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Research Article

The Effects of Low-Frequency High-Intensity Pulsed Electromagnetic Fields (Diamagnetic Therapy) in the Treatment of Rare Diseases: A Case Series Preliminary Study

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Abstract

Rare and orphan diseases are a group of multiorgan disabilities that limit the life quality in young and adult patients, affecting the socio-economic burden for the families and the community. Despite the continuous attempts in research, no standardized and effective therapies are nowadays available. Orthosis supports and rehabilitation remain the unique possibilities to alleviate these challenging conditions. Among the emerging therapeutic odds, Pulsed Electromagnetic Fields (PEMFs) express anti-inflammatory and regenerative effects on musculoskeletal and parenchymal tissues. They have also shown intriguing properties to stimulate the central and peripheral nervous system either as Transcranial Magnetic Stimulation (TMS) and Low Frequency - High-Intensity -Pulsed electromagnetic Field (LF-HI-PEMFs) or Diamagnetic Therapy (Diamagneto-therapy). This last modulates brain plasticity and is effective in pain, reducing muscles contractures and tissue oedema. Our experience refers to the use of Diamagnetic Therapy to rare and orphan diseases and reports promising functional and behavioural results, opening the possibility of therapeutic applications integrated with conventional rehabilitative methods.

Introduction

Rare and orphan diseases are a group of pathologies that affect, by definition, small numbers of patients. The classification criteria are different in the various countries as there is no unified categorization globally accepted. According to the United States Rare Diseases Act (2002), a rare disease is a condition that affects about 1: 1500 person while the European Commission defines a rare disease as any disease that affects less than 1: 2000 people and some definitions rely on the existence of proper treatments [1]. Currently, despite their low prevalence, almost 8000 existing rare diseases are esteemed to affect about 350 million patients, with a worldwide impact on healthcare and the socio-economic systems in terms of direct and indirect costs.

Recent progress in molecular biology, next-generation sequencing-based technologies, and genetics have enhanced the therapeutic choices: small-molecule drugs, protein-based therapeutics, antisense oligonucleotides, small interfering RNAs, gene and cell therapies [2] aim to trigger reparative molecular

mechanisms. Nevertheless, there is still a lack of appropriate diagnostic tools and treatments that need more specific knowledge [3]. Thus, despite the growing interest in this field, the high costs related to the rarity of the diseases and their obscure pathogenesis slow the progress in specific therapeutic tolls [1].

Given the frequent involvement of the nervous system, one of the recent therapeutic attempts is biophysical stimulation, whose target is to modify the excitability and plasticity of a specific brain or peripheral area. Repetitive Transcranial magnetic stimulation (rTMS) is a non-invasive painless technique for electromagnetic stimulation of the brain and the nervous system. Appropriate guidelines for the therapeutic use of rTMS derive from experimental evidence in pain, movement disorders, stroke, amyotrophic lateral sclerosis, multiple sclerosis, epilepsy, and other conditions [4]. On its own, the electromagnetic stimulation induced by Pulsed Electromagnetic Fields (PEMFs) retains biological effects worldwide recognized to be effective in the treatment of pain and inflammation as well as in regenerative medicine, drugs delivery, and Immuno-therapy [5]. PEMFs have been successfully applied also in musculoskeletal diseases [6] to modulate the activity of various neurotransmitters and the cortical plasticity in the brain [7,8].

Due to the recurrent ineffectiveness of conventional treatments, based on previous experiences, we employed a novel technology of PEMF to treat a series of 13 patients suffering from disabling neuro-motor and behavioral conditions related to a rare disease. We used a treatment based on Low Frequency - High-Intensity Pulsed Electromagnetic Fields (LF- HI- PEMFs) named Diamagnetotherapy (Diamagnetic Therapy), with a positive result.

Methods

From May 2019 to April 2021, at the Cell Regeneration Medical Organization in Bogotá (Colombia), a series of 13 variously aged and suffering from different neuro-muscular rare diseases were treated with Diamagnetic Therapy. The pathologies included 2 muscular dystrophies, 1 neuroaxonal dystrophy, 6 spastic cerebral palsies, 1 hemorrhagic stroke, 1 left focal seizure, 1 Dystonia 28, 1 Glass syndrome, 1 dysgenesis of the corpus callosum, 1 hypoplasia of the cerebellar bridge, and 1 dysgenesis of the dorsum -lumbar spine.

