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Case Report
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Chordata method combined with electrotherapy in functional recovery after brachial plexus injury: report of three clinical cases

Método Chordata combinado com eletroterapia na recuperação funcional após lesão do plexo braquial: relato de três casos clínicos

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ABSTRACT

Aims: To report three clinical cases of complex brachial plexus injury treated with an innovative physical therapy program, the Chordata Method, combined with electrotherapy.

Case description: Three patients suffered a complex brachial plexus injury. They were submitted to surgery and to long-term rehabilitation with the Chordata method (including suspension and tilting exercises) combined with electrotherapy. All patients exhibited significant signs of recovery in post-treatment electroneuromyography. Moreover, improvements in muscle strength and in the range of motion of the injured upper limb were also observed, leading to better posture and gains in activities of daily living (e.g., driving a modified car, holding objects, performing household chores, and doing leisure activities).

Conclusions: There was great functional recovery after the physical therapy program with the Chordata Method combined with electrotherapy, with an impact on patients' daily lives as well as on electroneuromyography findings. Randomized clinical trials are needed to confirm or refute this new non-pharmacological strategy for the treatment of brachial plexus injuries.

KEY WORDS: brachial plexus neuropathies; physical therapy modalities; peripheral nerve injuries.

RESUMO

Objetivos: Descrever três casos clínicos em que os indivíduos tiveram lesão de plexo braquial complexa, tratada com um programa inovador de fisioterapia, o Método Chordata, associado à eletroterapia.

Descrição dos casos: Três pacientes sofreram lesões complexas do plexo braquial. Os três sujeitos foram submetidos à intervenção cirúrgica e a um longo período de reabilitação com o emprego do método Chordata (envolvendo exercícios de suspensão e pendulação corporal), combinada com a eletroterapia. Todos os pacientes apresentaram sinais significativos de recuperação na eletroneuromiografia pós-tratamento. Além disso, os três também apresentaram melhora na força muscular e nas amplitudes de movimento do membro superior acometido. Observou-se melhor postura e ganhos importantes nas atividades de vida diária (tais como dirigir um carro modificado, segurar objetos, realizar tarefas domésticas e atividades de lazer).

Conclusões: Os resultados revelaram uma importante recuperação funcional após o programa de fisioterapia com o Método Chordata associado à eletroterapia, com impacto na vida diária dos pacientes, bem como nos achados eletroneuromiográficos. Ensaios clínicos randomizados são necessários para confirmar ou refutar esta nova estratégia terapêutica não farmacológica nas lesões de plexo braquial.

DESCRITORES: neuropatias do plexo braquial; modalidades de fisioterapia; traumatismos dos nervos periféricos.

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Abbreviations: BPI, brachial plexus injury; ENM, electroneuromyography; PUCRS, Pontifical Catholic University of Rio Grande do Sul.

INTRODUCTION

Brachial plexus injury (BPI), one of the most severe upper limb injuries in adults, is strongly related to traffic accidents and has high incidence rates worldwide [1,2]. In general, BPI can affect the upper trunk (C5-C6 Erb-Duchenne palsy), the extended upper trunk (C5-C6-C7 Erb-Duchenne palsy), the lower trunk (C8-T1 Dejerine-Klumpke palsy), or involve all the nerve roots (complete injury). Isolated upper trunk injuries have a better functional prognosis than isolated injuries of the trunk divisions and of upper or lower root injuries. Complete injuries and persistent pain for more than 6 months indicate a poor prognosis regardless of the injury level [2,3]. The history of traumatic BPI, whether from forceful trauma or iatrogenic trauma, is generally poor, with most natural improvements occurring within the first 6 months [4]. While surgery could increase the chances of functional recovery, many patients remain permanently disabled and one-half of those previously employed do not return to work [1,5]. A previous case series also suggested a traumatic global BPI with recovery of hand function 2 to 17 years after the injury [6].

