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REVIEW ARTICLE

ADVANCED RECONSTRUCTIVE STRATEGIES IN BRACHIAL PLEXUS AND PERIPHERAL NERVE INJURIES – INTERDISCIPLINARY COLLABORATION BETWEEN A HAND SURGEON AND A NEUROPHYSIOLOGIST

ZAAWANSOWANE STRATEGIE REKONSTRUKCYJNE W URAZACH NERWÓW I SPLOTU RAMIENNEGO – WSPÓŁPRACA INTERDYSCYPLINARNA POMIĘDZY CHIRURGIEM RĘKI A NEUROFIZJOLOGIEM

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ABSTRACT
High-energy injuries of the brachial plexus and major peripheral nerves represent some of the most challenging issues in reconstructive surgery. Prolonged regeneration distances, early muscle atrophy, and the risk of irreversible functional loss necessitate advanced microsurgical strategies. These cases also require close interdisciplinary collaboration between a neurophysiologist and a hand or nerve surgeon. This review summarizes current reconstructive approaches, including direct nerve repair, autologous and allogeneic nerve grafting, end-to-side, reverse end-to-side, and modern direct nerve transfers, or procedures using nerve conduction studies. It also emphasizes the crucial diagnostic and intraoperative contributions of neurophysiology to clinical decision-making.

Keywords: brachial plexus injury, nerve injury, nerve reconstruction, nerve transfer, hand surgeon, neurophysiologist, nerve regeneration

STRESZCZENIE
Urazy splotu ramiennego i głównych nerwów to jedne z najbardziej skomplikowanych wyzwań w chirurgii rekonstrukcyjnej. Długi czas regeneracji, szybki zanik mięśni i ryzyko trwałej utraty funkcji wymagają stosowania zaawansowanych technik mikrochirurgicznych. Przypadki te koniecznie obejmują ścisłą, interdyscyplinarną współpracę neurofizjologa z chirurgiem ręki lub chirurgiem nerwów. Niniejszy przegląd omawia obecne metody rekonstrukcji nerwów, takie jak bezpośredni szew nerwu, autologiczne i allogeniczne przeszczepy nerwów, transfery koniec do boku, odwrócony koniec do boku oraz bezpośrednie transfery nerwów i procedury z użyciem badań przewodnictwa nerwowego. Podkreśla także kluczową rolę neurofizjologii w decyzjach klinicznych, zarówno diagnostycznych, jak i śródoperacyjnych.

Słowa kluczowe: uszkodzenie splotu ramiennego, uszkodzenie nerwu, rekonstrukcja nerwu, transfer nerwów, chirurg ręki, neurofizjolog, regeneracja nerwów

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Introduction

High-energy trauma to the brachial plexus or high-level peripheral nerve lesions lead to a prolonged regeneration period, often exceeding the critical period before irreversible muscle atrophy begins. Traditional repair strategies are effective in selected cases but have limitations, such as long reinnervation distances, biological constraints of axonal regeneration, and variations in injury type, including nerve root avulsion [1,2]. Contemporary reconstructive nerve surgery seeks to shorten this interval through targeted nerve transfers, end-to-side (ETS) or reverse end-to-side (RETS) nerve transfer techniques, and advanced intraoperative neuromonitoring or electrostimulation [3–6]. Optimal outcomes result from integrated planning between neurophysiologists and peripheral nerve surgeons, whose combined expertise enables a personalized reconstructive pathway for each patient [3,7,8] (Figure 1).

Materials and methods

Pathophysiology of nerve injury and regeneration

Accurate classification of peripheral nerve injury severity is essential for guiding appropriate management. The Seddon classification – neurapraxia, axonotmesis, and neurotmesis – remains the most widely applied system in clinical practice [9]. Neurotmesis constitutes an absolute indication for surgical intervention, as spontaneous recovery is not possible. A more detailed system described in the literature is the Sunderland classification, which categorizes peripheral nerve injuries into five progressive grades [10]. Grade I corresponds to a transient conduction block without structural axonal damage. Grade II involves axonal interruption with preservation of the endoneurial tubes, permitting relatively predictable axonal regeneration. Grade III is characterized by disruption of both axons and the endoneurium, resulting in variable and often incomplete functional recovery. Grade IV denotes injury extending through the axons, endoneurium, and perineurium, with only the epineurium remaining intact, which markedly impairs spontaneous regeneration and typically necessitates surgical intervention. Grade V represents complete transection of the nerve, requiring operative repair to restore continuity.