They attended an individualized treatment of Diamagneto-therapy applying the CTU Mega 20® Plus Diamagnetic Pump machine (Periso SA – Pazzallo- Switzerland), in addition to the standard of care. Depending on the symptoms and features of the disease, the health personnel used different therapeutic protocols. This technology delivers a High Intensity – Low-Frequency Electromagnetic Field (2,2T – <50 Hz) and supplies a wide range of amplitudes of the Magnetic Field and variable electromagnetic frequencies able to match the electromagnetic properties of the body tissues, stimulating them at the cellular level [8]. The choice of the area of treatment depended on the etiopathogenesis of the disease. In pathologies of the Central Nervous System (CNS) a direct transcranial stimulation has been applied, if the Peripheral Nervous System and muscles were involved (PNS), we treated the peripheral region concerned. The main target of the treatments, as occurs for conventional technologies employing PEMF, was to stimulate the metabolic activity of the cells. Additionally, the CTU Mega 20 Plus machine offers the possibility to move diamagnetic substances such as water, ions, and proteins of the Extracellular Matrix (ECM), promoting the transmembrane flow at the cellular level. Furthermore, activates muscular apparatus, the electrical conduction of slow and fast nerve fibers, thanks to the possibility to variate, selectively, the electromagnetic frequencies and the amplitudes of the Magnetic Field, according to the proper of the biological tissues [8].

Table 1 summarizes the main characteristics of the treatment provided for each patient according to the diagnosis, the protocol and the area of treatment, the number of sessions.

Patient	Diagnosis	Treated Area	Diamagnetic Treatment	Sessions Number
Patient 1	Limb girdle muscular dystrophy	Gluteal-lumbar	Pain Control Slow Nerve Fibers stimulation Liquids Movement	10
Patient 2	Limb girdle muscular dystrophy	Gluteal-lumbar	Pain Control Slow Nerve Fibers stimulation Liquids Movement	7
Patient 3	Neuroaxonal dystrophy	Transcranial: frontoparietal region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	19
Patient 4	Spastic cerebral palsy	Transcranial: temporal region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	10
Patient 5	Spastic cerebral palsy	Transcranial: temporoparietal region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	6
Patient 6	Spastic cerebral palsy	Transcranial: temporoparietal region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	11
Patient 7	Spastic cerebral palsy	Transcranial: occipital region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	6
Patient 8	Hemorrhagic stroke	Transcranial: occipital region	Pain Control Fast Nerve Fibers stimulation Liquids Movement	10

Patient 9	Dystonia	Lower jaw and lumbar region	Pain Control Fast Nerve Fibers stimulation Slow Nerve Fibers stimulation Liquids Movement	13
Patient 10	Glass syndrome	Transcranial: temporo-frontal region	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	10
Patient 11	Dysgenesis of the corpus callosum	Transcranial: parietal region	Pain Control Fast Nerve Fibers stimulation Slow Nerve Fibers stimulation Liquids Movement	10
Patient 12	Hypoplasia of the cerebellar bridge	Transcranial: below the occipital process in glabella direction	Pain Control Fast Nerve Fibers stimulation Cell Membrane stimulation Liquids Movement	8
Patient 13	Dysgenesis of the anterior dorsum-lumbar spine	Transcranial: lumbar region	Pain Control Slow Nerve Fibers stimulation Muscle stimulation Liquids Movement	10

Table 1: Summary of the patients treated with diagnosis, stimulated area, protocol of therapy, number of sessions.

Results

Given the complexity and the diversity of these pathologies, standardized assessments of cumulative functional scores are not available to evaluate the response to treatments. Moreover, they are heterogeneous, require multiple rehabilitative therapies, and have unpredictable evolution. Then, the results of this study provide only a qualitative analysis of the clinical progression. These data are summarized in the table below (Table 2) as absence/presence of improvement compared to the starting conditions: motor and relationship difficulties typical for these diseases. Almost all subjects enjoyed motor and relational improvements. Only two patients reported, respectively, the decrease in upper limbs strength in a case of limb-girdle muscular dystrophy and only a weak improvement after the treatment of cervical spine in Dysgenesis of the anterior dorsum-lumbar spine.

