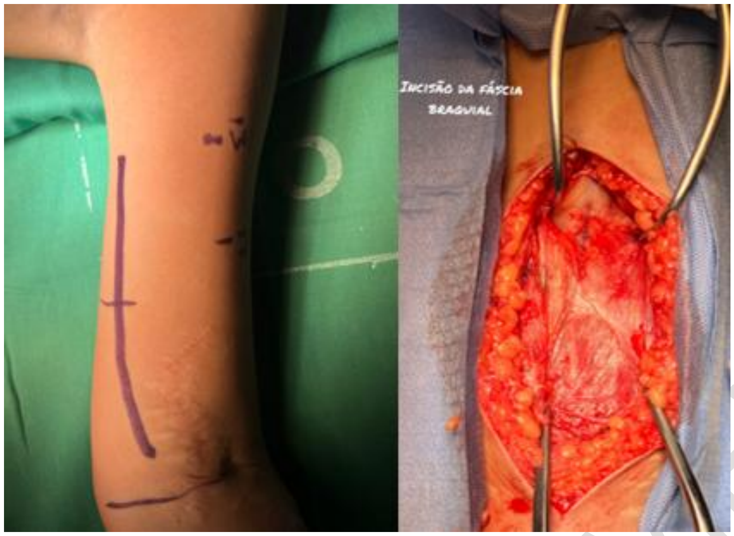


**Fig.1:** Supine position with the arm abducted and externally rotated. Forearm extended in supination (left). Incision of the brachial fascia (right).

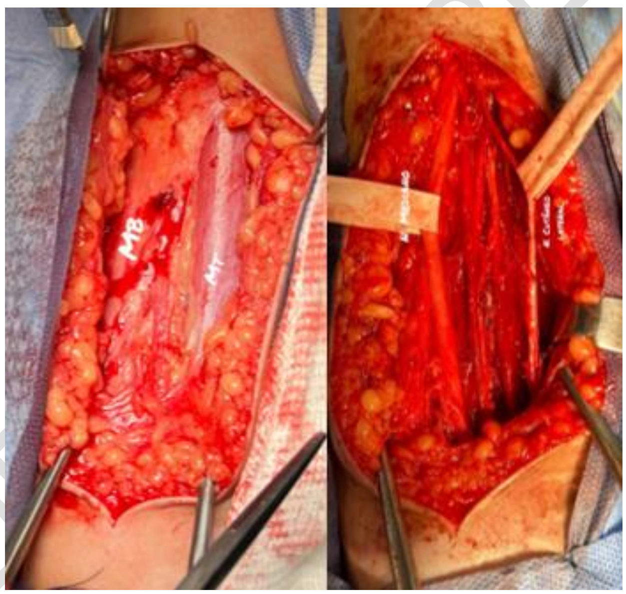


**Fig.2:** Muscle identification, biceps and tríceps. Vasculonervous bundle dissection with identification of the median nerve and lateral cutaneous nerve.

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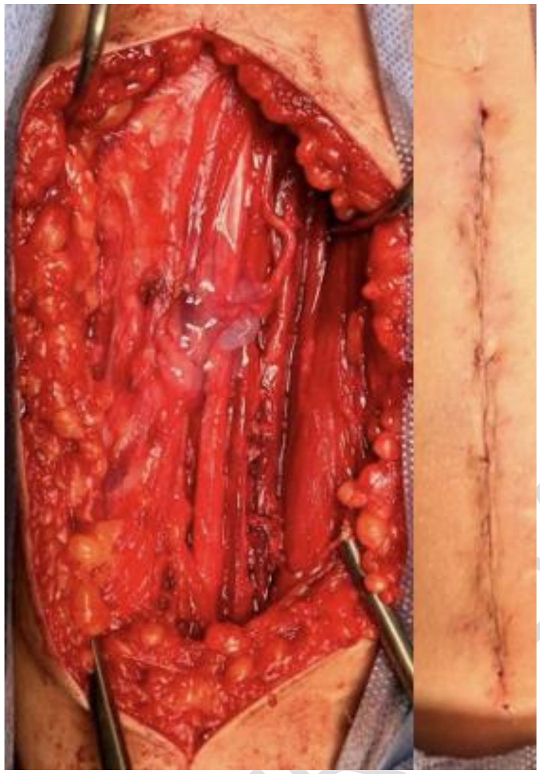

**Fig.3:** Lateral cutaneous nerve section and end-to-side transfer. Closing by planes and final appearance of incision.

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## 3. DISCUSSION

ETSN is based on the suture of the distal end of a transected nerve to the lateral side of a healthy donor nerve, aiming to restore neurons through peripheral plasticity [1]. The recipient nerve acts as a scaffold for the growth of branches from the donor nerve, promoting sensory-motor restoration. Potentially, factors related to metabolism, neuroendocrinology, donor-recipient neurocompatibility, the degree of surgical trauma, size of the contact area and other variables influence outcomes. [1,3,5].

The ETSN nerve repair technique was first described more than a century ago. However, as a result of previous failures, the technique was abandoned and only revisited in 1992, owing to advancements in neurobiology, microsurgical techniques and the contributions of Viterbo et al [1].

