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Interdisciplinary perspectives of rehabilitation in adult brachial plexus palsies

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Abstract: The aim of this study is to demonstrate that the interdisciplinary approach could have a positive result on the rehabilitation program in brachial plexus paralysis in adults. The prevalence of brachial plexus injuries is currently increasing worldwide, mainly due to the growing number of car accidents, extreme sports or work-related injuries. In this study we chose to present an analysis of one complex surgical case of brachial plexus paralysis, with clinical and electrophysiological investigations. (1) Background: Current reconstructive surgical nerve transfer procedures aim to rehabilitate elbow flexion in such cases. Surgical strategies are based not only on clinical evaluation or investigations by magnetic resonance imaging, but also on classical electrophysiological methods, such as electromyography (EMG). (2) Methods: Along with the other types of therapies already established, in the case of this pathology, Transcranial Magnetic Stimulation (TMS) is also used, which provides valuable information about cortical reorganization models concomitant with surgical procedures for nerve reconstruction in the last 3 decades. (3) Results: The study shows that interdisciplinary leads to a faster and more complex rehabilitation of the patient with brachial plexus paralysis and thatelectrophysiological signals could predict constant motor benefits when associated with rehabilitation programs.

Keywords: brachial plexus; electromyography; transcranial magnetic stimulation; neuroplasticity;

1. Introduction

In adults, brachial plexus palsies have various etiologies: trauma, infections, cancers or different kind of compressive situations. In some cases, these factors can lead to elongation or even avulsion of nerve roots. Beside the descriptive anatomical localization of a lesion, clinical and electrophysiological investigations can also provide analysis of the pathophysiological phenomena that occur: neuroapraxia, axonotmesis and neurotmesis. These describe either the interruption of the myelin stealth alone, either both myelin and axon, or all the nervous structures of the nerve.

After the brachial plexus lesion takes place, the proximal portion of the nerve is affected by apoptosis, followed by regeneration (in the case the neuron survives) and occurs Wallerian distally. These processes can result into a series of structural and electric modifications, leading to muscle atrophy, and eventually impairing the cortical sensory-motor representation of the affected limb. This is the moment when electromyography (EMG) can provide data about spontaneous and uncoordinated muscle activity, by recording fibrillation potentials [1].

The axonal growth speed is approximately 1 mm/day, therefore the restoration of the neuromuscular junction, determined by the moment the axon reaches the motor endplate, can be influenced by the integrity of the muscle, the distance to be achieved or the patient's age and health [1]. The axonal remielinization process is essential for rehabilitation of the injured nerve's function.

Reconstructive surgery provides neurotization techniques based on transfer of a healthy but at the same time, less valuable nerve, usually an extraplexal one, to facilitate reinnervation of the damaged structure. Historically, the surgical strategies in brachial plexus injuries started with the use of the spinal accessory nerve or intercostals nerves transferred into brachial trunks, cords or single nerves, to maintain/ restore the connection with the spinal cord. Nowadays, the surgeon's ingenuity correlates with the available exploratory techniques, to fulfill the purpose of restoring the elbow flexion. Reinnervation of the affected muscle should be obtained before atrophy signs appear, which is usually 6 months after the accident [1, 2].

Representation of the upper limb as projection among the cortex, as well as synaptic reorganization patterns that can be evidenced by TMS techniques are related to neuroplasticity [3]. Peripheral nerve trauma does indeed induce cortical remodeling in sensory-motor areas, as already proven by functional MRI analysis [4].

In patients with brachial plexus lesions, the loss of brain grey matter correlates to the difficult movement recovery process, thus facilitation of motor rehabilitation is considered key strategy to future research, especially related to modulation of cortical adaptative mechanisms [5, 6].

2. Objectives

The purpose of this paper is to improve the concept of interdisciplinary, in follow up of complex surgical brachial plexus cases. We aim to analyze possible correlations between surgical neurotization techniques and outcomes, EMG and TMS investigation. Since brachial plexus palsies represent important challenges upon quality of life, it is essential to better understand the complexity of this pathology in all its peripheral and central nervous system dynamics. Treating and diagnosing mainly young active adults provides perspectives towards identifying possible patterns of rehabilitation, risk factors for comorbidities that might affect the results, as well as better understanding of our patient's burden. Thus, assessing of rehabilitation of the elbow flexion is based on correlations with the clinical motor deficit and electrophysiological analysis.

