Pulsed Electromagnetic Field Therapy in Relation to Motor Conduction Velocity of the Neuropathic Common Peroneal Nerve Post Burn

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Abstract:

Background: Peripheral neuropathy is a well-documented and debilitating consequence of severe burn injuries. These lesions are linked to both thermal as well as electrical injuries. It is often not diagnosed or given enough attention in clinical settings. **Objective**: to assess the impact of Pulsed Electromagnetic Field Therapy (PEMFT) on the motor conduction velocity of the neuropathic common peroneal nerve after burn injuries throughout the post-hospitalization period. **Patients and methods**: A randomized controlled trial included forty patients; their percentage of total body surface area (TBSA) ranged from 20% to 30%. Their initial diagnosis was a 2nd or 3rd degree burn, and they were found to have peripheral mononeuropathy affecting the common peroneal nerve. The patients' ages ranged from 20 to 35, they were randomly assigned to one of two groups: one to receive conventional physical therapy and the other to receive PEMFT. Each group received 20 minutes of treatment daily for a total of three months. **Results**: - An improvement in MCV demonstrated that both PEMFT were substantially effective in enhancing nerve functioning. **Conclusion**: PEMFT demonstrated significant efficacy in enhancing nerve

functions, improving mobility, and enhancing physical capabilities of patients with burns, resulting in a rapid restoration of their ability to contribute to society.

Keywords: (Pulsed electromagnetic field therapy, Common peroneal nerve, Burn and Neuropathy).

1. Introduction:

Burned patients experience many issues as a result of the skin's natural protective activities being compromised, damage to the blood vessels and blood components, as well as intense metabolic stress causing abnormal capillary permeability, accumulation of protein-rich fluid outside the blood vessels, as well as reduced blood flow to the skin.

A burn injury can cause severe damage to the neuromuscular system. Patients frequently attribute weakness or lack of sensation to the overall effects of the burn damage along with the process of recovery. However, similar symptoms may be caused by peripheral neuropathies originating from either damaged nerve axons, myelin sheaths, or both. (1,3,10,13,15).

The burn wound will experience a delay in healing during all phases of the healing process due to the aforementioned burn complications and the resulting lymphatic injury. This will ultimately result in the development of contractures that influence the physical function of the burned patient.

Multiple mononeuropathy is a frequent occurrence following thermal injuries that affect more than 20% of the TBSA, with the number of nerves affected per patient ranging from 3 to 7. Burn-associated polyneuropathy (BAPN) is a prevalent complication of thermal injury. The electrophysiological manifestations of BAPN are evident in the first week following the burn, in both burned as well as unburned limbs. These manifestations were attributed to an inflammatory cascade that was induced by thermal injuries, resulting in changes in nerve function (1,3,10,15,18,21,25).

Peripheral neuropathy is the most common and debilitating neuromuscular consequence that occurs as a result of burns. However, burn neuropathy is frequently misdiagnosed or ignored due to its subtle and progressive onset. Our study aims to provide a comprehensive overview of existing research on burn-related peripheral neuropathy. Specifically, we will evaluate the prevalence, underlying mechanisms, diagnostic methods, as well as treatment options for peripheral neuropathy among burn patients (4).

Peripheral neuropathy is a well-documented and debilitating consequence of severe burn injuries. These lesions are linked to both thermal as well as electrical injuries. It is often not diagnosed or given enough attention in clinical settings. The prevalence of this condition varies significantly, ranging from 2% to 84% among patients, depending on the specific methodology employed in each study. Explaining the reason is challenging because of the complex metabolic nature of burn injury, the following administration of neurotoxic antibiotics, as well as the several iatrogenic factors that contribute to neuropathy (5).

The presentation of fibular neuropathy varies depending on the location of the lesion. Because of its anatomy, the nerve near the head of the fibula is vulnerable to damage from outside sources, especially because it is superficially located. Various processes can cause compression, acute damage, entrapment, or intrinsic nerve abnormalities of the fibular nerve. It is becoming more common to diagnose intraneural ganglion cysts when the underlying cause of neuropathy cannot be determined from the patient's medical history. Electrodiagnostic testing can help determine the exact location and nature of the pathological condition that is impacting the nerve (6).

Objectives:

To assess the impact of Pulsed Electromagnetic Field Therapy (PEMFT) on the motor conduction velocity of the neuropathic common peroneal nerve after burn injuries throughout the post-hospitalization period.