Patient	Pathology	Clinical Outcome
Patient 1	Limb girdle muscular dystrophy	Improvement in lower limbs muscle strength, less falls, possible bi-podalic standing.
Patient 2	Limb girdle muscular dystrophy	Decrease in upper limbs strength.

Patient 3	Neuroaxonal dystrophy	Improvement of the spontaneous motor activity and better control of hand movements. More reactive to external stimuli: smile, eye movements, more attentive to lights and sound.
Patient 4	Spastic Cerebral Palsy	Increase of hand movements, better cephalic control, and disappearance of primary reflexes.
Patient 5	Spastic Cerebral Palsy	More language skills, increase of movements and attention.
Patient 6	Spastic Cerebral Palsy	Increase of motor activity, more sociable, more fluent language, and better memory.
Patient 7	Spastic Cerebral Palsy	Increase of motor activity, starting to crawl.
Patient 8	Hemorrhagic stroke	Better ocular response to external stimuli, more reactive to external light, colors, and objects. Increase of motor activity.
Patient 9	Dystonia	Decrease of abdominal pain and of the tremor in lower jaw.
Patient 10	Glass syndrome	Increase in motor activity and more attention. Possibility to introduce integrative treatments (occupational, music and hippo-therapy).
Patient 11	Dysgenesis of the Corpus Callosum	Increase of motor activity and languages.
Patient 12	Hypoplasia of the cerebellar bridge	General increase on motor activity
Patient 13	Dysgenesis of the anterior dorsum-lumbar spine	Small, general improvement after the treatment of Cervical Spine

Table 2: Diagnosis and general clinical results for each patient at the end of the treatment.

Discussion

Rare diseases are severe life-threatening chronic syndromes usually beginning in childhood. The rarity, lack of validated and standardized procedures for care and rehabilitation, the limited clinical expertise, and the low number of specialist hospitals significantly complicate their management. Moreover, the pathophysiology, the natural course, and the epidemiological data are scarce and sometimes totally unavailable. These factors delay appropriate diagnose, adequate treatment, and prevention [2].

Over recent years, emerging therapeutic perspectives in molecular biology, genetic and biophysics, aim to stimulate neuroplasticity and neuromodulation in the nervous system, considering this frequent involvement. Among these technologies, biophysical stimulation induced by variable PEMFs has shown interesting perspectives in treating various pathological conditions in force of their regenerative and anti-inflammatory properties, also in the nervous system [5,6,8]. For its part, repetitive Transcranial -Magnetic stimulation (rTMS) affects cortical excitability outlasting the stimulation period and acting both in motor and non-motor brain areas, with local and nonlocal effects on cerebral activity. The TMS is a highly effective, painless way to generate suprathreshold current in the brain. The peak magnetic field strength is like that of the static field in a Magnetic Resonance Imaging (MRI) scanner (1–2 T), allowing the impulse to penetrate the brain without attenuation by the scalp or skull and generate a current according to the electromagnetic induction phenomenon.

As for Trans-Electrical Stimulation (TES), TMS stimulates axons rather than the neuron's body since the latter have a much longer electrical time constant and higher threshold [9,10]. Furthermore, clinical studies show inhibitory and facilitatory effects to modulate nervous excitability and synaptic plasticity [11].

PEMFs exert multilevel electrochemical interactions with cell membranes and inhibit the IL-6 transcription activated by the pro-inflammatory factor IL -1a [12]. This control of inflammation mediated by the A2A and A3 Adenosine Receptors [13] would prevent and treat degenerative changes occurring in various tissues thanks to the well-known regenerative effects of PEMF [14] by the trigger of metabolic responses according to the Intensity and the Magnetic Field Gradient (T/sec) [15]. The electromagnetic induction provided by the device employed in the present study (CTU Mega 20® Plus Diamagnetic Pump Machine – Periso SA

– Pazzallo- Switzerland) delivers, at the source, a High -Intensity MF (2,2T) offset by the safe gradient range (400T/s), at the origin of the repulsive or Diamagnetic effect. It consists of the fast movement of diamagnetic liquids and solutes from the extracellular to the intracellular environment and vice versa. Furthermore, the machine delivers a broad spectrum of electromagnetic frequencies, which selectively stimulate the biological tissues according to the proper specific frequency bandwidth, including parenchymal and muscle-skeletal tissues, nerve fibres, and cell membrane [8,18].

