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PULSED MAGNETIC FIELD VERSUS SURGERY IN CARPAL TUNNEL SYNDROME: A RANDOMIZED, PLACEBO CONTROLLED DOUBLE BLIND STUDY

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Abstract: This study investigated the efficacy of pulsed magnetic field therapy (PMFT) versus surgical intervention in case of mild and moderate carpal tunnel syndrome (CTS) in a randomized, placebo-controlled, double-blinded study. Forty five female patients diagnosed as mild to moderate CTS were included in the study. Their ages were 35:55 years with mean age 41 ± 2.5 years. Patients were divided randomly into three equal groups, placebo group received sham exposure, and group II received PEMT at frequency of 50 Hz, and the III group received surgical interference. The outcome measurements were median nerve sensory distal latency (SDL), motor distal latency (MDL) and Boston carpal tunnel questionnaire (BCTQ). Measurements were carried out at baseline and three months later. Paired analysis for comparison between pre and post treatment measurements in each group showed significant decrease of SDL, MDL and BCTQ scores of both magnetic and surgery groups. In other hand there were non-significant increases of any variable in the placebo group. Despite the equal baseline of all groups before treatment, there were significant decrease of all measurements of both magnetic and surgical groups than placebo group and significant decrease of all measurements of magnetic group than surgical group. The results suggested that PEMT might be beneficial in improving median nerve electrophysiological function and improving hand functional abilities.

Keywords: magnetic therapy, carpal tunnel syndrome.

Introduction

Carpal tunnel syndrome, the most common focal peripheral neuropathy,results from compression of the median nerve at the wrist. (Sternbach, 1999) The syndrome affects an estimated percent of adult Americans and is approximately three times more common in women than in men. (Atroshi et al, 1999)

The classic symptoms of carpal tunnel syndrome are pain, numbness, and tingling in the distribution of the median nerve (Figure 1), although numbness in all fingers may be a more common presentation. Symptoms are usually worse at night and can awaken patients from sleep. To relieve the symptoms, patients often “flick” their wrist as if shaking down a thermometer (flick sign). (Stevens et al, 1999)

In patients with carpal tunnel syndrome, pain and paraesthesia may radiate to the forearm, elbow, and shoulder. Decreased grip strength may result in loss of dexterity, and thenar muscle atrophy may develop if the syndrome is severe.

Although one hand typically has more severe symptoms, both hands often are affected. (von Schroeder and Botte, 1996)

Nonspecific flexor tenosynovitis is the most common cause of carpal tunnel syndrome. However, many conditions, including aberrant anatomy, infections, inflammatory diseases, and metabolic disorders, can cause or exacerbate the syndrome. (Stevens et al, 1992)

CTS is the most well-known and frequent form of median nerve entrapment (AAOS, 2007), and accounts for 90% of all entrapment neuropathies (Aroori and Spence, 2008). An entrapment neuropathy is a chronic focal compressive neuropathy caused by a pressure increase inside non-flexible anatomical structures (Lo et al, 2002). CTS is a neuropathy caused by entrapment of the median nerve at the level of the carpal tunnel,

delimitated by the carpal bones and by the transverse carpal ligament. (Atroshi, 1999) Physiological evidence indicates increased pressure within the carpal tunnel, and therefore decreased function of the median nerve at that level. (Stevens et al, 1999; Lo et al, 2002; Amirlak et al, 2010; Padua et al, 1997)

CTS is the most frequent entrapment neuropathy (Atroshi et al 1999; Uchiyama et al, 2010; Alfonso et al, 2010), believed to be present in 3.8% of the general population. (Atroshi et al, 1999) 1 in every 5 subjects who complains of symptoms such as pain, numbness and a tingling sensation in the hands is expected to have CTS based on clinical examination and electrophysio- logical testing (Stevens et al, 1999; von Schroeder and Botte, 1996), idiopathic CTS being the most common diagnosis in patients with these symptoms (Uchiyama et al, 2010)

