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Psychomotric Perspectives of Rehabilitation in Chronic Brachial Plexus Palsies

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Abstract: ***Background***. *The perspective of ongoing electric signals within the motor cortex, conditioned by continuous rehabilitation strategies (doubled by adherence to the treatment protocol), is of interest related to understanding how cerebral plasticity is being modulated in adult traumatic brachial plexus (BP) lesions. Very often, patients with chronic BP lesions tend to be less compliant to rehabilitation therapy over time, since multiple reconstructive microsurgery interventions may not always offer a proper upper limb functionality, especially in severe, complex BP cases.* ***Material and methods***. *In order to asses the ongoing psychomotric projection of the limb's representation among the motor cortex, in relation with long term rehabilitation protocol we followed up a group of 11 chronic patients, by transcranial magnetic stimulation (TMS) during a time-lapse of two years.* ***Results***. *Although modest in relation with amelioration of the deficit on the MRC scale, the patients had mild improvements of the parameter latency, but more important, by assessing the amplitude of the motor evoked potential (MEP), we observed a dynamism of the motor area. This we consider suggestive for ongoing psychomotor components stimulated by rehabilitation: ideomotricity, perceptual-motor coordination, laterality and body representation, as a foundation in maintaining a proven measurable potential of continuous neuroplasticity.* ***Conclusion***. *From clinical perspective, since psychomotricity actually means interdisciplinarity, this is the common denominator found in the collaboration between medical specialties: plastic surgery and reconstructive microsurgery, clinical neurology, electrodiagnostic and neuromotor rehabilitation.*

Keywords: *psychomotricity; brachial plexus; transcranial magnetic stimulation; rehabilitation.*

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Introduction

Psychomotricity is the study of the human body's motility in connection to the environment and its inner world. It also addresses the potential for accurate perception of objects in the immediate environment (Berdila et al., 2019). It explains a central nervous system (CNS) phenomenon that is still present. It is normal for ideomotricity, the mental projection of the movement to be realized and its appropriate action, to be compromised as a result of altered motor function in brachial plexus (BP) lesions, as the deficiency is typically rather severe. During the dynamics of evolution of the lesions of BP, starting with initial Wallerian degeneration in the proximal region of the affected nerve, up to the first signs of muscle atrophy, all the cascade of physiopathological events will eventually impact the sensory-motor representation of the affected limb at the cortical level (Stamate, 1998; Lundborg, 2003; Lundborg, 2000).

The main purpose of the study is to find correlations between the lesions of the BP, surgical procedures and electrodiagnosis findings, different postsurgical milestones, as well as interpret this data from the point of view of the cortical reactivity as a response to long term rehabilitation plans.

The discussion of interdisciplinarity in BP pathology in adults is of interest in the context in which only approximately 40% of patients with BP lesions undergoing nerve transfer are able to raise the affected limb against gravity 25 years later (Zhang & Gu, 2011).

Combined techniques of explorations are useful during the whole period of follow-up of the injury, but especially during the recovery after a nerve repair, as there is a possibility that the motor axon reaches another muscle or another level of sensitive endings, leading to cortical adaptive changes according to the new signals (Stamate, 1998; Lundborg, 2000).

Functional deficits resulting from peripheral nerve injuries can be compensated by the phenomenon of reinnervation, but with a negative impact on topognosy or tactile discrimination, as well as on fine motor control, including manifestations related to neuropathic pain (Stamate, 1998; Lundborg, 2000). These phenomena are reflected in a cascade of events, which from the level of molecular signaling, to the appearance of excitatory and inhibitory synaptic alterations, will lead to the emergence of new connections in neural networks with determinism on the reorganization of sensory and motor cortical maps, however, not always in a harmonious manner (Lundborg, 2003; Navarro, X. 2009).

Assessments of sensitivity after contralateral C7 transfer, both by Semmes-Weinstein monofilament testing and sensory nerve action potential (SNAP) measurement, correlated with functional magnetic resonance imaging (fMRI) follow-up, suggest an overlapping phenomenon in the sensory area on the ipsilateral hemisphere with the representation of the healthy limb, mechanism of postoperative sensitive synchronicity (Cai et al., 2021).

These details constitute the starting point for studies such as our own, but also for the orientation of treatments, whether surgical, recuperative, or mixed, in an effort to modulate CNS activity towards a recovery of lost functions and reduction of unwanted effects.