In this context, physical therapy is the only alternative to maximize functional adaptation. Conventional therapies, such as electrotherapy, proprioceptive neuromuscular facilitation stretching, and exercises that stimulate functional skills are often used. However, the recovery results do not tend to be very encouraging [7]. Thus, usual therapies are mainly designed for movement adaptation. In spite of recommendations for conventional physical therapy, unfortunately, there is no consensus about ideal protocols and doses for BPI rehabilitation programs, which reinforces the importance of clinical studies in the field [8].

Verônica Baptista Frison, a physical therapist working on neuroscience research and clinical neurorehabilitation projects, developed the Chordata Method® in 1999. The aim of her method is to provide neuromuscular reactivation, movement facilitation and, consequently, return to activities of daily living using exercises especially designed to be performed on the Chordata apparatus. The rationale behind the method is that neuromuscular "reactivation" takes precedence over movement "adaptation." This change in paradigm might result, hypothetically, in an improved level of functionality and recovery. Briefly, the Chordata apparatus consists of an iron structure shaped like an inverted U, which is mounted onto the walls of the room where it is installed and uses springs and materials as the ones used in climbing gear. It allows body suspension, limb tilt, movement oscillation, and dislocation of the body mass center beyond the body gravity center, resulting in optimized antigravity muscle activity. Since there is a lack of scientific evidence about the efficacy of the method in the rehabilitation of neurological diseases, the Pontifical Catholic University of Rio Grande do Sul (PUCRS) and the Chordata Method Institute established a research partnership.

Overall, previous results have shown that the Chordata method is safe for the training of elderly people, allowing them to improve their balance and functional mobility [7]. Additionally, other results have revealed that the Chordata Method could increase functionality and quality of life of subjects with spinal cord injury (unpublished data). Thus, gathering scientific data on the method is crucial to encourage further clinical trials to evaluate the cost-effectiveness of this neurorehabilitation method.

Therefore, we report three complex BPI cases, in which the patients were submitted to an innovative physical therapy program – the Chordata Method – combined with electrotherapy. Three retrospective case reports were prepared, in which patients with BPI were referred to an innovative rehabilitation program that included a triangular waveform device (electrotherapy) and Chordata Method training (emphasis on body suspension and tilt). The patients were treated at the Rehabilitation Center of PUCRS and at the Chordata Institute between November 2011 and April 2014. Two patients had undergone surgery (performed by the same surgeon). The study protocol (no. 978.279) was approved by PUCRS Ethics Research Committee and all enrolled subjects signed a free and informed consent form.

CASES DESCRIPTION

Three patients suffered a complex BPI. They were submitted to surgery and to long-term rehabilitation using the Chordata method combined with electrotherapy. Detailed information on the cases is provided after the Procedures subsection.

Procedures

All patients received 20 minutes of daily electrotherapy (triangular waveform) using an Intellect Combo 48 (Chattanooga, USA) device. The phase term ranged from 70 to 100 milliseconds (ms) and the phase interval ranged from 800 and 1,000 ms. Elbow and wrist extensors, as well as external shoulder rotators, were the stimulated muscle groups.

The Chordata Method program involved suspending the body on the apparatus while performing tilting exercises (mean of three times/week). The apparatus consists of an iron structure with special springs and a harness specifically manufactured for practicing the Chordata Method. During the training sessions, the prescribed exercises emphasize the repetition of movements designed to promote different types of muscle contractions (concentric, eccentric, static) performed in different body positions and at different joint angles (**Figure 1**). Thus, patients experienced maximal functional performance through motor memory evocation. Each session of tilting and oscillation exercises lasted around 90 minutes. These exercises were performed actively with suspension of the "injured" upper limb (up to 90 degrees of shoulder flexion) in different body positions: seated, supine, and lateral decubitus. During the exercises, patients coordinated concentric, eccentric, and isometric muscle contractions. Overall, patients experienced tilt and oscillatory movement repetitions until signals of fatigue or undesired compensations emerged. We advised patients to perform a quick inversion of