In all western countries, an increase is reported in the number of work-related musculoskeletal disorders (WMSDs) caused by strain and repeated movements (biomechanical overload). In Europe, in 1998, over 60% of upper limb musculoskeletal disorders recognised as work-related were CTS cases. (Monograph…, 1996) Some industries such as fish processing have reported the prevalence of CTS in their workers to be as high as 73 %. (Kim et al, 2004)

NCS is considered to be the gold standard in the diagnosis of CTS because it is an objective test that provides information on the physiological health of the median nerve across the carpal tunnel. The standard method of diagnosis is comparing the latency and amplitude of a median nerve segment across the carpal tunnel to another nerve segment that does not go through the carpal tunnel, such as the radial or unlar nerve. The nerve is stimulated by a transcutaneous pulse of electricity, which induces an action potential in the nerve. (Werner and Andary, 2002; Salerno et al., 1998)

A recording electrode, placed either distally or proximally, detects the wave of depolarization as it passes by the surface electrode (Werner and Andary, 2002). It is more accurate to compare the median nerve response to another nerve segment that does not travel through the carpal tunnel, as opposed to using 'normal' values for the amplitude and latency of individual nerves. This is because there are many factors that may influence the amplitude and latency of an individual nerve, giving a false positive or false negative result. Such factors include age, gender, finger diameter, concurrent systemic disease, obesity and temperature (Salerno et al., 1998; Stetson et al, 1998; Sunderland, 1976). The use of a relative comparison of two nerve segments controls these factors. This is the most sensitive and accurate technique, with a sensitivity of 80-92% and specificity of 80-99% (Werner and Andary, 2002). The study of motor conduction velocity and of distal motor latency (DML) in the median and ulnar nerves in the same hand may provide additional data (Stetson et al, 1993; Sunderland, 1976).

The aims of NCS (Weerner and Andary, 2002; AAOS, 2007)

1. To confirm a focal damage to the median nerve inside the carpal tunnel .
2. To quantify the neurophysiological severity by using a scale .
3. To define the nerve pathophysiology: conduction block, demyelination or axonal degeneration .

Nerve Conduction Analysis (AAOS, 2007) and The electrophysiological classification (Werner and Andary, 2002), in agreement with the AAEM guidelines, follows the neurophysiological progression of CTS severity and includes the following classes:

Negative CTS: Normal findings on all tests (including comparative and segmental studies

Minimal CTS: Abnormal findings only on comparative or segmental tests.

Mild CTS: SCV slowed in the finger-wrist tract with normal DML.

Moderate CTS: SCV slowed in the finger-wrist tract with increased DML.

Severe CTS: Absence of sensory response in the finger-wrist tract with increased DML .

Extreme CTS: Absence of thenar motor response .

The treatment of CTS falls under two categories: conservative and surgical. Conservative treatment is generally offered to patients suffering from mild to moderate symptoms of CTS. Options of such treatment include oral and transvenous steroids, corticosteroids, vitamins B6 and B12. (Sato et al, 2005) nonsteroidal anti-inflammatory drug (NSAIDs), ultrasound, yoga, carpal bone mobilisation and the use of hand splints. (AAOS, 2007; Sato et al, 2005)

O'Connor et al., reported that patients experienced significant short term benefits with this method of treatment, but have concluded that their efficacy in the long term remains unclear. Other conservative treatment options such as magnet therapy, exercise or chiropractic treatment did not show any significant improvement in symptoms when compared to a placebo or control (O'Connor et al, 2003)

Surgical treatment of CTS is in the form of a carpal tunnel release (CTR); a procedure in which the transverse carpal ligament (TCL) is cut to increase the space in the carpal tunnel and hence reduce the interstitial pressure. Approximately 70- 90% of patients have good to excellent long-term outcomes following CTR. (Turner et al, 2010)

Surgical release of the carpal tunnel can be performed under local anaesthetic using either open or endoscopic techniques. The aim of surgery is to dissect the transverse carpal ligament to relieve compression on the nerve thereby alleviating symptoms. Open surgery involves a single longitudinal incision at the base of the palm whereas endoscopic surgery can be performed using either one or two smaller access incisions. (Turner et al, 2010; Scholten-Rob et al, 2007)