3. Patient characteristics

The case is represented by a male patient, who 12 years ago, at the age of 31, with no significant illnesses at that time, suffered a work related accident by falling from a height of approximately 20 meters while working in a constructions site. While falling he manages to grab hold of some level of support from the nearby wall with his right arm, resulting in serious cervical roots elongation with complete motor deficit in the right limb. The patient's history is laborious, with poor medical recordings and information. A first neurological exam from that time revealed a fallen right shoulder, total right limb motor deficit, MRC 0/5, hypotonia, all osteotendinous reflexes (OTR) in that limb absent except for a diminished bicipital reflex, paresthesias in C3-T2 territory, algezic and vibratory hypoesthesia in C4-C8 territory, limb-girdle atrophy.

4. Examination Findings

EMG performed back then shows no electrophysiological response in all 3 major nerves: median, ulnar and radial, up to the Erb point and axilla (see figure 1).

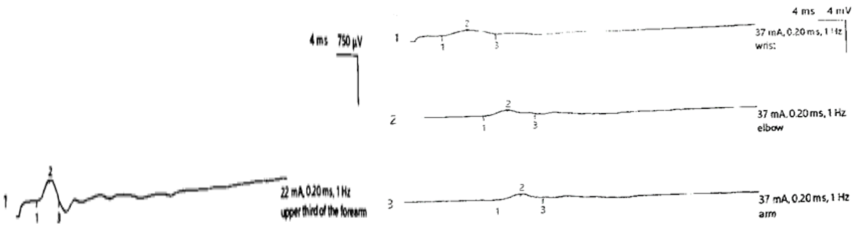

Figure 1 Motor nerve conduction study for right radialis nerve and ulnar nerve – low amplitude

Table 1 numerical values for motor nerve conduction study

N	Stimulation site	Dist. mm	Lat. ms	Ampl. mV	Ampl. Norm. mV	Ampl. Dev. %	Dur. ms	Vel. m/s	Vel. Norm m/s	Vel. Dev. %
Right extensor indicis, Radialis, C6 C7 C8										
1	Upper third of the foream	60	3.8	0.3			4.0			
Right abductor digiti minimi, Ulnaris, C8 T1										
2	wrist	80	4.5	0.7	10.0	-93.5	7.7			
3	elbow	275	10.7	0.6	10.0	-94.0	7.3	44.4	60.0	-25.9
4	arm	110	13.1	0.6	10.0	-94.4	6.3	45.2	60.0	-24.7

The following years he undergoes several surgical neurotization procedures, in different Reconstructive Surgery medical centers across the country (Targu-Mures, Bucuresti, Iasi), and periodic rehabilitation (Iasi, Suceava). In spite of the poor history documentation and difficult anamnesis, we highlight that one year after the first surgical intervention, a transfer of lattissimus dorsi to the biceps brachii tendon (which occurred at approximately 3 months after the accident), he regains mild abduction of the arm and discrete flexion of the fingers, maintaining hypotonia, paresthesias (burn-like sensations) maintaining absent OTR at the time. After 2 years from the trauma, an MRI (see figure 2) of the right shoulder reveals cartilaginous modifications and subcondral humeral old fractures.

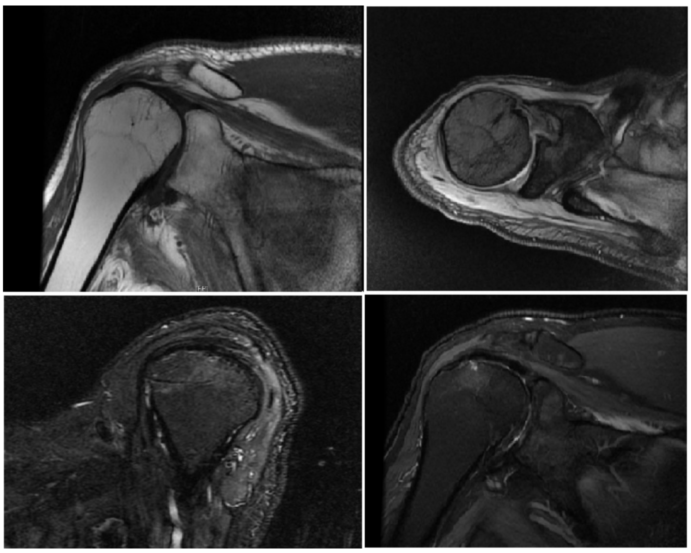

Figure 2 Shoulder MRI (patient 1): joint space narrowing, chronic subchondral fractures, signal modifications of the supraspinatus tendon and the glenohumeral cartilage