In an extensive PB lesion, specific interventions are also often required to restore hand functionality, including muscle and/or nerve transfer (Limthongthang et al., 2013). This is also important from the point of view of cortical plasticity, given that, outside of BP lesions, even functional deficits from a carpal tunnel syndrome can lead to reorganization of the primary somatosensory cortex (Maeda et al., 2014).

Another example of the need to restore hand functions separately is the situation of total PB lesions, where the contralateral C7 root transfer, although providing satisfactory results in restoring elbow adduction and extension, hand and finger extension remains modest (Wang et al., 2018; Radu & Petrea, 2022).

These data are valid and can also be found in the case of BP affected patients with surgical interventions to regain the functionality of the hand. The Oberlin procedure, like many other BP interventions, has itself a modest effect on hand function (Teboul et al., 2004; Sungpet et al., 2000; Tjokorda, 2018).

The representation of the body schema in the pathology of the nervous system (both central and peripheral), reflects the ability to keep the mental representation of one's own body, in static and dynamic situations, with its possibilities but also its limits in relation to the environment. According to some authors, this is even synonymous with the notion of "self-image". The integrative process involves the identification, localization and orientation in space of the different body segments (Berdila et al., 2019).

Even in the individual in full apparent health, the dynamics of cortical maps can be influenced over time either by modulating psychomotricity (practicing sports or professional activities that require a certain dexterity and perfecting certain motor functions), or by the presence of modifiable risk factors (such as consumption of alcohol or certain drugs) (Bolbocean, 2011; Feng et al., 2016). Since the dominant upper limb is responsible for several tasks with a cognitive substrate, a PB lesion at its level will lead to several adaptive brain changes, especially in case of avulsion as a mechanism of production (Feng et al., 2016; Feng et al., 2015). All authors contributed equally to this work.

Material and methods

We retrospectively evaluated results from 11 patients with complex BP lesions (including total plexus injuries) and poor outcomes in time due to the severity and extent of the trauma. These patients did not have in common the same dominant limb lesion level, nor attended to any form of standardized treatment protocol. All patients were assessed at various time intervals, after different surgical procedures meant to restore the upper limb's functionality. In the case of all these 11 patients there was no history of a common surgical intervention.

In the early stages after the plexus injury, the microsurgical reconstruction procedure, planned in accordance with the changes that appear in the electromyographic examination (EMG), initially involves mainly the regaining of forearm flexion on the arm, respectively the ability to raise the shoulder. Later, in evolution, other interventions may be necessary, either if the first ones are not accompanied by sufficiently good results, or when improvements with a more palliative value are needed, reaching multiple interventions over time. The affected BP was already in chronic state when evaluated, each patient possessing a history of 2 up to 4 surgical interventions (table 1).

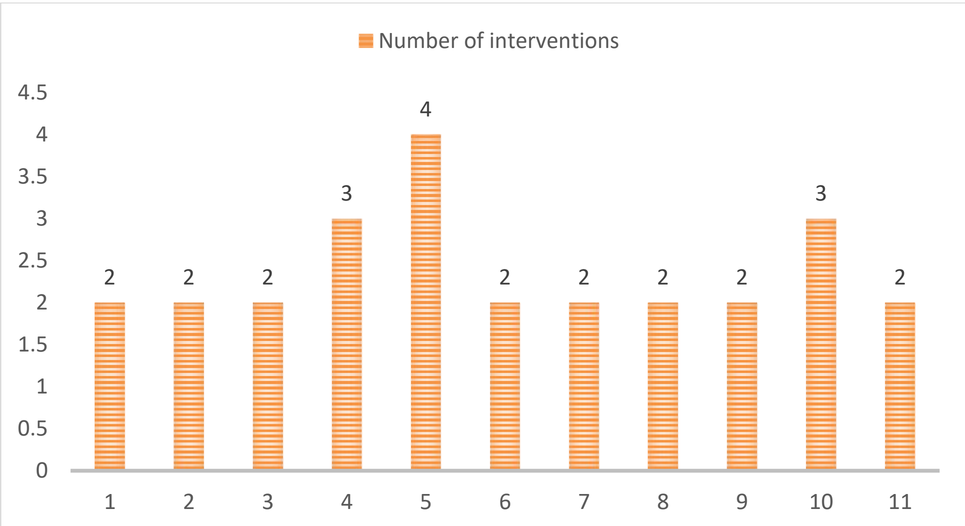

Table 1 Total number of surgical interventions in each of the 11 patients

We analyzed the deficit on the MRC scale (McGillivray et al., 2022) within a time-lapse of one year (table 2), while assessing transcranial magnetic stimulation (TMS) by a Magstim Rapid® device: Magstim Co Ltd, Whitland, Dyfed, UK, using the "butterfly" shaped coil.