Materials and Methods:

This is a randomized controlled trial, conducted on a sample of forty patients, consisting of 30 males and 10 females, with ages ranging from twenty to thirty-five years recruited by convenience sampling technic. The patients were recruited from the out-clinics of Kasr-El-Aini (Cairo University hospitals) as well as Om-Al-Misrieen hospital (Ministry of Health). Patients who were unfamiliar with the technique of PEMFT and experiencing burns in the chronic phase (after being discharged from the hospital), specifically affecting their lower limbs, with TBSA ranging from 20% to 30%. These burns were diagnosed as 2nd or 3rd degree and were complicated by peripheral mononeuropathy impacting the common peroneal nerve. Selected participants exhibited the level of cooperation essential to the investigator obtaining the necessary data and were free of any other pathological conditions with the exception of pre-existing and concurrent neuropathies. Participants were randomly allocated into two groups: an experimental group consisting of 20 patients who received PEMFT, as well as a control group consisting of 20 patients who received conventional physical therapy.

Sample size and sampling technic:

A representative sample of 40 participant, an intervention group containing 20 participants and a matched control group containing an equal number, by convenience sampling technic, Open Epi I program was used to calculate the suitable sample size, at confidence interval of 95% and power of 80%.The ability to detect a difference of at least 10% between the case and control groups was wanted; so, the minimum required number of participants in each group was 20 participants.

Instrumentation:

The measurement equipment and tools used in the current research were The Neuropack 2 MEB-7102K was used to objectively assess the MCV. The Neuropack 2 MEB-7102K is specifically engineered to function as a small and self-sufficient device. An advanced electrode junction box with isolation amplifiers along with an articulated arm are part of the main unit, which also includes a multi-purpose stimulator, a floppy disk drive, a high-resolution thermal array recorder, as well as high-performance 2-channel amplifiers. An optional cart with a shelf for a keyboard as well as a drawer for accessories is also available.

while the therapeutic equipment was the The JAMAVA® S Magneto therapeutic apparatus, a pulsed electromagnetic field therapy unit, has been manufactured under license from the Ministry of the Czech Republic as well as Ministry of Health of the Slovak Republic. It has also received approval from the State Institute of Drug Control in Prague, Czech Republic, the Electro Technical Testing Institute in Prague, Czech Republic, the Testing Institute of Medical Equipment LGA

Nürnberg in Germany, the State Institute of Drug Control in Bratislava, Slovak Republic, and the Electro Technical Testing Institute in Banska Bystrica, Slovak Republic [8,9,12,18].

Procedures:

Evaluation:

Measurement procedures: Protocol of the MCV measurement; Position of subject and electrodes: Upon arriving, the individual was instructed to lie on their back on a therapeutic platform (in the same posture as previously stated) for around 5 minutes to rest, relax, and become acquainted with the surroundings. The recording electrode was positioned directly above the central portion of the EDB muscle, which is situated in the front and side region of the proximal midtarsal area. The reference electrode was positioned at a distance from the small toe, whereas the ground electrode was positioned on the medial part of the foot. Stimulating electrodes: In the distal stimulation: The stimulating cathode was positioned 8 cm closer to the active recording electrode in order to establish a consistent distal latency segment. In the proximal stimulation: The stimulating cathode was positioned in the lateral region of the popliteal fossa, specifically located just medial to the biceps femoris tendon. The recording electrodes, together with the ground electrode, were wet with gel and securely affixed in position using adhesive plaster Experimental technique of the common peroneal nerve MCV measurement: The MCV recording technique was performed in a room with air conditioning. A thermometer was used to monitor the temperature of the room throughout the experiment. The thermostat of the air-conditioning system was adjusted to maintain a comfortable as well as a consistent temperature between 24 oC and 28 oC. This helped minimize any temperature differences along the nerve being tested. Additionally, the tested extremity was warmed by a deep stroking massage for 5 minutes. These measures ensured that any variability in the results due to temperature was eliminated [5,11,14,17].