The EMG performed at the same time shows normal sensitive conduction velocities (SCV) in the 3 nerves, normal motor conduction velocities in the median nerve, with a reduced compound motor potential (CMAP) at this level up to 40%, and very low CMAP amplitudes, 10% and 20% in the right radial and ulnar nerves. No CMAP is visible at axillary level. Needle EMG shows chronic neurogenic affectation in all territories, except for the right deltoid, where the denervation appears complete. This analysis is compatible with multiradicular chronic lesion by elongation, predominant C7, C8 and T1 affectation, severe axilary neuropathy (neurotmesis).

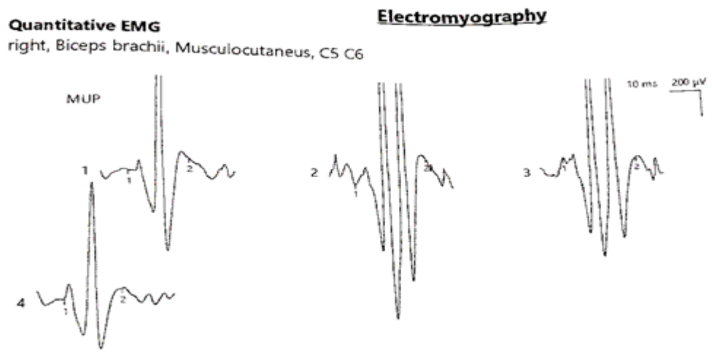

Figure 3 EMG on patient 1 that shows chronic neurogenic process

Table 2 MUP duration and amplitude values from needle EMG that demonstrates chronic neurogenic affectation in all territories

MUP duration				MUP amplitude					
Min.dur. ms	Max.dur. ms	Mean dur. ms	MUP count	Min. Ampl µV	Max Ampl µV	Mean Ampl µV	Apl Norm µV	Ampl Dev %	Polyphase %
16.9	23.6	2.06	4	1177	3681	2312	750	+208	75.0

Clinical Hypothesis

Another two years later he undergoes an arthrodesis procedure for the right fist, followed by tenorrhaphy of digits II-IV; the following year he has another surgery: the extensor tendon of the 4th right toe is transposed to the flexor ulnaris tendon in order to reconstruct the policis opposition. In evolution, the clinical picture consists of important hypotonia with hypotrophy of the right shoulder and limb, with a mild flexion of the forearm of 2/5 MRC and a 3/5 MRC flexion of fingers. OTR are still absent.

He continues rehabilitation throughout the following years, especially physical therapy, but stops therapy approximately one year before our evaluation. The EMG evaluation is similar to the previous evaluations, therefore suggestive for the chronic severe lesion of the right brachial plexus.

Intervention

We performed TMS by placing surface electrodes at the site of the first dorsal interosseous muscle (FDI) and the biceps brachii, and we stimulated the cerebral hemispheres and the cervical spine using a round shaped coil, using a Magstim Rapid® device. The stimulator generates a magnetic field of up to 1.2 Tesla. We preferred the round coil to the butterfly one, in order to avoid diffuse stimulation. We mainly investigated the latencies of the Motor Evoked Potential (MEP), as well as the central conduction time, CMCT (defined as the difference between cerebral MEP latency and cervical MEP latency). At the first TMS evaluation, we observed a prolonged MEP latency. When moving the electrodes on the biceps brachii, we obtained no MEP in both the cerebral and the cervical stimulation.