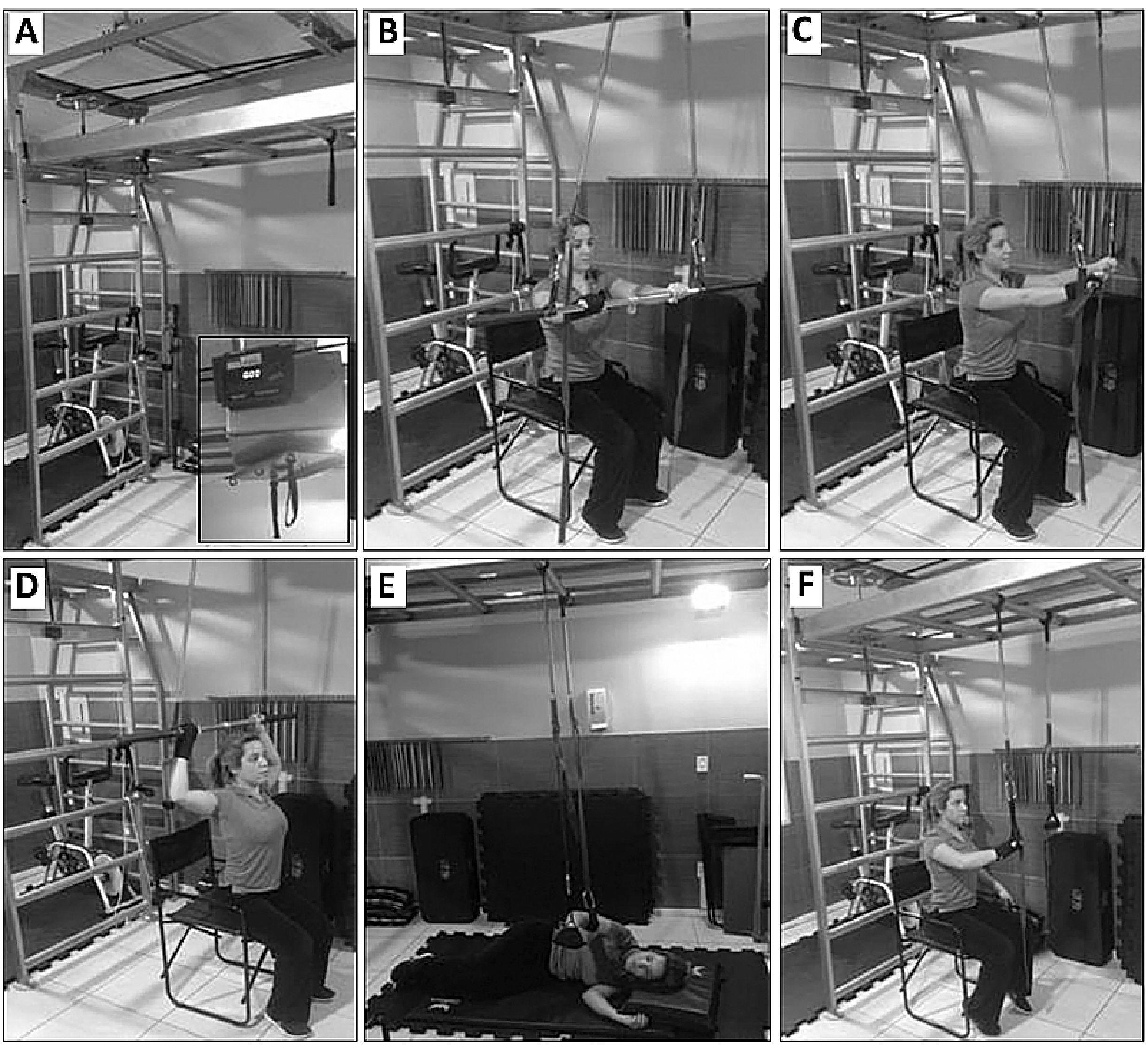

Figure 1. (**A**) The Chordata apparatus (a load cell, in detail). (**B-F**) Illustration of exercises performed during the rehabilitation program.

motion at the end of each movement by changing from horizontal flexion to horizontal extension, shoulder and elbow flexion/extension, etc. All sessions usually finished with wrist and finger strengthening, employing the same principles of movement facilitation.