Following a neurotmetic injury, Wallerian degeneration occurs in the distal segment of

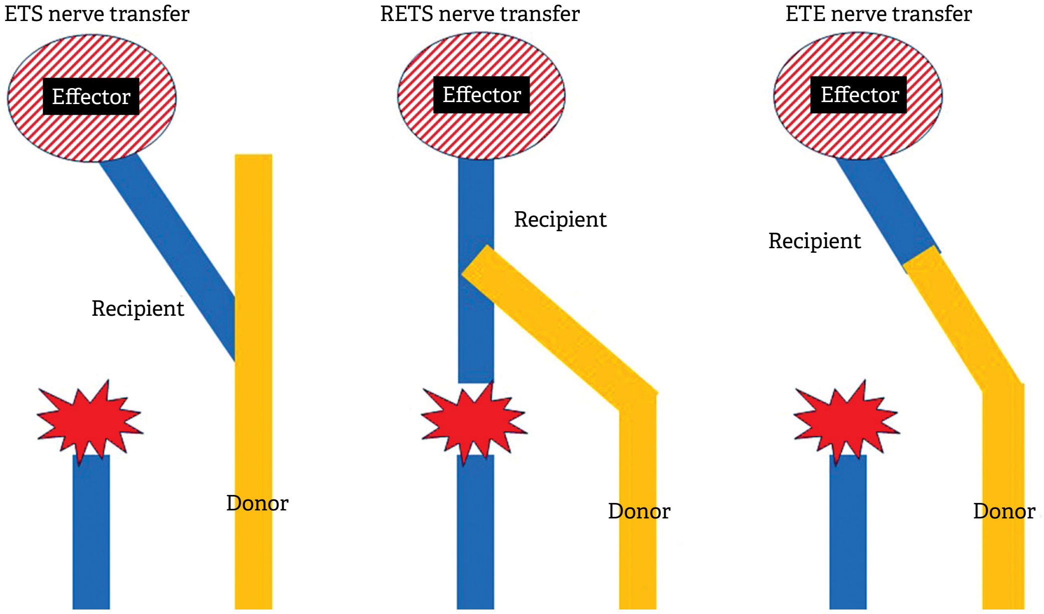

Figure 1. Schematic presentation of classical end-to-side (ETS), reverse end-to-side (RETS), and direct end-to-end (ETE) nerve transfer

the nerve. This process typically begins within the first 72 hours from an injury and involves degradation of the axon, its terminal branches, and the myelin sheath. Schwann cells undergo rapid proliferation, while macrophages are recruited to the lesion site by chemotactic and inflammatory signaling molecules. Together, these cells clear myelin debris and create a permissive microenvironment for regeneration. In the proximal stump, axons reorganize and generate growth cones, which extend distally. Proliferating Schwann cells align longitudinally to form Bands of Büngner, creating tubular structures that guide regenerating axons toward their target organs. Under optimal physiological conditions, axonal elongation proceeds at approximately 0.5–9 mm/day, with an average clinically accepted rate of ~1 mm/day [11–13] (Figure 2).

Despite these intrinsic regenerative processes, motor end plates undergo progressive atrophy. This begins about 6 months after denervation. Degeneration becomes largely irreversible after 12–24 months. This narrow therapeutic window underscores the critical importance of timely diagnosis and early surgical reconstruction. Acting early maximizes the potential for meaningful functional recovery [5,14].

Diagnostic evaluation

Clinical examination

A structured physical assessment remains fundamental and includes:

- sensory evaluation: superficial and deep sensation, paresthesias, two-point discrimination;
- motor evaluation: muscle strength, joint movement range, amyotrophy evaluation;
- autonomic findings: trophic changes, skin moisture, and texture of digital pulp.

These components help raise early suspicion of nerve injury [15–17].