Outcome

The patient started rehabilitation therapy from that moment, 2 weeks every 3 or 6 months, based on kinetotherapy and neuroplasticity enhancing techniques, such as mirror therapy. He also followed an associated neurotrophic treatment (alpha-lipoic acid 600 mg daily, benfotiamine and Citicoline/Bacopa monnieri supplements). One year later, he had completed 3 therapy sessions and we performed the same procedure. At FDI level, we noticed a decrease of the MEP latency. At biceps brachii level we were able to record 25.0 ms latency at the cerebral stimulation and 19 ms at cervical stimulation. At bicipital level, CMCT mildly decreased, suggesting a slight electrophysiological improvement (see figure 3). We were now able to record a MEP both for cerebral and cervical stimulation, which correlates with a mild amelioration of the elbow flexion, nevertheless, without significant correspondent so far with MRC grading or EMG findings.

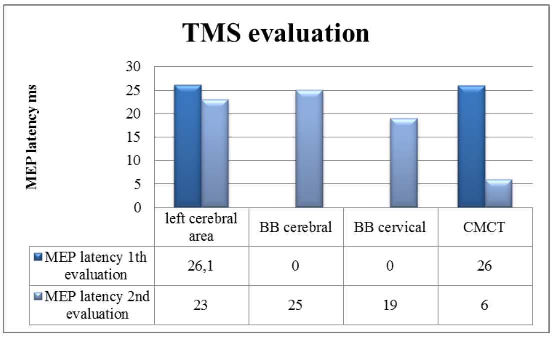

Figure 4 TMS evaluation showing the improvement after rehabilitation program

Discussion

A nerve transfer is usually based on using inferior brachial plexus, rami of the pectoral or intercostals nerves, or fascicular groups. Potential donors for neurotization are considered to be: the spinal accesoy nerve, motor rami of the triceps for the radial nerve, motor grephon from the ulnar nerve (the Oberlin technique), grephon from the median nerve (McKinnon technique), intercostal nerves, the phrenic nerve, the controlateral C7 root or using nerves from pectoralis major for restoration of shoulder stability. The medial pectoral nerve can be also used as transfer to the axillary nerve in order to restore the deltoid [7, 8]. In 1994, Oberlin described the motor grephon transfer from ulnar to the biceps muscle (musculocutaneous) obtaining a good flexion of elbow [9, 10].

If a satisfactory restoration does not occur, or in case of an insufficient effect after the first procedure, tendon or even muscle transfer is preferred. For elbow restoration there are various muscle-tendon transfer techniques are available: transfer of the common origin of forearm muscles to a proximal section (the Steindler technique), transfer of latissimus dorsi to the biceps brachii tendon, transfer of the brachial rami of the pectoralis major tendon to the brachial biceps (the Clark technique) or triceps to biceps transfer [6]. Gracillis muscle transfer is also an option sometimes, however a complex and difficult technique [7].

Usually, the association of more surgical methods suggest better outcomes, as already proven that associating direct neurotisation, neuro-neuronal neurotization, as well as muscle transfer, combined, allow better rehabilitation of elbow flexion [4, 10]. Such as direct coaptation of C5-C6-C7 roots with good (3-4/5 MRC) restoration of elbow flexion 6 months after the surgical procedure [11].

Our patients' history goes back in time, and an accurate history is poorly documented. Both patients underwent several reconstructive procedures in different centers. The ones mentioned are related to their medical documents and clinical assessment at the moment of presentation. They both received nerve transfer procedures throughout the years, without ability from the patients' to offer valuable data for this matter, except for a vague history. In absence of a centralized digital recordings system, the documents they provide are few. The major clinical and paraclinical assessment strategies rely mainly on the current clinical aspect and actual investigations. These difficulties suggest the serious burden this pathology carries. The brachial plexus pathology also increases the risk for accidents and comorbidities, as in the second patient's case.

The patient, in spite of a more severe motor deficit, presents an electrophysiological improvement when associated with continuous rehabilitation. This supports the neuroplasticity theories. This leads to the possibility of brain mapping perspectives the cortical area as it undergoes reorganization following rehabilitation.

Because of the epidemiological difficulties and restrictions related to the Covid-19 pandemics, the compliance to rehabilitation has been affected lately for both patients.

Conclusions

Electrophysiological signs of improvement might predict constant motor benefits when associated to rehabilitation programs. We suggest that maintaining a good cortical representation of the motor area can be the fundament for further brain mapping studies and neurotization intentions, according to the obtained and maintained signs of amelioration. This also encourages a continuous physical therapy approach for these patients, in the attempt to ameliorate the quality of life.

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