Grade	Description
5	Normal muscle strength
4	Contraction and movement possible against moderate resistance
3	Defeats gravity, but not any additional resistances
2	Possible movement of the examined member in the plane of the bed, without being able to overcome gravity
1	Isometric contraction, palpable, sometimes accompanied by fasciculations, but without visible voluntary movement
0	Absence of movement when attempting voluntary contraction

Table 2 MRC Scale (adapted from McGillivray et al., 2022)

For the determining of the motor threshold at the TMS investigation, the coil was positioned above the cerebral motor area (the projection of the upper limb), studying the response from the first dorsal interosseous (FDI), in conditions of muscle relaxation. However, since the motor deficit was significant, we used the voluntary contraction of the investigated muscle in attempt to facilitate the movement. The stimulation was performed with 100% intensity (considering the increase of the peripheral latency). During the procedure, we used surface electrodes positioned at FDI level (active) and on the 2nd or 3rd phalange (reference). The ground electrode was a bracelet type, attached to the forearm.

After recording MEP at cortical stimulation, we stimulated at cervical level, recording on FDI and biceps brachii (BB), using the same coil, in lateral-vertebral C7 incline position (in order to stimulate the nerve roots, not the spine). The "8" or "butterfly" shaped coil was preferred instead of the circular one for its better propagation of the field. In this manner, we adapted the method which we usually use for central/ pyramidal tract pathology (cerebrovascular, multiple sclerosis etc.) to the current situation, in which we investigate the block or the delay in conduction towards the peripheral segment.

We evaluated the patients up to one year later, after they had undergone several rehabilitation procedures in the mean time.

The gender distribution is 64% male patients, 36% female patients, in total the male sex in the young active age range being more prone to BP traumatic events (tables 3 and 4).

Age decades	14-19	20 - 29	30 - 39	40 - 49	> 50
Number of patients	2	5	2	1	1

Table 3 Distribution of patients by age

No	Patien t	Sex	Age at the first evaluation	Circumstances of BP trauma
1	G.A.	M	32	Road accident (pedestrian hit)
2	M.G.	M	26	Car accident (passenger in the right front seat)
3	G.R.	F	25	Car accident (passenger)
4	M.F.	F	41	Fall from a height (approx. 4 m)
5	G.V.	M	44	Fall from a height (work accident); during the fall, he gets caught in the scaffolding, resulting in an extensive BP injury, including root avulsions
6	A.D.R.	M	23	Car accident (driver)
7	P.M.	M	22	Road accident (motorcycle driver)
8	M.S.	F	28	Car accident (passenger)
9	B.A.M.	M	31	Road accident (motorcycle passenger)
10	O.F.	F	33	Falling and rolling on a steep slope (mountain hiking)
11	R.A.	M	53	Accidental fall from height (in own household)

Table 4 Details of the lot and the circumstances of the BP injuries

The patients present a complex surgical history (table 5).

Patient	Dominant side	Affectation level/ Affected side	Surgical history
1	left	Right C5-C6-C7	Neurotization of the accessory spinal nerve to the suprascapular nerve Neurotization of the motor branch from the triceps to the axillary nerve
2	right	Left C5-C6-C7,	Neurotization of the accessory spinal nerve to the suprascapular nerve Oberlin technique
3	left	Right C5-C6-C7 (C5-C6 avulsion)	C5 root neurotization to the suprascapular nerve Neurotization of intercostal nerves 3,4 to musculocutaneous
4	right	Left C5-C6-C7 (avulsions)	Phrenic nerve neurotization distal to C5 Transfer of intercostal nerves 3,4 and 5 to musculocutaneous Tendinous transfer of tendon from flexor carpi radialis to extensor of fingers I-V
5	right	Right C5-C6-C7 (avulsions)	Phrenic nerve neurotization distal to C5 Muscle transposition: transfer of the lattissimus dorsi to the biceps tendon Right fist arthrodesis Transposition of the extensor digitorum IV tendon of the right foot to the flexor carpi ulnar tendon
6	right	Left C5-C6-C7	Neurotization of the suprascapular accessory nerve Oberlin technique
7	right	Left C5-C6-C7-C8 (avulsions)	Neurotization of the accessory spinal nerve to the suprascapular nerve Neurotization of intercostal nerves 3,4,5 to musculocutaneous
8	right	Left C5-C7 (avulsions)	Neurotization of the accessory spinal nerve to the suprascapular nerve Mackinnon procedure
9	right	Right C5-C6 (avulsions)	Pectoralis major transposition Mackinnon procedure
10	right	Left C5-C6 (avulsions)	Neurotization of the accessory spinal nerve to the suprascapular nerve C5 and C6 root neurolysis Oberlin technique
11	right	Right C5-C6 (avulsions)	Neurotization of the accessory spinal nerve to the suprascapular nerve Transfer of medial pectoral nerve to musculocutaneous