The participants were instructed to lie down on their backs for approximately 5 minutes to receive a leg massage and to relax. This also allowed them to become familiar with the testing room environment. The EMG machine was turned on. Next, the EMG12 software program was loaded by inserting the EMG12 program disk. All necessary electrodes for the test were applied. The electrodes were connected to both the positive & negative input of the active channels of the EMG head-box, as well as the common electrode. After pressing any key once and the enter key twice on the alphanumeric keyboard, the program automatically shifted to the ready state for the neurography 1 motor NCV test, the impedance of the active channels' electrodes was verified to be less than 5 k Ohm. The information acquisition process commenced upon pressing the run key on the keyboard. The stimulus was gradually increased until the desired figure (trace) was reached. Subsequently, the stop key was pressed, and the cursor was moved to measure latency. The print key and the paper key, which advanced the paper, were also pressed. Throughout the recordings, a sensitivity of 1 mv/division was utilized, as well as the sweep speed was set at 3 ms. The stimulus intensity ranged from 0.1 to 99 mA, and supramaximal recording was achieved using these stimuli. The distances among the points of stimulation, marked by a marker pen placed midway among the two stimulating electrodes, were measured using a tape measure. The formula used to calculate NCV outlined below:

Conduction velocity =L1 - L2

Distance in (cm) ´ 10

Where: L1 = proximal latency and L2 = Distal latency10,11,12.

Data collection procedures: Prior to commencing the experiment, an initial measurement of the common peroneal nerve was conducted for each subject in both groups. This served as the first record. The second record was taken following 3 months of treatment. To minimize the impact of any variable that could potentially cause slight changes in the data, both tests were administered at approximately the same time of day [10,11,20,22].

- Treatment procedures:

Position of subject and the active surface of the PEMFT apparatus:

The individual was lying on their back, relaxed, with their hips somewhat flexed as well as rotated laterally. Their knees were also somewhat flexed (just 10 degrees), while their ankles were somewhat planter flexed. A pillow was placed under their head to make it comfortable for them. The PEMFT apparatus was placed on the outer edge of the popliteal fossa for a period of ten minutes, followed by another 10 minutes on the outer surface of the fibular head. Each treatment session lasted for a total of 20 minutes and was repeated daily for a duration of 3 months [(2,4,7,12)].

Data analysis:

Prior to commencing the experiment, an initial measurement of the MCV of the common peroneal nerve was taken for each individual in both groups. This was the first measurement. The second measurement was conducted following a period of 3 months of therapy. The collected data was entered into a computer for statistical analysis. Descriptive statistics, such as the mean, standard deviation, minimum, as well as maximum, have been determined for each group. A t-test was conducted to determine the mean difference between the two groups prior to and following the application, as well as within each group. A significance level of 0.05 was utilized as the alpha point,16.

Ethical considerations:

Approval from Research Ethics committee (REC) of Faculty of Physical Therapy, Cairo University was obtained before starting field work (Date: 31/08/2023).

Informed consents was obtained from all participants who accepted participation in the study after explaining for all candidates the steps of the study, the aim, the potential benefits and the potential risks and their right to withdraw from the study at any time without affecting the medical services they need.

All procedures were performed according to ethical regulations and guidelines.

Results:

As presented in table (1) in addition figure (1), the mean value of the Motor conduction velocity (MCV) changes in meter/second, in the experimental group (A) (PEMFT application group): was (32.7040 ± 2.0770) in meter/second , while after application of the PEMFTR group after 3 months of PEMFT treatment was (37.5500 ± 0.436). These findings revealed a highly substantial improvements in the mean value of the MCV ($P < 0.0001$). While in the Control group (Pre -the traditional physical therapy): was

(32.7030 ± 2.0110) in meter/second , but after 3 months application of the traditional physical therapy after 3 months was (32.7020 ± 2.0443). These findings revealed Non- substantial changes in the mean value of the MCV (P > 0.05).

Table (1): Comparison of the mean values of the Motor conduction velocity (MCV) changes in meter/second, in the experimental group (A) (PEMFT application) and the Control group (traditional physical therapy).

	Before treatment		After treatment		Mean difference	T.value	P.value
	Mean in degrees	± SD	Mean in degrees	± SD			
Experimental group (PEMFT)	32.7040	2.0770	37.5500	1.9805	-4.84600	-7.55	< 0.0001
Control group traditional physical therapy)	32.7030	2.0110	32.7020	2.0443	0.001000	0.00	0.999