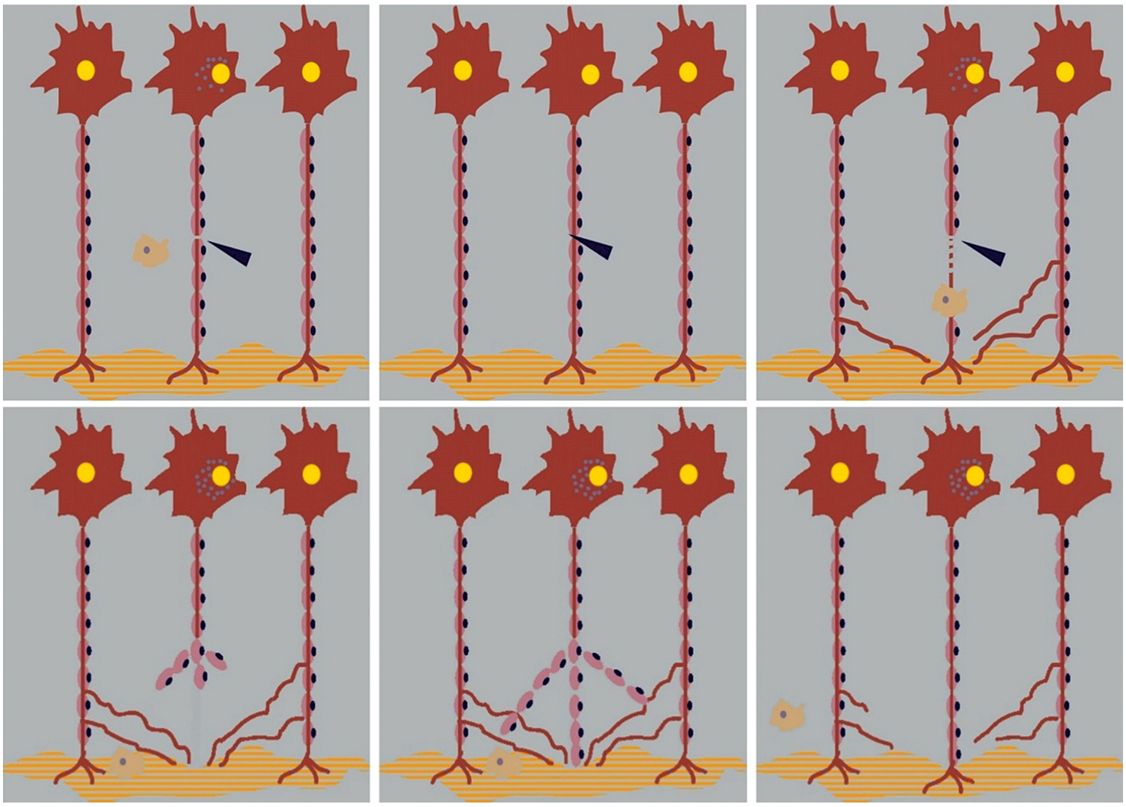

Figure 2. A schematic illustration depicting the successive stages of degeneration and subsequent regeneration of an injured nerve fiber (available from: https://www.slideshare.net/slideshow/3-degeneration-a-regeneration-of-nerve-fibres-pptx/274811933) [14]

Neurophysiological testing

Electroneurography (ENG) and needle electromyography (EMG) offer objective, quantitative assessments of peripheral nerve conduction abnormalities and muscle denervation. The diagnostic accuracy of these modalities is critically dependent on the timing of the examination following injury [18,19].

- ENG may produce false-negative results during the first 7–10 days. Wallerian degeneration in the distal segment has not yet fully developed. Conduction along the injured nerve fibers may still be partially preserved at this stage.
- EMG findings may also remain unremarkable for 3–4 weeks. Fibrillation potentials and positive sharp waves then emerge as electrophysiological markers of active denervation.

A standard neurophysiological evaluation incorporates:

- compound motor (M-wave, compound muscle action potential [CMAP]) and sensory conduction studies of the evoked potentials with the analysis of amplitudes and latencies parameters;
- antidromic F-wave latency and frequency evaluations;
- EMG spontaneous activity evaluation at the resting state of muscle (fibrillations and positive sharp waves indicating the motor unit denervation processes);
- EMG single motor-unit potentials parameters evaluation (amplitude, duration, and sensory index analysis);
- EMG signs of reinnervation (e.g., increased polyphasia, reduced recruitment pattern during the muscle's voluntary contraction).

Moreover, experimental and clinical studies indicate that motor evoked potentials (MEPs) elicited by transvertebral or transcranial magnetic stimulation closely correlate with electroneurographic findings. This strong concordance validates MEP assessment as a reliable non-invasive method for diagnostic evaluation and for monitoring the progress of nerve regeneration [20].

Imaging

Ultrasound and magnetic resonance imaging provide essential structural information for evaluating peripheral nerve and brachial plexus injuries. These modalities visualize nerve continuity or discontinuity, characterize the type and extent of injury (e.g., root avulsion), assess the size of a nerve gap, and identify scarring or nerve compression. These imaging findings are critical for clinical decision-making. They help determine whether direct end-to-end repair is feasible, whether more complex reconstruction is required, or whether urgent salvage surgery is indicated [21].

Surgical strategies in nerve reconstruction

Direct end-to-end repair

Direct microsurgical coaptation offers the highest regenerative potential when a tension-free approximation of the nerve ends can be achieved. This technique is most often feasible immediately after injury. It can also be performed later, if resection of neuromas leaves a defect small enough to allow tension-free approximation of the stumps. The standard method is an epineural repair. The surgeon precisely aligns and sutures the epineurium of the proximal and distal stumps. The coaptation is performed using the minimal number of interrupted microsutures required to ensure accurate approximation. This reduces foreign-body reaction and minimizes scar formation. Proper stump orientation is facilitated by identifying the nerve's vascular pattern and understanding the fascicular architecture at the specific injury level. This is especially important for matching fascicles containing mainly motor, sensory, or autonomic fibers (Figure 3).

Despite its advantages, direct repair is often not feasible in high-energy trauma, where segmental nerve loss may extend over several centimeters, necessitating alternative reconstructive strategies [22–24].

Autologous nerve grafting

When a segmental defect of the nerve trunk is detected, either primarily, or secondarily after resection of a traumatic neuroma or a failed previous repair; the proximal and distal stumps may be bridged using one or more autologous free nerve grafts (e.g., sural nerve, medial or lateral antebrachial cutaneous nerves). The grafts should fill the defect and, ideally, exceed the cross-sectional diameter of the reconstructed nerve by approximately 10–15% to ensure adequate fascicular matching and minimize tension. Regenerative outcomes following nerve grafting are generally inferior to those achieved with direct end-to-end coaptation. This is attributable to the presence of two coaptation sites, the smaller diameter of the donor grafts compared to the recipient nerve, and the increased regeneration distance associated with longer grafts. Purely sensory or purely motor nerves tend to regenerate more reliably through grafts, whereas mixed nerves show less predictable outcomes (Figure 4).

The length of the reconstructed nerve gap should ideally not exceed 7–10 cm. Longer grafts are linked to significantly reduced regenerative efficiency. If the defect surpasses this length, alternative reconstructive strategies, such as nerve transfers, should be considered [23–25].