Table 5 Surgical history of the patients

All patients underwent recuperative treatment in the mentioned time interval (table 6), according to the ambulatory protocols, respectively days or continuous hospitalizations in different medical recovery facilities, in the ideal situation meaning 10 days of treatment once every 6 months (the notion of cure below refers to 10 days of treatment).

The rehabilitation treatment was based on various combinations of NeuroMuscular Electrical Stimulation (NMES), Proprioceptive Neuromuscular Facilitation (PNF), Transcutaneous Electrical Nerve Stimulation (TENS), Physical Therapy (PT) or even Balneology (B) (some patients went to specialized resorts).

Patient	1	2	3	4	5	6	7	8	9	10	11
Time-lapse	2 yrs	10 mths	20 mths	15 mths	8 mths	14 mths	2 yrs	1 yr	1 yr	2 yrs	1 yr
Treat-ment,no. of cures	2 (TENS + NMES)	1 (PT, NMES, PNF)	2 (NMES, B)	1 (PT, NMES)	1 (PT, NMES, PT)	2 (PT, NMES, PNF)	2 (PT, NMES, PNF)	1 (PT, TENS, massage)	2 (NEMS, PNF)	1 (PT, B, TENS)	1 (PT, PNF)

Table 6 Rehabilitation protocols

None of the patients followed had comorbidities that would limit access to TMS (no history of epileptic seizures, no pacemaker).

The Ethics Committee of the University of Medicine and Pharmacy "Grigore T. Popa", Iasi, gave its approval for the retrospective study, which was conducted in compliance with the Declaration of Helsinki's standards. Consent was given in writing by each patient, following ethical guidelines. Over a period of seven years, the patients were followed up at the Neurology Clinic of the Clinical Rehabilitation Hospital, Iaşi, as well as in an ambulatory regimen.

STATISTICA 6.0 StatSoft (Europe) was used to conduct the statistical analysis. Using the t test and an ANOVA analysis, the first and second ratings were compared. Standard variation analysis was used to evaluate the data, with a significance level of $p<0.05$.

Results

Motor Evoked Potential's (MEP) latencies at the TMS examination slightly improved in patients that managed to attend rehabilitation for repeated protocols, nevertheless, without adherence to any kind of standardized protocol for the mentioned period of time.

Better values were obtatined in the majority of the follow ups, in some cases initial no response became measurable (tables 7 and 8)

Patient	Initial TMS					
	Cerebral		Cervical			
	Right	Left	Bicipital		FDI	
			Right	Left	Right	Left
	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)
1	21,5	26,2	0	14,5	0	15
2	24,7	17,5	16,5	45	16,5	56
3	17,5	27,5	38	14,5	26	16,5
4	28,3	15,6	18,3	0	20,2	0
5	17	28	0	17,2	0	18
6	29	17,1	15	28	15	19
7	27	16,2	16,2	32	16,2	35
8	0	21	17,1	29	17,1	31,2
9	17	28	17,1	36	17,1	27
10	28	17,3	16,2	37,1	16,2	39,2
11	17	0	0	14,5	0	15,2

Table 7 Initial TMS

Patient	Control TMS					
	Cerebral		Cervical			
	Right	Left	Bicipital		FDI	
			Right	Left	Right	Left
	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)	MEP Latency (ms)
1	21,5	25,8	28	14,5	29	15
2	22	17,5	16,5	30	16,5	45
3	17,5	26	31	14,5	19	16,5
4	27,3	15,6	18,3	29	20,2	30
5	17	26,9	35	17,2	39	19
6	26,8	17,1	15	24	15	16,5
7	25,1	16,2	16	28	16	32
8	28	21	17	27,8	17,1	29,8
9	17	25,2	17	33,1	17	23
10	27,1	17,3	16,2	36,3	16,3	37,9
11	17	29	37	17	38,3	17

Table 8 Second TMS (better results in **bold** characters)

Discrete better values were also present on the MRC scale (table 9) (also for the others patient's appreciation of amelioration around the value of 0.5).