Success rates for surgery (as defined by overall improvement in symptoms at three months) range from 80% to 98%. (Scholten et al, 2007; Gerritsen et al, 2002; Brown et al, 1993) The rate of major complications (structural damage to nerves, arteries or tendons) for both surgical approaches is low (0.19% endoscopic, 0.49% open). (Scholten et al, 2007) Endoscopic surgery is associated with more transient nerve problems (neurapraxia, numbness, paraesthesia) than open surgery, which is associated with more wound problems (infection, hypertrophic scarring, scar tenderness). (Scholten et al, 2007; Gerritsen et al, 2002) The rate of repeat operations required does not differ significantly between the two approaches (OR 1.24, 95%CI: 0.50 to 3.07). (Scholten et al, 2007)

PEMFs have been used for many years. They reportedly are effective for treating nonunions, delayed unions, osteotomies avascular necrosis of the femoral head, bone grafts, and spinal fusion. (Cadossi et al, 1992; Mammi et al, 1993; Massari et al, 2007) Although the therapeutic properties of PEMFs are well known, the sequence of events by which electromagnetic stimulation can bring about its desirable effects on bone healing is not completely understood.

PEMFs modify some important physiologic parameters of cells, such as proliferation, transduction, transcription, synthesis, and secretion of growth factors. (Brighton et al, 2001; Aaron et al, 1999)

In many respects, magnetic field based therapy involves the delivery of a particular form of energy to the tissues. The application of energy to the tissues will result in a physiological change or stimulation, which can in turn be used to generate therapeutic effects. (Watson, 2008 and 2010)

Sutbeyaz et al (2006) evaluated the effect of PEMF based therapy on pain, movement and functional capacity for a patient group with cervical OA. The therapy was delivered via a mat which the patient used (laid on) for 30 minutes a session, 2 x daily for 3 weeks. The treatment group showed significant pain reduction whilst the placebo group did not. Similarly, there were significant changes in range of movement and functional capacity. The mat produced an EM field with a mean strength of 40μT delivered in a pulsed mode at a range of frequencies between 0.1 and 64Hz.

From all that have been reviewed, it is clear that we are in need to well-designed researches to clarify and establish the effects of PEMF versus surgical release in mild and moderate CTS. So the current randomized, placebo-controlled, double-blind study was conducted to determine the effect of PEMF versus surgical release in case of mild and moderate CTS.

Material and Methods

Subjects:

A total 45 female patients either right or left hands CTS were included in the study. Their ages were 35:55 years old with mean age 41 ± 2.5 year. All patients were diagnosed as mild and moderate CTS by clinical examination and electro diagnostic tests. Patients had been complaining for at least 6 months to one three years with fluctuating symptoms from summer to winter (aggravated in winter).they were referred by consultant orthopaedist. Subjects were enrolled if they had any neuropathic symptoms of numbness, tingling or burning pain in the territory of the median nerve at hand, positive tinel or phalen signs and supported by the presence of electro diagnostic finding including median nerve sensory distal latency (SDL) > 3.7 msec and motor distal latency (MDL) > 4.0 mesc (21).

The exclusion criteria were cervical radiculopathy, diabetic peripheral neuropathy, thoracic outlet syndrome and patients with other predisposing aetiology such as pregnancy.

Study design:

This study was randomized placebo-controlled, double-blind study.Patients were randomly assigned into 3 groups each containing 15 patients. (Placebo group I, magnetic group II, surgery group III).

Randomization was allocated using the numbered envelop method. 15 Subjects were choosing for surgical releases while other 30 subjects were divided randomly into group I and II, subjects were blinded about which group they were allocated.

Testing procedures:

Measurements included electro diagnostic studies and functional assessment. Measurements were conducted at the beginning of the study and after 3 months of cessation of either magnetic sessions or surgical release. Measurements were conducted by an assessor who was blinded about subject group allocation.