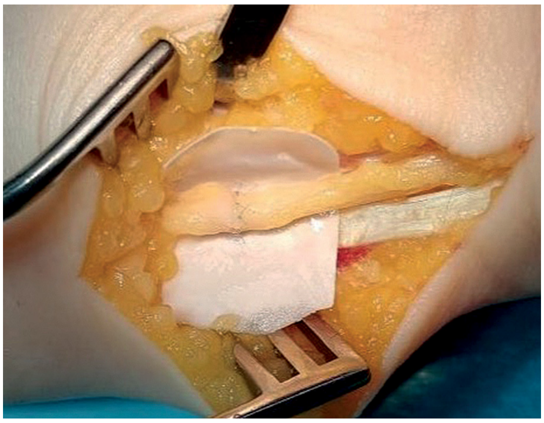

Figure 3. Intraoperative photograph showing direct epineural repair of an injured nerve

Allogeneic nerve graft

The first successful human use of nerve allografts was reported by Mackinnon in 1992 [25] for nerve gaps too extensive for autografting, including a 23-cm sciatic nerve reconstruction. Unprocessed allografts have been used only rarely, in a small number of cases, and their true efficacy remains uncertain, partly because they were often combined with autograft cables. Temporary immunosuppression is required during regeneration and carries risks such as nephrotoxicity, although tacrolimus may additionally enhance axonal regeneration.

To eliminate the need for immunosuppression, decellularization techniques were developed, leading to the FDA-approved acellular nerve allograft Avance (Axogen), produced via a modified Hudson protocol [26]. Avance is widely used in the United States for peripheral nerve gaps up to 70 mm. Evidence suggests outcomes comparable to autografts for short sensory defects, though

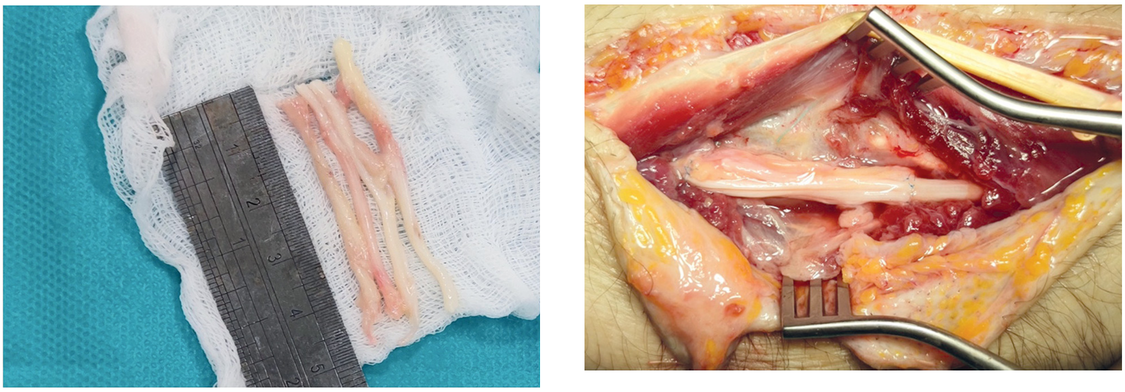

Figure 4. Intraoperative photograph demonstrating the harvested sural nerve grafts (left side) and the median nerve reconstruction using these grafts (right side)

many available studies are subject to funding bias and rely on overlapping datasets. A recent meta-analysis reported no significant difference in meaningful recovery between Avance and autograft for defects up to 70 mm, but larger randomized trials are still needed [27]. Allografts are substantially more expensive than autografts, although higher implant costs may be offset by reduced operative time [4,28].

Nerve conduits

Simple conduit-based entubulation is an accepted method for repairing sensory nerve defects up to 30 mm [29]. The proximal and distal stumps are secured within a tubular scaffold, but outcomes for motor nerves or longer gaps are poor [30]. Modern Food and Drug Administration (FDA)-approved conduits are all absorbable to avoid compression and the need for removal. Available devices include natural (collagen-, porcine-, or chitosan-based) and synthetic polymer conduits (e.g., polylactic acid, polycaprolactone, polyglycolic acid). Natural materials may enhance biocompatibility, while synthetic conduits provide consistent mechanical properties and eliminate disease-transmission risk. Although no direct comparative trials exist, published studies suggest that conduits can achieve results comparable to autografts in short sensory defects [4,31].

Direct nerve transfers

Modern reconstructive algorithms increasingly favor nerve transfers in cases of high-level peripheral nerve injuries, non-regenerating brachial plexus lesions, or their root avulsions. This strategy involves redirecting a functionally less critical donor nerve branch to the distal segment of the injured nerve, thereby bypassing the primary site of injury. The markedly shorter regeneration distance enables faster reinnervation of target muscles and facilitates earlier functional recovery. Targeted neurotization also enhances reinnervation specificity, contributing to superior functional outcomes [3,4,32].

For restoration of active shoulder and elbow function following brachial plexus injury, the most commonly used donor nerves include the accessory nerve, the long thoracic nerve, the radial nerve branch to the triceps brachii muscle, intercostal nerves, and selected motor fascicles from the ulnar nerve and median nerve [32,33].