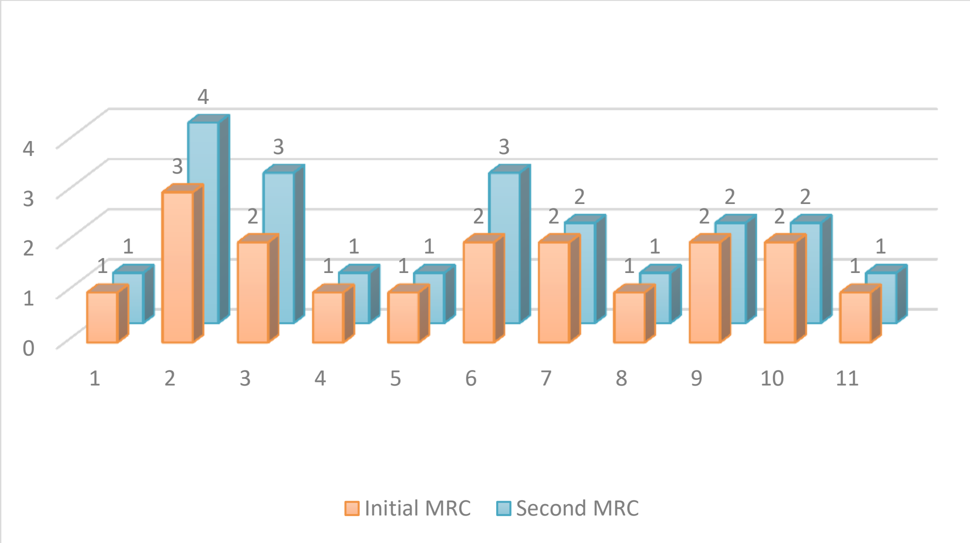

Table 9 MRC evolution

These data do not correlate with a statistical significance, neither at the level of the whole lot of patients (table 10), nor from the point of view of the right (table 11) or left side (table 12) involvement.

All patients	Initial	Final	p
Right cerebral TMS	20.636 ± 8.462	22.391 ± 4.654	0.5536
Left cerebral TMS	19.491 ± 8.226	21.600 ± 5.039	0.4767
Right bicipital TMS	14.036 ± 11.039	22.455 ± 8.493	0.0507
Left bicipital TMS	24.345 ± 13.241	24.673 ± 7.722	0.9443
Right FDI TMS	13.118 ± 8.933	22.127 ± 9.014	0.0289
Left FDI TMS	24.736 ± 15.108	25.609 ± 10.039	0.8748
MRC	1.636 ± 0.674	1.909 ± 1.044	0.4753

Table 10 Statistical apreciation of evolution in all patients

Right affectation	**Initial**	**Final**	**p**
Right cerebral TMS	18.000 ± 1.969	18.000 ± 1.969	1
Left cerebral TMS	21.940 ± 12.287	26.580 ± 1.484	0.4262
Right bicipital TMS	11.020 ± 16.802	29.600 ± 7.861	0.0555
Left bicipital TMS	19.340 ± 9.386	19.260 ± 7.846	0.9887
Right FDI TMS	8.620 ± 12.216	28.460 ± 10.357	0.0243
Left FDI TMS	18.340 ± 4.988	18.100 ± 3.090	0.9294
MRC	1.400 ± 0.548	1.600 ± 0.894	0.6811

Table 11 Statistical apreciation of patients with right affectation

Left affectation	**Initial**	**Final**	**p**
Right cerebral TMS	22.833 ± 11.286	26.050 ± 2.206	0.5088
Left cerebral TMS	17.450 ± 1.883	17.450 ± 1.883	1
Right bicipital TMS	16.550 ± 1.097	16.500 ± 1.103	0.9388
Left bicipital TMS	28.517 ± 15.305	29.183 ± 4.038	0.9199
Right FDI TMS	16.867 ± 1.770	16.850 ± 1.781	0.9873
Left FDI TMS	30.067 ± 19.016	31.867 ± 9.516	0.8399
MRC	1.833 ± 0.753	2.167 ± 1.169	0.5701

Tabelul 12 Statistical apreciation of patients with left affectation

In one of the patients, G.V., we attempted a dynamic measurement insisting of measuring different amplitudes of the MEP by moving the coil above the surface of the motor area in order to record multiple MEP. Different amplitudes resulted in the form of a central maximal amplitude located in the center of the motor area, gradually decrease once moving to the peripheral areas, as the number of neurons dedicated to a specific contractile ability decreases.