Rare diseases are challenging to treat and are characterized by various degrees of neurologic involvement, showing impairment of motor control, coordination, language, and cognitive status [19]. Severity is often difficult to detect. In isolated agenesis of the Corpus Callosum (AAS), prenatal diagnosis detects chromosomal abnormalities, anomalies at prenatal or post-natal MRI, or the clinical evaluation. On the other hand, animal models of Corpus Callosum Dysgenesis have shown reactive heterotopic connectivity [20]. This experimental model is in accord with the belief that resting-state functional brain networks supporting cognitive control are at least partially preserved in individuals with CCD [21]. In Neuroaxonal Dystrophy, palliative treatments (i.e., botulinum toxin injections) locally reduce spasticity and dystonia, relieve pain and momentarily facilitate rehabilitation and nursing [22]. It confirms the theoretical possibility to use complementary treatments in these diseases. On the other hand, we must consider that, in addition to genetic factors, chronic inflammation would play a proper role [23].

In chronic inflammation, Reactive Oxygen Species (ROS) are in balance with the antioxidant processes in the cell. When oxidative stress prevails, inflammation misses its protective role, and ROS overproduction may lead to an exaggerated inflammatory response. In this case, the release of neurotoxic factors causes the loss of neuronal structure and function, with motor and cognitive impairment [24,25]. Considering that, at least in part, chronic inflammation contributes to neurodegeneration, starting from current data from the literature; we hypothesized to support the conventional treatments in rare diseases employing a novel therapy based on the effects of LF-HI- PEMFs or Diamagnetic Therapy. As already explained, this technology exploits the repulsive behaviour of diamagnetic materials once exposed to a High-Intensity Magnetic Field and the therapeutic effects arise from the consequent molecular acceleration induced on diamagnetic substances like water ions and proteins [8]. Like the low-intensity Magnetic Fields applications, this technology offers the possibility to treat inflammation, including neuroinflammation, but in a more selective manner stimulating the proper functions of the various tissues. For this reason, a rationale to employ this non - invasive technology, at least in support of conventional treatments, exists and is sustained by incoming clinical experiences [8,26]. Our results (Table 2) show a functional improvement in muscle applications like in Limb-Girdle Muscular Dystrophy, with a significant reduction in the number of falls and better ability to maintain the bipedalism standing. One patient reported a decrease in upper limbs strength, even if the treatment interested the gluteal and lumbar region, but this could be due to a proper progression of the disease affecting the upper limb. A general improvement in spontaneous motor activities concerned three cases of Spastic Cerebral Palsy, including better reactivity in hand movements, the maintenance of cephalic control, the disappearance of primary reflexes, and better cognitive skills. Finally, a better reactivity to external stimuli and the ongoing activity of the hand resulted in Neuro Axonal Dystrophy, and improvement of spontaneous gesture involved a case of Corpus Callosum Dysgenesis. In the case of Glass Syndrome, the motor improvement was sufficient to allow the integrated treatment with the rehabilitative program. No side effects we observed in all the treated subjects.

We recognize the weakness of this study, having not a control group necessary to validate and enforce these results. Nevertheless, the impossibility of enrolling more subjects, the characteristics of the disease from a subjective and functional point of view, practical and ethical concerns justify this choice.

Conclusions

Diamagnetic therapy was demonstrated to be safe, improving several clinical aspects in rare diseases, mainly from the social point of view. We know that these diseases do not change easily but worsen over time. Nevertheless, we may consider that those, though limited improvements, can positively change the quality of life in such patients and their families. Further studies are needed to assess further improvements and integration with other treatments.

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