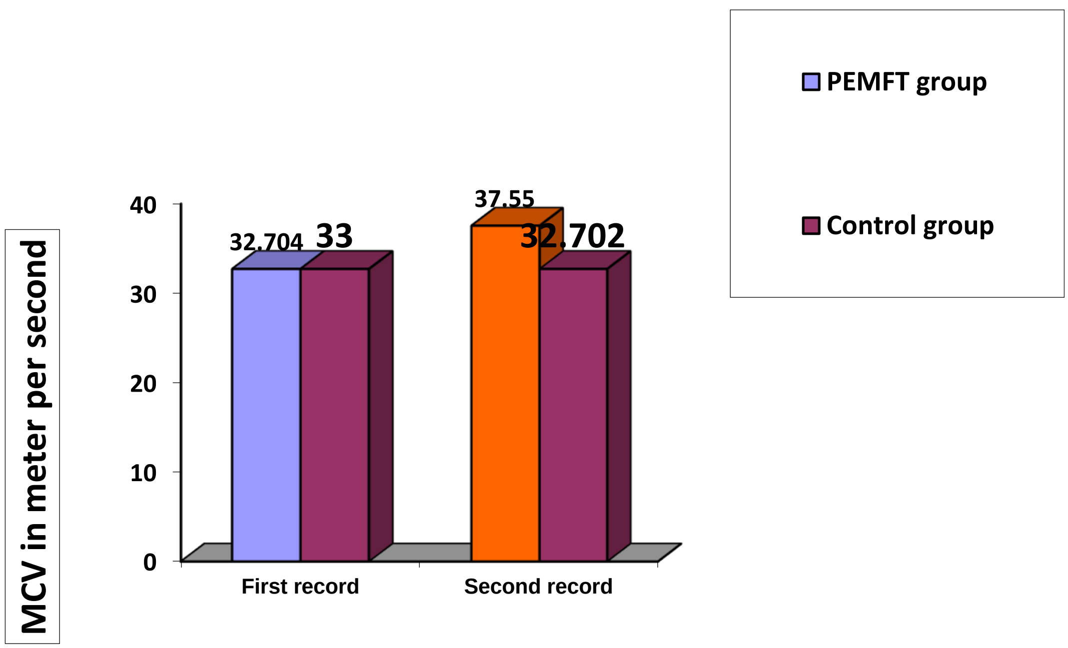

Fig (1): Mean values of the Motor conduction velocity (MCV) changes in meter/second of the two groups.

Discussion:

The period immediately following a burn is referred to as the EBB phase. During this phase, there is a decline in the flow of nutrients as well as oxygen to cells, resulting in a reduce in the basal metabolic rate (BMR). Following the EBB phase, there is a gradual boost in the metabolic rate, eventually reaching the normal BMR of 40 ± 10% C/M2/hr. This rise in metabolic rate can exceed the normal level, reaching up to twice or even two and a half times the normal value. This phase is referred to as the FLOW phase. The FLOW phase occurs as a result of a significant release of catecholamines from the adrenal medulla as well as the nerve endings of the sympathetic division of the ANS. This leads to widespread vasoconstriction, raised vascular resistance, and impaired peripheral circulation, affecting the skin, muscles, and nerves, ultimately resulting in changes in nerve function. Vascular burn complications in the peripheral body parts occur due to the dominant sympathetic tone as well as the presence of a circumferential third-degree burn. These complications result in reduced arterial blood flow caused by arterial compression. The combined effects of the dominant sympathetic tone as well as the circumferential third-degree burn can lead to ischemia and the manifestation of the "five P, S" symptoms: pain, pallor, pulselessness, paraesthesia, as well as paralysis [1,3,10,15].

Two probable mechanisms of injury during surgery include ischemic injury to tissue distal to the tourniquet and direct compression of underlying nerves caused by an elastic tourniquet used for an extended period of time to create a bloodless field. In the upper limb, the ulnar nerve as well as the superficial branch of the radial nerve which runs through the dorsum of the hand are particularly vulnerable to injury; in the lower limb, the tibial nerve as well as the common peroneal nerve near the fibular head are particularly vulnerable.

Neural tissue exhibits a significantly low electrical resistance and is highly vulnerable to damage in cases of electrical burns. This damage occurs due to the direct impact of the electric current on the nerve and its surrounding tissues, as well as the enlargement of the affected muscle compartment. Proper positioning as well as splinting of a patient's limbs are crucial to avoid deformities. However, it is important to be cautious as improper positioning as well as splinting can result in nerve injuries. Specifically, three areas require careful management to avoid nerve injuries: the shoulder for brachial plexus injuries, the elbow for ulnar nerve lesions, as well as the knee for tibial nerve in addition common peroneal nerve lesions.

The dorsiflexors of the foot as well as toes are supplied by the peroneal nerve with its branches, which also convey sensory fibers from the lateral aspect of the lower leg along with the dorsum of the foot. Medically, the compression of this nerve is identified by a sudden occurrence of foot drop that is occasionally accompanied by sensory dysfunction in the area of the superficial or deep peroneal nerve. The common peroneal nerve, also known as the lateral popliteal nerve, originates from the sciatic trunk within the popliteal fossa and branches off laterally. The composition comprises fibers originating from the L4, L5, and S1 nerve roots. Following its origin, the nerve quickly becomes visible as it wraps around the outer side of the head of the fibula. At this point, it enters the leg and releases a little recurrent nerve, which supplies the patella with sensation. Afterwards, it divides into the superficial as well as deep peroneal nerves.