8 months after the first evaluation (while doing kinetotherapy, NEMS and PNF), along with a central motor conduction time (CMCT) decrease from 10 ms to 7.9 ms, the central maximum amplitude increased from 1.08 mV to 1.49 mV, and so did the amplitudes of the MEPs recorded in the farthest spots, from 0.69 mV to 0.89mV. Not only did the maxim amplitude increase, but it also was being recorded around the central spot (aprox. up to 2 cm around) in a pattern resembling a plateu, rather than a peak.

This dynamics correlates with improved values of MEP latencies and is also correlated with the improvement of the CMCT parameter.

Discussions

PB pathology can involve a long-term disability, with a negative impact on the quality of life, especially as a result of the fact that most cases occur either at very young ages or during very active adult life (Stamate, 1998). This is where the psychomotor component comes into play.

The notion of psychomotricity is applicable through its components affected by traumatic pathology. In general, the psychomotor domain is constituted by a series of elements, each important for certain stages in life, both in the child (following its development and corresponding motor, cognitive and psychosocial acquisitions) and in the adult, as key points in the initiation of the protocol recuperative for various pathologies, central or peripheral (Berdila et al., 2019).

The main components of psychomotricity are ideomotricity, body representation, laterality, balance, ambidexterity, eye-hand and eye-foot coordination, perceptual-motor coordination or precision and fine and global motility (Berdila et al., 2019). In PB lesions, as it is often a matter of a considerable motor deficit in terms of severity, ideomotricity (the mental design of the movement to be carried out and its execution) suffers, by altering the implementation of the motor act. The mechanism by which a central plan is generated for putting the movement into action is disrupted by breaking the connection with the effector organ, the muscle. Perceptual-motor coordination will be affected later, by affecting the perception of the shape of objects with the affected limb, but hand-eye coordination can be used as a tool in the recovery procedure to restore stereognosia.

Laterality refers to the dominant function of a cerebral hemisphere (presupposes differences between the two right and left halves of the body). In all this dynamic, in the end, even the body representation (the perception of one's own body or its various components) will be affected.

While performing TMS we used the phenomenon of facilitation. The patients in the study, with severely influenced MRC for elbow flexion use the adjacent, spared muscles, hence the clinical aspect of a tendency to raise the upper limb by elevating the shoulder (when upper BP is spared) and especially by activating the extensors (of course, depending on the particularity of the case). Considering the complexity of the cases, we also included TMS assessment with picking on FDI for correlations with functionality on the MRC scale.

For TMS investigation of the small muscles of the hand, the circular coil placed at the vertex is usually used. Anticipating the problematic peripheral latency, we chose the butterfly coil protocol for better field targeting. Also for these reasons, we used maximum stimulation intensity, in contrast to CNS neurological pathologies, in which the motor threshold is considered to be the minimum intensity of the stimulus that causes the appearance of PEM (of at least 50 μV in at least 5 out of 10 stimulations) (Feng et al., 2015; Hötting & Röder, 2013).

In some patients, peripheral latencies were shorter at FDI than at BB. This is precisely explained by the delay at the C5-C6/C7 level.

Central motor conduction time (CMCT) represents the time interval required for conduction from the motor cortical level to the spinal cord level. The peripheral conduction time (between the anterior medullary horn and the muscle) is subtracted from the conduction time from the central level to the muscle. For the upper limb, CMCT is pathological if it is greater than 9 ms, by recording at the level of abductor digiti minimi (Hötting & Röder, 2013). We consider latency much more relevant for characterization of peripheral reinnervation. Even if the value of CMCT may, in some cases, show a decrease dependent on the amelioration of latency, we considered it to be less useful in this peripheral affectation.