In cases of high-level peripheral nerve injury outside the brachial plexus, the choice of donor nerve depends on the function requiring restoration and the location of the lesion. Distal to the injury, potential donor nerves include the anterior interosseous nerve, the motor branch to the abductor digiti minimi (ADMi), or other terminal motor branches selected according to the specific

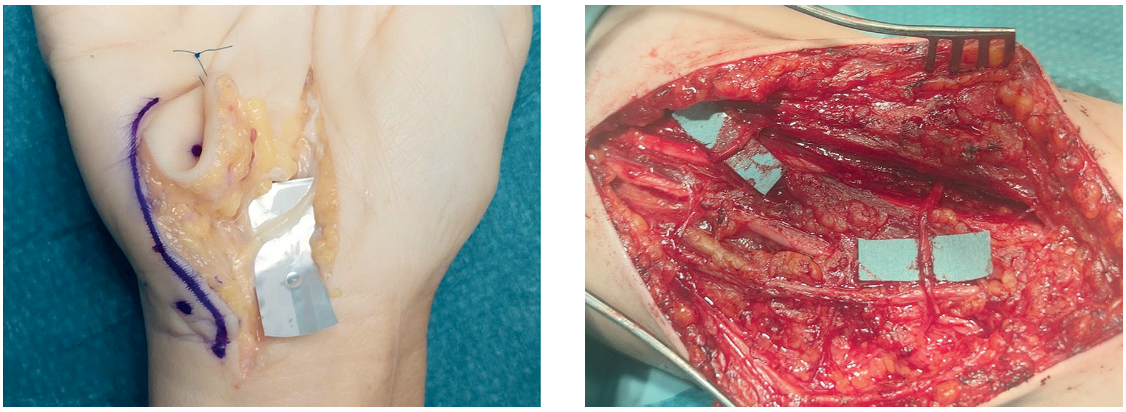

Figure 5. Examples of direct nerve transfers: on the left, transfer of the motor branch to the abductor digiti minimi to the motor branch of the abductor pollicis brevis; on the right, transfer of fascicles to the flexor carpi ulnaris from the ulnar nerve to the motor branches of the biceps muscle

functional deficit to be reconstructed [34] (Figure 5).

ETS transfers

ETS nerve transfer involves coapting the distal stump of an injured nerve to the side of an intact donor nerve, allowing collateral axonalsprouting to reinnervate the target. ETS is primarily indicated for high-level peripheral nerve injuries, large segmental defects, or situations where the proximal stump is unavailable [14,35]. Animal studies demonstrate functional regeneration comparable to conventional reconstructive techniques, although regenerated fibers typically have smaller diameters and cross-sectional areas. Clinical outcomes, particularly for motor recovery in humans, are inconsistent and generally inferior to traditional methods. Potential limitations include donor-nerve compromise and central nervous system reorganization [4,36,37].

The operative technique involves freshening the distal stump and suturing it to the donor nerve, with or without an epineural window, whose necessity remains unproven. ETS has shown the most consistent success in sensory nerve repair, especially in digital nerves, and in select proximal motor reconstructions. Specific applications include tumor resection, large gaps, neuroma prevention, brachial plexus injuries, and cases lacking suitable end-to-end nerve transfers. While ETS remains a valuable experimental and adjunctive technique, further research is required to establish its efficacy and safety in motor reinnervation [4,38,39].

RETS transfers (supercharge/babysitting)

In RETS nerve transfer, the distal portion of a healthy, functionally less critical donor nerve – most commonly the terminal branch of the anterior interosseous nerve (AIN) – is coapted distally and in an ETS fashion to the injured or chronically compressed but salvageable recipient nerve, typically the ulnar or median nerve [4,14,40]. The objective of this technique is to introduce donor motor axons into a partially injured or proximally repaired nerve at a high level (arm or elbow) to:

- maintain the viability of denervating muscles and prevent irreversible motor endplate degeneration until the native axons regenerate (“babysitting”);
- augment reinnervation by providing an additional pool of motor axons to a nerve that regenerates poorly or insufficiently (“supercharge”) (Figure 6).

This approach enhances functional outcomes by preserving muscle receptivity and reinforcing axonal input during the critical regenerative period. RETS procedures are particularly valuable in cases of high-level nerve injuries, partial nerve lesions, or advanced compressive neuropathies, where native regeneration alone may be inadequate [4,41,42].

Intraoperative and postoperative neurophysiology

Direct nerve stimulation and intraoperative electromyographic (EMG) analysis [43,44] provide real-time information regarding donor fascicle selection, target muscle viability, and the immediate functional response to neurotization. Intraoperative neuromonitoring is particularly crucial during complex brachial plexus reconstruction, especially when multiple potential donor branches must be evaluated. It also enables detailed assessment of the degree of nerve injury and

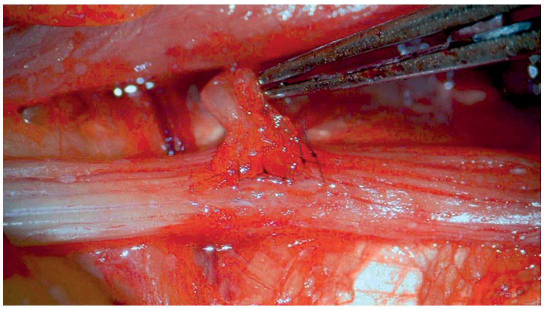

Figure 6. Intraoperative photograph from the microscope showing reverse end-to-side nerve transfer of the anterior interosseous nerve to the side of the motor fascicle of the ulnar nerve

residual conduction, thereby guiding intraoperative decision-making regarding the most appropriate reconstructive strategy – such as direct nerve transfer versus RETS augmentation [4] (Figure 7).