Even today, the efficacy and clinical usefulness of ETSN are debated in the literature, with disparities between experimental and clinical results [8]. Nevertheless, many studies have reported the feasibility of this technique in clinical practice [3].

Franciosi et al. reported on 5 patients with brachial plexus injuries who underwent the procedure, of whom 4 (80%) obtained a notable improvement in their initial clinical condition, achieving grade 4 elbow flexion after just a few months of surgery. Mennen described a series of 56 patients who were treated by ETSN, achieving better results in proximal motor and distal sensory reinnervation, highlighting the relevance of this technique [8, 9].

ETSN generally cannot replicate model technique's efficacy, such as in brachial plexus repair, but remains valid in select cases [4]. Studies by Tos et al. and Lykissas et al. demonstrated ETSN effectiveness for nerve defects exceeding 3-4 cm and when proximal neuronal trunks or donor nerves are unavailable [3,4]. Amr et al. reported successful digital

nerve reconstruction and traumatic brachial paralysis cases treated with end-to-side and side-to-side neurorrhaphy, all showing satisfactory outcomes [3,10].
Other studies evaluated ETSN efficiency. Haninec et al. analyzed ETSN for brachial plexus reconstruction, achieving a 43.5% satisfactory rehabilitation rate in patients undergoing ETSN with perineural window opening during a two-year follow-up. Previous studies findings, such as perineural suture as optimal intervention for reinnervation of nerves with large diameters, like the brachial plexus, and superior sensory reinnervation over motor after ETSN, reinforced our therapeutic choice [11].
Despite promising studies, such as the one by Czarnecki et al., which demonstrates the good efficacy of ETSN with prognostic results similar to other techniques and without compromising the donor nerve [2], others, such as those by Tos et al., point to a possible increase in axonal growth time via the ETSN technique, which could be a contributing factor to unsatisfactory results. However, even those studies state that ETSN can be considered a valid therapeutic option in selected situations, associated with other strategies, in the event of failure of other previous attempts at repair or when other approaches are not viable [3].
Differences between experimental and clinical results in studies of ETSN may arise from incomplete neuronal regeneration understanding. Regenerated axons in the donor nerve's epineurium are thought to originate from Ranvier nodes near the ETSN site, however, histological evidence is scarce [12]. Partial neurotomy of the donor nerve, promoting endogenous activation of neuroendocrine factors, may enhance motor neuron regeneration through ETSN [3]. Physical and chemical factors, including phototherapy, FK506 and acetyl-L-carnitine, could also stimulate post-ETSN neuronal regeneration, encouraging future research for technique improvement [4].
Due to experimental studies which demonstrated histologic evidence of axonal growth and evidence of reinnervation, ETSN was revived as a potential technique to promote axonal reinnervation. The literature suggests two mechanisms of axonal regeneration: terminal sprouting and collateral sprouting. In the former, axonal growth occurs along the uninjured axonal length, while in the latter, axonal growth occurs in the distal mediations of the axons, which may or may not be injured. Contrary to what the initial studies stated, the process of axonal regeneration provided by the ETSN technique involves collateral sprouting in the intact axon side of the donor, which is the principle of regeneration promoted by ETSN. This process begins in the nodes of Ranvier, proximal to the lesion, as mentioned above. However, this topic is still under research [5].
Despite the fascicular transfer higher success rate, ETSN serves specific cases, particularly those involving risk of distal movement interruption due to donor nerve fascicle transection, a common concern in combined supraclavicular and infraclavicular brachial plexus injuries, leading to hand function impairment. Haninec suggests that ETSN should only be considered for axillary nerve repair in brachial plexus reconstructive surgery when typical donor nerves are unavailable or when the risk of donor nerve fascicle transection is high, mirroring our patient. Neurotrophin use for support reinnervation is a potential method to enhance future outcomes and technique visibility [4,11].
Viterbo et al. and Frutan et al. explored other variables in ETSN that could influence its efficacy, comparing it to other neurorrhaphy methods. Frutan’s study compared techniques with and without window, assessing functional and non-functional parameters. Results revealed that functional factors were not statistically different between groups, while non-functional aspects exhibited higher axonal fiber concentration in the ETSN with window technique, suggesting its sensitivity to neurotrophic factors. Salehi attributed this disproportionality to non-selectivity neural regeneration and metabolic variations [1,12].
Viterbo et al. also examined ETSN with and without a window, evaluating various neuronal parameters over 6 months. No differences were found between the two neurorrhaphy techniques regarding electrophysiological tests, muscle weight, histological evaluation, muscle fiber areas or nerve fiber counts. This finding is significant, as non-removal of

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perineurium makes ETSN easier, faster and safer, reducing the risk of donor nerve injury [12].

## 4. CONCLUSION

ETSN technique proved to be efficient for peripheral nerve injuries with inaccessible proximal trunks or long nerve defects. The discussion surrounding ETSN remains controversial, making this study essential for expanding scientific knowledge on the subject, providing greater clarity and understanding.

## CONSENT

The authors report that they have the patient's consent, which is available upon request.

## ETHICAL APPROVAL

Not applicable.

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