We value the stimulation of cortical reactivity through a better propagation of the phenomenon called ideomotricity towards the activation of neighboring muscle areas, through nearby nerve branches, in order to generate MEP (sometimes even without significant movement of the limb), when a satisfactory facilitation cannot be achieved through muscle contraction due to a motor deficit. Since patients were unable to adequately activate their muscles for optimal forearm flexion on the arm, we utilized the FDI muscle to help with the facilitation phenomena. Note that our goal was not to draw attention to the previously established correlation (which would have been modest) between the cortical representation and the bicipital motor deficit. Rather, we looked at the psychomotricity of the PB lesions and how, after various surgical procedures and long-term recuperative treatment, ideomotricity translated into the activation of complementary muscle groups, could increase the degree of cortical activation, which is consistent with the idea of continuous neuroplasticity.

The patients have a lengthy medical history that includes numerous surgical and rehabilitation-based restoration techniques. Long-term psychomotor training can be used to monitor recovery when the damage is chronic and the muscle exhibits atrophy. The mechanisms by which the motor nerve component of the affected muscles is stimulated, correspondingly, to maintain a contractile potential and prevent or stabilize the atrophy phenomenon are the basis for the functioning of ideomotricity. These mechanisms occur simultaneously and in proportion to the density of the muscle fibers in the muscles. Additionally, therapeutic approaches can focus on the sensitive component by teaching tactile discrimination, which enhances perceptual-motor coordination, restores stereognosis, and implicitly rearranges the body's perception of the damaged area (Stamate, 1998).

Chronic sensory-motor impairment in a topographic pattern involving the brachial plexus suggests either segmental demyelination or axonal disruption, sometimes both at multiple levels within the plexus. The degree of decrease in muscle strength is proportional to the number of affected axons, and pain and the abolition of kinesthetic sense often worsen the functional deficit. PB damage can give some of the most confused patterns of motor, sensory and vegetative interest (Stamate, 1998; Hötting & Röder, 2013). On clinical examination, the loss of motor functions, the evidence of osteotendinous areflexia phenomena or sensory deficits may not always follow a very specific pattern of root or nerve trunk damage (Stamate, 1998; Hötting & Röder, 2013).

Reintegrating peripheral impulses at the cerebral level is the most difficult aspect of regaining lost motor function, both from a sensory and motor perspective. Through time, a loss of cortical control center function could happen if there is no kinetic and sensory feedback from the effectors (Lupescu, 2006). As a result, the damaged limb's function will be less represented at the cortical level. In this situation, functional rehabilitation is required following the peripheral nerve microsurgical intervention (s). As part of the redesign strategy at the level of the sensory-motor homunculus, the lost cortical functions will need to be relearned (Stamate, 1998; Lundborg, 2003; Lundborg, 2000). This is why protracted rehabilitation processes are required.

From the perspective of adaptive mechanisms within neural lesions, neuroplasticity refers to the acquisition of new motor behaviors, while integration of various body parts into a series of perceived as natural or intelligent movements (i.e., requiring minimal energy or effort) is the ultimate goal of recuperative therapy and represents psychomotority (Navarro, 2009). Last but not least, improving the cortical function of integrating the position of the affected body segment (in our study, the upper limb), will allow from a psychomotor perspective the reorganization within the lateralization phenomenon (Navarro et al., 2007).

In the case of patients with such complex traumatology and a long history of limitation of usual daily activities, psychomotor activity suffers severly after the first years (dominated by motor impotence and finally by acceptance to a variable extent from patient to patient, of limited motor function prognosis). Hence psychomotor activity we also refer to the connection between the mental and the motor components, recovery therapy having the role of attempting to restore this correspondence, the very notion of ideomotricity being able to be helped by rehabilitating laterality, as we saw especially in our right-handed patients with damage to the plexus on right, apparently (considering the small sample size) with slight better evolution. Here the major limitation of the study regarding a small number of patients should be mentioned (Daia, 2022).

The possibility of long-term follow-up is necessary (including left-handed patients with left-sided damage, respectively patients with left-dominant hand and right-handed damage and vice versa, with the aim of obtaining concrete data about the involvement of laterality or the activation of ambidexterity, useful to be evaluated imaging and / or electrophysiological from the perspective of interhemispheric transmission). It is necessary: the realization of standardized protocols of periodic evaluation and an adequate recovery treatment, the correlation of the clinical evolution with the dynamics of cortical activity over several years and ideally, the creation of a group of patients with very recent interventions or even enrolling them in studies before the first microsurgical intervention with a remedial purpose, which is however difficult to achieve in a time frame of only a few years.