Electroneuromyography (ENM) and daily movement activity data were collected from patient records (**Table 1**).

Table 1. Clinically relevant changes in electroneuromyography before and after the rehabilitation program with the Chordata Method.

Case	Pre-PT ENM	Post-PT ENM
Case 1	Sensory: DN Motor: +	Sensory: + Motor: ++
Case 2	Sensory : DN Motor: DN	Sensory: ++ Motor: ++
Case 3	Sensory: + Motor: +	Sensory: +++ Motor: ++

PT: Physical therapy intervention. ENM: electroneuromyography. DN: Denervation. +: poor innervation; ++: moderate innervation; +++: normal innervation.

CASE 1

A 35-year-old man who sustained C5-C7 brachial plexus stretching and C8-T1 avulsion injuries due to a motorcycle accident, causing right upper limb monoplegia and right shoulder subluxation, underwent surgery 4 weeks post-injury to remove fibrosis. A few months later, the same patient underwent intercostal neurotization with sural nerve grafting. Initially, the ENM revealed a right-sided BPI involving the three trunks and their terminal branches. After the rehabilitation program, consisting of four weekly sessions between November 2011 and April 2014, the post-treatment ENM showed significant signs of recovery, mainly in the upper and middle trunks of the injured brachial plexus (**Table 1**). An improvement in strength was observed, leading to better posture (shoulder girdle realignment) and to gains in daily functions, such as driving a modified car, holding objects, performing household chores, and doing leisure activities such as cycling (**Table 2**).

Table 2. Functional tests at baseline and after the treatment of three patients with complex brachial plexus injury submitted to the Chordata Method combined with electrotherapy.

Endpoint	Baseline data			Post-treatment data		
	Patient 1	Patient 2	Patient 3	Patient 1	Patient 2	Patient 3
Active goniometry						
Shoulder flexion	0°	0°	0°	90°	90°	165°
Shoulder abduction	0°	0°	0°	90°	90°	120°
Horizontal shoulder flexion	0°	0°	0°	complete	complete	complete
Shoulder external rotation	0°	0°	0°	90°	85°	complete
Elbow flexion	0°	0°	0°	90°	95°	complete
Elbow extension	0°	0°	0°	complete	not performed	complete
Wrist flexion	0°	0°	0°	90°	90°	complete
Wrist extension	0°	0°	0°	not performed	not performed	complete
Finger flexion	0°	0°	0°	85°	not performed	complete
Finger extension	0°	0°	0°	not performed	not performed	complete
Oxford (modified from Kendall) Strength Scale						
Shoulder flexors / extensors	0	0	0	-3 / 1	-3 / 1	-3 / 1
Shoulder abductors	0	0	0	-3	-3	-3
Horizontal shoulder flexors	0	0	0	+2	2	5
Shoulder external rotators	0	0	0	-2	-2	+3
Elbow flexors / extensors	0	0	0	-3 / 4	-3 / 1	5 / 5
Wrist flexors / extensors	0	0	0	-3 / 1	-3 / 1	5 / 5
Finger flexors / extensors	0	0	0	-2 / 1	0 / 1	5 / 5
Superficial Sensitivity						
Hypoesthesia	NA	NA	NA	From shoulder to wrist	From shoulder to wrist	Preserved
Hypoalgesia	NA	NA	NA	From shoulder to wrist	From shoulder to wrist	Preserved
Anesthesia	From shoulder to hand	From shoulder to hand	From shoulder to hand	Hand	Hand	Preserved
Analgesia	From shoulder to hand	From shoulder to hand	From shoulder to hand	Hand	Hand	Preserved
Deep Sensitivity						
Pressure on bone ends	Reduced in the arm	Reduced in the arm	Reduced in the arm	Reduced in the hand	Reduced in the hand	Preserved

NA, not applicable.