Postoperative evaluation using MEPs and EMG provides objective, longitudinal monitoring of reinnervation and the functional progression of nerve regeneration [20,45].

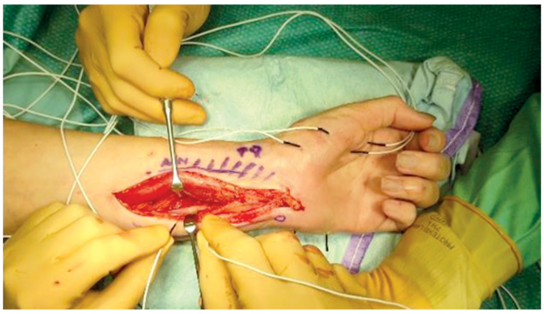

Figure 7. Illustrates the use of intraoperative neuromonitoring of the ulnar nerve before reverse end-to-side transfer of the anterior interosseus nerve

A case of posttraumatic mononeuropathy of the median nerve

The patient underwent median nerve transection in the proximal forearm (Figure 8). Surgical anastomosis of the nerve stumps was performed. Due to the lack of nerve regeneration following the procedure and significant atrophy of the muscles innervated by the median nerve, a sural nerve transplant was performed to restore the regenerative capacity of the median nerve and to initiate reinnervation in the flexor carpi radialis (FCR) and abductor pollicis brevis (APB) muscles.

The needle EMG examination revealed active denervation in the FCR and APB muscles. Significantly elevated motor units action potentials parameters indicated a neuro -genic injury profile in the examined muscles. The conclusion from the neurophysiological study was as follows: "Severe axonal damage to the median nerve, accompanied by segmental demyelination at the forearm level, and active denervation and reinnervation in the examined muscles," as presented in Figure 9.

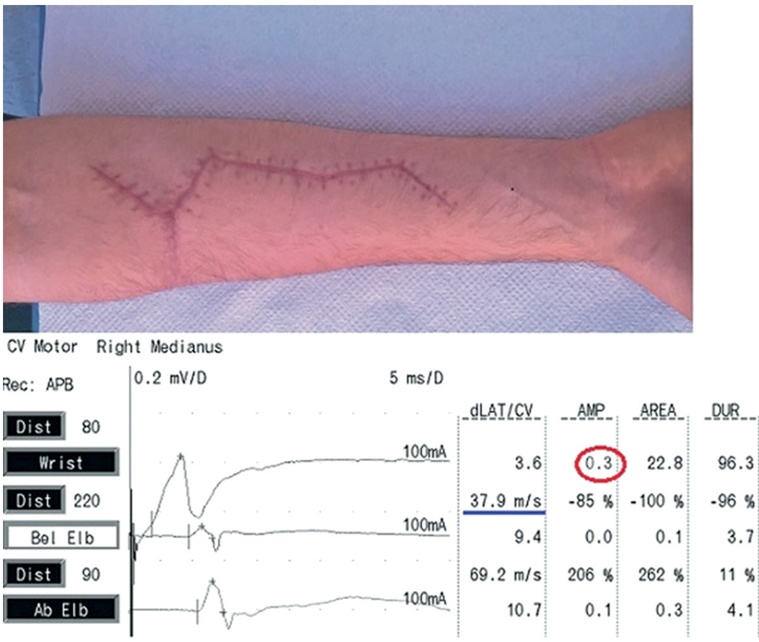

Figure 8. A photograph showing a post-traumatic scar in the topography of the median nerve in the proximal forearm, in the transverse line, and a second scar from a surgical sural nerve transplant in the longitudinal line. Electroneurography of the median nerve showed a significant reduction in compound muscle action potential (CMAP) amplitude (red outline) following distal stimulation at the wrist. Following stimulation from the antecubital fossa and the arm, a CMAP with severely reduced amplitude was recorded, accompanied by a slowing of conduction velocity at the forearm (blue outline). No sensory potentials were recorded from the median nerve