The neuroplasticity of the sensory-motor cortex as a continuous phenomenon highlighted in the last decades by both imaging and electrophysiological techniques, is based on Hebb's law, which postulates that the repeated or persistent stimulation of an A cell by a B cell, causes metabolic changes in one or both neurons and possibly axo-dendritic that modulate the efficiency of synaptic transmission. In other words, "cells that fire together, connect" saying that suggests that when two neurons are excited together, a connection is created or strengthened between them. This theory attempts to explain associative learning and underlies current and future neurorehabilittion techniques (Hötting & Röder, 2013; Navarro et al., 2007).

It is of particular interest to restore the motility of the hand in complex PB lesions, in the cases presented being patients with interventions to restore the opposition of the wrist or a better movement of the fingers. These details are related to the immense cortical representation of the hand, which is one of the reasons behind the orientation of the presented study, to use the FDI for the placement of the active electrode.

Another limitation of the presented research, apart from the previously mentioned small sample size, comes from the very etiology of the investigated injuries: all being traumatic, it is difficult to estimate the individual initial performance of muscle strength or the degree of amplitude of the movement. And here the notion of psychomotricity can be developed in the future to provide assessments and even stagings according to the level of psychomotor training that the individual had before the trauma occurred (Hötting & Röder, 2013).

A future solution for maintaining and even improving cortical plasticity comes from the direction of prosthetic devices or myoelectric elbow orthoses, represented by robust and reliable interfaces (especially for keeping patients inserted in the work field, where the basic profession requires manual labor), but also of hybrid devices, of the "artificial hand" type controlled by means of surface electromyographic electrodes (Webber et al., 2021; Godfrey et al., 2021).

Since the period of functional psychomotric re-education spans several years, and this allows the association of different electrodiagnostic, imaging and clinical techniques to follow the evolution, with the aim of finding correlations and even establishing a relevant correspondence between the paraclinical, clinical and psychosomatic domains. It is reassuring and hopeful for future medical breakthroughs since active mechanisms persist at the cortical level, even in cases when the body segment represented at that level has a significant impairment.

Conclusions

Brachial plexus pathology remains one of the challenges of medicine to find more effective solutions to reduce the long-term negative impact on the patient, especially since he is often at a young age, in the period compatible with an intense professional activity, but also with a life active psychosocial. Based on the results obtained, we believe that intervention through recovery therapy and adherence to a long program can stimulate the dynamics of body representation and ideomotricity by stimulating the phenomena at the level of the primary motor area and facilitating the reorganization at the level of the responsible cerebral hemisphere in the most harmonious manner, as much as possible in correspondence with the affected plexus.

Benefits associated with reductions in motor deficit may not usually follow improvements in TMS parameters. Only in situations where the patient is receiving long-term recovery treatment (NEMS, PNF) is there a possible correlation between the improvement of the electrophysiological parameters at the cortical level and minor improvements in the motor deficit associated with the flexion of the forearm on the arm.

In order to preserve a demonstrated, quantifiable potential for ongoing neuroplasticity, TMS thus supports the necessity of progressive rehabilitation therapy targeted at enhancing the impacted psychomotor components: ideomotricity, perceptual-motor coordination, laterality and body representation.

Since the data do not consistently and significantly correlate with one another, techniques that can be applied to larger patient populations, such as observational studies or extended clinical case series, are required.

The presented study, in spite of the small sample size and the irregular methodology, is original by aiming towards decoding the motor deficit and its impact from the perspective of the notions of cortical reactivity, long time after the moment of the trauma. Hence a translation of how the ideomotricity affected in these plexopathies leads to the alteration of the cortical representation of the affected segment, but also providing proof that the ideomotricity can also be stimulated by the recuperative program in order to stimulate the restoration of the correspondence between the peripheral and the central.

The understanding of the mechanisms involved in this traumatic pathology of the young adult through the prism of the correlations between the mentioned investigative components, but also from a psychomotor perspective of the post-surgical functionality of the brachial plexus, is unique at this moment.

As the foundation of recovery procedures, the idea of psychomotricity is real and has applications in many medical and psychosocial domains. Psychomotricity is the common concept that harmoniously blends the peripheral and central conceptions of the individual considered as a whole, with the goal of the most harmonious functionality, at the boundary between numerous specialties.

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