The superficial peroneal nerve, also referred to as the musculocutaneous nerve, innervates the peroneus longus as well as brevis muscles, which are responsible for plantarflexion as well as eversion of the foot. Following its innervation of the peroneal muscles, the nerve branches out into the medial as well as intermediate dorsal cutaneous nerves as it descends. Capillaries in both unburned and wounded tissue exhibit aberrant permeability in burns above 25 % of the body. Plasma leaks into the interstitial space, leading to the development of edema.

Fluid resuscitation necessary to counteract acute burn shock leads to an increase in edema. When skin loses its collagen and elastic fibers, it becomes less pliable and unable to stretch to absorb pressure. This can lead to a tourniquet effect, which in turn can engulf peripheral nerves as well as the soft tissue beneath and beyond the burn, as well as compress the neuro vascular bundles, causing progressive ischemia (14,17,18,19).

The diagnosis of peripheral neuropathies is aided by nerve conduction studies (NCS) and EMG. Nerve conduction testing evaluates the speed that a nerve conducts an electrical impulse along its axon. While EMG, evaluates the integrity of a motor unit & allows localization of lesions. Pathological findings usually are related to axonal failure, damage to myelin, a combination of both and pathologies in motor units. Sequential electrophysiological testing can monitor reinnervation and recovery of a motor unit. NCV is calculated by dividing distance by time. Distance is measured in millimeters between the two stimulation sites and divided by the difference in conduction time in milliseconds among the distal stimulation site & the proximal stimulation site. Electrophysiological testing is helpful in identifying the type and severity of nerve injuries; however, enough time must be allowed for the abnormalities to manifest themselves. Immediately after complete transection of a nerve, no motor unit activity exists with voluntary contraction; however the distal portion of the nerve remains electrically excitable for 3 to 5 days, subsequently, the nerve becomes unexcitable & conduction ceases. The motor end plate maintains its whole excitability for a period of 5 to 10 days.

Therefore, the electrodiagnostic studies must be delayed a minimum of 14 days [5,6,9,14].

Pulsed Signal Therapy, a distinct variant of PEMFT, has been accessible for clinical application and scientific investigation for over a decade. Nevertheless, the investigation into the impact of electrical stimulation on bone commenced as early as the 1960s. This discovery led to the establishment of Pulsed Electromagnetic Field stimulation of non-union, which is now a common procedure in many clinics worldwide.

The early study on Pulsed Electromagnetic Fields is comprehensively documented in the book "The Body Electric" by Robert et al., published in 1985. This book extensively discusses the physiological studies that supports the use of electrical stimulation for bone stimulation. Andrew Bassett was a pioneering individual who transitioned the technology of electrical stimulation to the electromagnetic form. Over the past four decades, pulsed electromagnetic fields have been utilized as therapeutic agents due to strong evidence demonstrating their ability to promote bone growth through electric currents. Since it was shown that applying physical stress to bones caused them to generate tiny electric currents that are associated with bone growth, electromagnetic-field stimulation gained the credibility as a treatment. Electrical stimulation of chondrocytes has been found to stimulate the production of proteoglycans, the main constituent of cartilage matrix [2,7, 19].

The results of the current study indicate a substantial and statistically significant improvement in the mean MCV values in the study group (PEMFT application) compared to the control group (the conventional physical therapy application) (P< 0.0001).

The results of the study demonstrated a substantial and statistically significant improvement in the mean values of the second MCV record (following 3 months of PEMFT administration) compared to the first MCV record (prior to PEMFT application) (P< 0.0001).

The findings of this study indicate that there were no significant changes in the means of the second record MCV (2) (following 3 months of conventional physical therapy application) compared to the first record MCV (1) (prior to the conventional physical therapy application) (P > 0.05).

The findings of this study confirm the hypothesis that the use of PEMFT had a beneficial impact on the neuropathic common peroneal nerve following a burn injury, as indicated by the substantial improvement in the MCV of the common peroneal nerve.

Conclusions:

The application of PEMFT had a beneficial impact on the neuropathic common peroneal nerve following a burn, as demonstrated by the considerable and significantly higher improvements in the MCV of the common peroneal nerve.

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