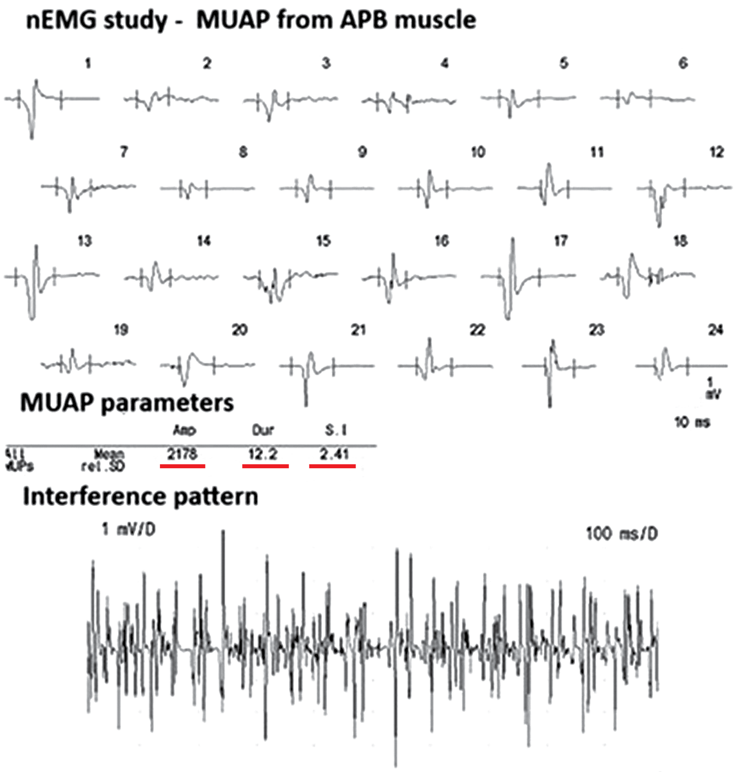

Figure 9. Example of needle EMG recording. Motor units action potentials parameters from the abductor pollicis brevis muscle demonstrate increased amplitude and Size Index, as well as prolonged duration (highlighted in red), confirming the neurogenic nature of the muscle damage. The interference pattern recording is poor (low frequency) and exhibits a higher amplitude parameter than expected

Results

The authors' clinical experience mainly involves direct nerve transfers to restore shoulder and elbow function in upper brachial plexus injuries, along with distal peripheral nerve transfers and RETS procedures. The outcomes achieved with these techniques – outlined below – have been detailed in previous studies.

Nerve transfers to restore shoulder and elbow function in traumatic upper brachial plexus palsy

The study group included 16 patients (3 women and 13 men) with an average age of 28 years. All exhibited a lack of active shoulder movement and no active elbow flexion due to injuries affecting the upper and middle trunks of the brachial plexus. Surgical reconstruction involved transferring the accessory nerve to the suprascapular nerve and/or transferring a branch of the radial nerve from the triceps muscle to the axillary nerve. Additionally, single or double Oberlin transfers were performed, which involved redirecting fascicles from the flexor carpi ulnaris of the ulnar nerve and the FCR or flexor digitorum superficialis from the median nerve, with coaptation to the motor branches of the biceps and brachialis muscles.

Functional outcomes demonstrated average shoulder flexion of approximately 100° and abduction of approximately 80°, with more than half of the patients achieving muscle strength graded M4 or greater. Elbow flexion of around 90°, also with strength of M4 or higher, was commonly restored. Notably, patients who underwent double nerve transfer achieved superior results compared with those who underwent single nerve transfer, both in shoulder function and in elbow flexion recovery [21].

A transfer of the motor branch to the ADMi to the motor branch of the APB in cases of high-level median nerve injury

The patient presented with a high-level median nerve injury at the level of the arm. A primary repair had been performed, but no signs of regeneration were observed after five months. Surgical exploration and neurolysis of the median nerve at the original repair site were carried out. Owing to progressive atrophy of the thenar muscles and the considerable regeneration distance required for reinnervation of the APB muscle – placing it at high risk of irreversible denervation – the decision was made to perform a direct nerve transfer. The ADMi motor branch from the ulnar nerve was transferred to the APB (via the median nerve) to shorten the regenerative pathway and accelerate functional recovery. The objective of this targeted neurotization was to restore APB function, which is essential for palmar abduction of the thumb – a key component of functional opposition and grip [34].

Six months after surgery, regeneration of the median nerve to the wrist and finger flexors (forearm-level muscles) was observed, and APB function had returned with active thumb opposition to the tip of the little finger and strength graded M4+. Follow-up EMG confirmed the success of the transfer, demonstrating activation of APB muscle fibers upon stimulation of the ulnar nerve, thereby verifying effective reinnervation through the transferred motor branch.

RETS nerve transfer in median and ulnar nerve injuries [14]

Case 1

A six-year-old boy presented with severe ulnar nerve dysfunction after injury at the elbow level, characterized by the absence of intrinsic muscle activity, clawing of the fingers, and advanced intrinsic muscle atrophy. The injury had occurred six months earlier, and neurolysis at the lesion site was performed during surgical exploration. Given the significant functional deficit, a RETS transfer was performed, using the AIN nerve to augment the ulnar motor fascicle.

Postoperatively, the patient achieved full motor recovery, with complete restoration of intrinsic hand function except for mild residual weakness in interosseous muscle adduction. Clinical improvement was observed consistently during the eight-month follow-up period.

Case 2

A thirty-nine-year-old woman presented ten months after an ulnar nerve injury at the elbow level, managed conservatively, with no prior surgical intervention. Preoperatively, she exhibited no intrinsic muscle function, pronounced clawing deformity of fingers, and marked intrinsic muscle atrophy. Intraoperative assessment confirmed the indication for a RETS procedure using the AIN on the ulnar motor fascicle, aimed at enhancing reinnervation of the distal motor targets.