Electrodiagnostic testing:

Electrodiagnostic included median nerve sensory latency(SDL) and motor distal latency (MDL). All tests were conducted using EMG neuroscreen apparatus.

Before testing, for all patients several steps of preparation were conducted. Skin under both stimulating and recording electrode were cleaned with alcohol and conducting gel (20/20 type) was put under recording electrode. The room temperature was kept at 24°C.

For SDL orthodromic measurement, the recording electrode in the form of circled bar electrode was placed near proximal wrist crease at the volar aspect of the wrist, the stimulating electrode placed around the proximal and distal interphalangeal joints of digit of thump. The earth electrode was fastened on dorsum of the hand at wrist joint.

For measurement of MDL of the median nerve, two recording electrode were placed over the abductor policies brevis. Active recording electrode were placed halfway between 1st carpometacarpal joint and metacarpophalngeal joint of the thump while reference electrode were placed on the tip of the thump. The stimulating electrode was placed on the volar aspect of the wrist between tendons of the flexor carpi radialis and palmarislongus muscle. The ground electrode was fastened on the dorsum of the hand at wrist joint.

For testing procedures the sweep speed set at 50 msec, the sensitivity was 5000.0 μVand duration of the stimulus was 0.1 msec, apparatus was grounded for safety and accurate purposes, patient sited on wooden chair with arm rest for the testing hand. The intensity was increased until action potentials reached maximal amplitude and then latency was recorded.

Functional assessment

TheBoston carpal tunnel syndrome questionnaire (BCTQ) is a standardised, patient-based outcome measure of symptom severity and functional status in patients with carpal tunnel syndrome. The evidence base of the psychometric properties indicates that the BCTQ is a valid, reliable, responsive and acceptable instrument and should be included as a primary outcome measures in future CTS trials. (Leite, 2006)

The functional level of patients were determined using boston carpal tunnel syndrome questionnaire(BCTQ) which has been reported to be reliable and valid method of measuring progression of CTS state. (Leite, 2006) that patient answer questionnaire in beginning of intervention and after 3 months without looking in her initial answer.

The questionnaire included two scales, symptoms severity scale including 11 questions about neurogenic symptoms as pain severity and frequency, parathesia, numbness and weakness. The second part is the functional status scale including 8 items covers daily activities commonly affected by CTS.

The patient rated their symptoms on the scale of the 1 (mildest symptoms or no problems with activity) to 5 (sever symptoms or cannot perform the activities at all). Then the mean of the scores for each scale was calculated.

Treatment procedures

Each subject in surgical group were answer (BCTQ) in initial evaluation and after 3 months of surgical interference in addition to (SDL) and (MDL) were measured in beginning of evaluation and after 3 months of surgical interference.

Each subject in other two groups appear to be exposed to pulsed electromagnetic field while subjects in group I (placebo group) received sham exposure. PEMF exposure for group II was delivered using I-TECH medical division apparatus (made in Italy), the treatment regime consisted of 4 days/ week for 1 month. Subjects exposed to PEMF over the area of the median nerve at wrist and forearm with frequency 50 Hz, intensity 40 gauss and for duration of 1 hour.

Subjects in all groups were allowed to receive their oral analgesic in first 10 days only (diclofenac sodium and potassium 750mg twice daily as well as their routine medication of vitamin B6, B12 until the end of the treatment.

Data analysis was performed using (SPSS) FOR WINDOWS evaluation version 16.0, descriptive statistics in the form of mean, standard deviation and percentage of improvement of the SDL, MDL and score of BCTQ pre and post treatment were calculated.

Paired t test comparing pre and post measurements was performed for individual group. ANOVA test was performed for each variable comparing the three groups pre and post treatment. Post- hoc test was then used to determine the differences between each two group. Significance level was set at (0.05).

Results

Electrophysiological parameters

As shown in table 1 and 2 when comparing pre and post measurement using paired t test there were significant decrease of both SDL and MDL in both group II and group III while there no significant increase in group I (placebo group).The highest percent of improvement was recorded in magnetic group.