Case 2

A 25-year-old man sustained a root avulsion injury compromising the upper, middle, and lower trunks of the brachial plexus due to a car accident, leading to right upper limb monoplegia and right shoulder subluxation. After 4 months, he underwent nerve avulsion correction surgery. The pre-treatment ENM showed progressive acute axonal degeneration in the three trunks of the injured brachial plexus. The recovery program consisted of an average of five weekly sessions from December 2012 to April 2014. A post-treatment ENM revealed progressive axonal regeneration of the upper trunk; while the other trunks demonstrated improved sensitivity (**Table 1**). From a functional point of view, strength increased, leading to better posture (shoulder girdle realignment) and to gains in activities of daily living such as driving a modified car and holding objects (**Table 2**).

Case 3

A 40-year-old woman diagnosed with a comminuted fracture, dislocated humerus, and injury to the trunk of the axillary, radial, and median nerves underwent osteosynthesis in July 2011. She presented a monoparetic left upper limb and the ENM revealed signs of severe axonal injury in the three trunks of the brachial plexus. The rehabilitation program consisted of an average of 2.5 weekly sessions from December 2011 to December 2012. The follow-up ENM demonstrated a process of reinnervation of the muscles innervated by the axillary, radial, and median nerves (**Table 1**). In December 2012, increased strength was observed, leading to improved activities of daily living such as brushing her hair, getting dressed, typing, hanging clothes, driving, and practicing simple tennis movements (**Table 2**).

DISCUSSION

Active movements can induce electrophysiological and morphological changes in the physiology of the neuromuscular junction. For instance, motor endplates are continuously remodeling in response to functional demands [9]. Therefore, stimulating the "muscle nerve interface" can prompt nerve growth, facilitating repair by the action of neurotrophins [10,11]. In these cases, we hypothesized that an increase in neuromuscular function had occurred due to stimulation of movements that would not be possible without suspension and tilting. Furthermore, it is thought that electrical stimulation associated with active movement might be helping the recovery process, at least partially. Unfortunately, there are no previous studies with definitive results on this matter [12].

It is known that intention to move actively in a post-injury period can plastically modulate sensorimotor brain areas and, consequently, contribute to functional recovery [13]. Thus, we also hypothesize that the Chordata Method combined with electrotherapy might stimulate the motor memory and learning, facilitating nervous system recovery/adaptation. However, these specific mechanisms should be a matter for further studies.

Considering the severity of the injuries and poor prognosis in these three cases, the outcomes were surprising. The ENM results highlight the evolution from denervation to reinnervation patterns. Functionally, a significant increase in muscle strength and in active range of motion, which allowed the patients to carry out many normal life tasks, was noted.

A mean of 4.16 weekly sessions during 2.45 years was necessary to improve functionality at clinical level in the reported cases. However, it is also clear that more disabled/severe cases needed more frequent and longer therapy. While this finding is coherent with the current paradigms of neuromuscular plasticity, further studies are needed to clarify the effects of frequency, session length, and therapy duration on BPI recovery.

A limitation of the current study concerns the measure of exercise intensity. Unfortunately, the precise level of exercise intensity during each training session was not available from the patient records. Notwithstanding, further studies are needed to explore the potential of exercise intensity on functional recovery.

The present case reports suggest that the Chordata Method associated with electrotherapy might be a potential strategy to maximize rehabilitation after BPI. Further controlled and randomized trials are needed to prove the efficacy of this innovative and promising treatment.

NOTES

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Conflict of interest disclosure

Frison VB owns the Chordata apparatus rights (patent register INPI-16120002074) and is the Head of the Chordata Institute. Oliveira and Menezes are physical therapists at the Chordata Institute. The other authors declare they have no conflicts of interest.

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