During 18 months of postoperative follow-up, the patient experienced complete functional recovery, including full restoration of intrinsic hand strength and resolution of the clawing deformity.

Case 3

A nine-year-old boy with a median nerve injury at the forearm level presented nine months after the initial trauma – radial shaft fracture. He demonstrated loss of thumb adduction and significant thenar muscle atrophy. Intraoperatively, a partial median nerve injury was identified, caused by compression from a bone fragment. Surgical management included neurolysis at the lesion site, excision of a lateral neuroma, and end-to-end microsurgical repair of the median nerve. To address the risk of prolonged denervation of the thenar musculature, a RETS transfer using the AIN to the side of the median motor fascicle was additionally performed.

At the twelve-month follow-up, the patient showed partial functional recovery, achieving M4 strength in the reinnervated muscles, although mild residual muscle atrophy persisted. Functional improvement allowed a meaningful return of thumb function with good grip strength.

Discussion

This review emphasizes the crucial importance of interdisciplinary collaboration between neurophysiologists and peripheral nerve surgeons in diagnosing, intraoperative evaluation, and reconstruction of traumatic nerve injuries. Consistent with evidence from both clinical and experimental research, coordinated preoperative planning greatly improves diagnostic precision, aids intraoperative decision-making, supports the selection of the best reconstructive strategies, and enables a more objective evaluation of postoperative functional recovery. This integrated approach is especially valuable in high-energy brachial plexus and peripheral nerve injuries, where prompt, well-planned intervention significantly increases the likelihood of achieving meaningful functional outcomes.

Advanced reconstructive techniques, including direct nerve transfers, ETS, and RETS neurotization, are increasingly chosen over traditional nerve grafting in cases of high-level nerve injuries or brachial plexus root avulsions, where the distance for axonal regeneration would make conventional repair ineffective [4,15]. The better outcomes seen after double nerve transfers in shoulder and elbow reconstruction highlight the importance of careful donor–recipient selection, guided by electrophysiological and anatomical factors [21].

A key part of modern treatment algorithms lies in neurophysiological monitoring, both preoperatively and intraoperatively. ENG and EMG provide well-established diagnostic measures for conduction deficits and muscle denervation; however, their value is strongly time-dependent, particularly in the early post-injury period. During surgery, direct electrical stimulation and real-time EMG analysis help accurately identify healthy nerve fascicles, evaluate nerve continuity and conduction, and inform decisions regarding whether to perform direct reconstruction, nerve transfer, or RETS techniques [44,45]. As shown in our clinical series – including direct nerve transfers at the shoulder and elbow, distal targeted neurotization, and RETS transfer – such decision-making requires immediate, dependable electrophysiological feedback, which can only be provided through close collaboration between the surgeon and neurophysiologist [14,21].

An increasingly important adjunct is the use of MEPs obtained through transvertebral or transcranial magnetic stimulation. MEPs closely correlate with ENG findings and provide a valuable non-invasive way to assess efferent conduction [20,45]. Clinical studies have shown significant differences in MEP parameters between healthy individuals and patients with disc–root conflict, confirming the method's diagnostic sensitivity. This is especially beneficial in pediatric patients and for postoperative monitoring [46]. However, limitations exist in elderly patients or those with advanced muscle atrophy caused by chronic axonal pathology, as fewer responsive motor units may reduce the amplitude of muscle-recorded MEPs. These factors emphasize the potential advantage of recording MEPs directly from peripheral nerves using surface electrodes along their anatomical course, which may yield more stable parameters than muscle-recorded responses [20,36,45,46].

Brachial plexus injuries often require complex surgical reconstruction. Intraoperative neurophysiological monitoring (IONM), using techniques such as EMG and transcranial electrical stimulation with MEP recording, is crucial for decision-making, confirming nerve root integrity, preventing further damage, and assessing the effectiveness of repair by providing real-time feedback on nerve function during surgery. IONM helps surgeons identify critical structures and ensure that nerve grafts/transfers function properly, improving the prognosis of severe upper extremity injury treatment.

Overall, the convergence of surgical innovation, advanced neurophysiological monitoring, and structured interdisciplinary collaboration forms the foundation of current best practices in peripheral nerve reconstruction. As demonstrated by our clinical experience, timely decision-making guided by precise electrophysiological assessment is essential for optimizing outcomes. Future research should continue to improve the integration of magnetic stimulation techniques, evaluate nerve-recorded versus muscle-recorded MEPs in pathological conditions, and establish standardized protocols that further enhance diagnostic accuracy and postoperative monitoring in both adult and pediatric populations.

Conclusions

Advances in nerve transfer techniques, ETS/RETS procedures, and modern neurophysiological assessment methods have significantly improved the management of brachial plexus and peripheral nerve injuries. Early and accurate diagnosis, assessment of motor unit viability, and well-planned reconstructive strategies allow for predictable functional recovery within a favorable time frame.

Crucial to this advancement is interdisciplinary collaboration between neurophysiologists and hand surgeons. This partnership guarantees precise preoperative evaluation, informed selection of the most suitable reconstructive technique, and objective monitoring of postoperative regeneration, ultimately giving each patient a personalized, evidence-based treatment plan.

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