Table 1

Sensory distal latency in msec pre and post treatment for all three groups

	Placebo group I		PEMF group II		Surgery group III	
	pre	post	pre	post	pre	post
Mean	5.1	5	4.9	3.8	4.7	3.9
SD	0.07	0.32	0.91	0.60	0.33	0.62
Diff %	1.8 %		- 15.6%		-14.1 %	
T	1.43		7.7		7.1	
p	0.12		< 0.000*		< 0.000*	

SD: standard deviation, % diff: percentage of difference, * significant

Table 2

Motor distal latency in mesc pre and post treatment of all three groups.

	Placebo group I		PEMF group II		Surgery group III	
	pre	post	pre	post	pre	post
Mean	5.2	5.1	5.3	4.2	5.2	4.5
SD	0.43	0.76	0.61	0.50	0.63	0.58
Diff %	1.8 %		- 13.6%		-12.1 %	
T	1.43		9.1		8.9	
p	0.12		< 0.000*		0.001*	

SD: standard deviation, % diff: percentage of difference, * significant

For determining the difference among the the three groups in median nerve SDL and MDL, ANOVA test revealed that there is no significant difference pre-treatment but there were significant difference among three groups post treatments.(table 3).

ANOVA test results for comparing the three groups pre and post treatment.

	Pre		Post	
	F	P	F	P
SDL	1.3	0.2	13.2	< 0.000*
MDL	1.1	0.1	9.7	< 0.000*
BCTQ	0.5	0.8	10.6	< 0.000*

SDL: sensory distal latency, MDL: motor distal latency, BCTQ: Boston carpal tunnel syndrome questionnaire, * significant.

Table (4) represent the results of post hoc testfor comparison of the three groups post treatment,compared to placebo group there were significant improvement of SDL and MDL of magnetic group I than placebo ($P < 0.000$), also there is significant improvement of surgery group than placebo $P < 0.000$, and $p< 0.001$ respectively.

Also there was significant improvement of magnetic group II than surgery group III where P was < 0.000 for SDL and MDL

Table 4

Post hoc comparison of the tested parameters at post treatment

	SDL		**MDL**		**BCTQ**	
	t	p	t	p	t	P
Placebo Vs magnetic	8.2	< 0.000*	8.8	<0.000*	11.9	< 0.000*
Placebo Vs surgery	7.8	< 0.000*	8.7	0.001	3.4	0.003*
Magntic Vs surgery	8.0	<0.000*	8.5	< 0.000*	10.4	< 0.000*

Table 5

BCTQ: Boston carpal tunnel syndrome questionnaire pre and post treatment for the three groups:

	Placebo group I		PEMF group II		Surgery group III	
	pre	post	pre	post	pre	Post
Mean	5.5	5.9	5.4	2.9	5.1	3.0
SD	0.63	0. 6	0.61	0.70	0.73	0.58
Diff %	8.8 %		33.6%		30.1 %	
t	0.4		11.0		9.9	
p	0.91		< 0.000*		< 0.000*	

The results of the ANOVA test presented in table 3 showed there is no significant difference of pre-test groups scores of BCTQ among three groups (P = 0.5) but there was significant difference in post test scores among three groups (P<0.000).

The results of post hoc test shows that there is significant decrease in the scores of both magnetic group and surgery group and when comparing magnetic group with surgery group, there was significant decrease in BCTQ of magnetic group than surgery group P< 0.000

Discussion

CTS may result from numerous conditions, including inflammatory or non-inflammatory arthropathies, recent or remote wrist trauma or fractures, diabetes mellitus, obesity, hypothyroidism, pregnancy, and genetic factors.3 4 Risk for CTS strongly increases with age and among peri-menopausal females for unclear reasons. In the unusual instance that CTS is acutely, traumatically induced work-related activities may also cause or contribute to the development of CTS.

The current study was conducted to investigate the effectiveness of PEMF versus surgical interference in case of carpal tunnel syndrome in improvement of neural function of the median nerve and decrease functional disability result either from pain or thenar muscles wasting.

The results of current study demonstrated that PEMF improved median nerve functions and decrease pain, numbness and hand parathesia as well as improve functional use of affected hand. To explain this effect we have to make scoping of effect of PEMF on cells and microcirculation.

It would appear that the cell membrane is the primary target of the magnetic energy. The likely (proposed, most strongly supported and reasonably evidenced) pathway is that the magnetic field affects the signal transduction pathway, ion binding and ion transport. Ca ions are the strongest evidenced (as they are with ultrasound, laser, microcurrent and other therapies). Ca ++ binding to CaM (calmodulin) is modulated as a result of the applied energy.

Myosin light chain kinase (MYLK or MLCK) is an enzyme strongly associated with muscle activity, though its role is not confined to muscle biochemistry. Calmodulin activates this enzyme, so if the magnetic field effect increases Ca++ ion transport, resulting in a change of calmodulin activity, and thus an alteration of enzyme activity, a potential chain reaction linking therapy to biological effect can be recognised.(Watson, 2008 and 2010; Shen et al, 2010)

In non-muscle cells MLCK activation of myosin II is implicated in a wide range of cellular processes, including cell spreading, migration and cytokinesis, as well as cell type specific processes such as neurite outgrowth and platelet morphogenesis. Shen et al (2010) provide some useful insight with regards the role of MLCK outside the muscle contraction effects, relating to pathology, inflammation and microvascular flow. (Shen et al, 2010) There certainly appears to be a strong relationship between MLCK and microvascular

permeability. Whether this is relevant to therapeutic effects remains to be seen, but it is currently a strong contender. (Aziz et al., 1996)

On other hand Literature reviews comparing surgical and non-surgical treatment for CTS.A Cochrane review conducted in 2008 comparing surgical to non-surgical interventions for carpal tunnel treatment found that surgery was more effective than splinting at 3, 6 and 12 months in terms of clinical improvement of symptoms such as pain, paresthesia or improvement of hypoaesthesia or muscle weakness. (Scholten-Rob et al, 2007; Verdugo et al, 2008)

That appear to be contradict with our current study which may be explained Complications associated with CTS surgery include painful or hypertrophic scars; wound haematoma and infection; stiffness, swelling or discomfort of the wrist and reflex sympathetic dystrophy.

Two studies reported complication rates for both the surgical and non-surgical groups. However, one of these includes surgical complications in people in the splinting group who received surgery during follow up. In this study, high levels of complications were observed in both groups (57% in group allocated to surgery, 52% in non-surgical group). (Shi and MacDermid, 2011)

The authors noted large variation as some studies reported all complications while others only reported clinically important adverse events. Overall pooled results indicated that non-surgical treatment for CTS was associated with fewer complications than surgery. (Scholen-Rob et al, 2007; Verdugo et al, 2008)

The most common complications in the surgery group were skin irritation and haematoma; in the splinting group it was swelling of the wrist, hand and finger. In their discussion of the results, the authors concluded that given the treatment differential and potential for adverse effects and that conservative interventions benefitted a substantial proportion of patients, current practice of a trial of conservative management with surgical release for severe or persistent symptoms is supported by evidence. (Shi and MacDermid, 2011)

In the current study we used BCTQ to evaluate the patient progress regarding neurogenic symptoms and functional disability. Manyauthors consider BCTQ reliable and valid methods in dealing with CTS. (Leite et al, 2006)

Improvement appear in case of BCTQ as well as SDL and MDLin case of magnetic group than both placebo and surgical group may explained in basis of PEMF enhanced sub-cellular levels (including ion binding and molecular conformation at cell membrane level), with an ever increasing scale of effect through to whole organism (or 'organism wide') bio effects.

All those effects combined with the improvement of the neural functions which reflected on patient activities and showed in higher percent of score of BCTQ score.

Conclusion

The results of this controlled study demonstrate the efficacy of PEMF upon surgical interference in case of mild and moderate CTS which appear in enhancing median nerve function and decrease pain, numbness, parathesia as well as improve hand functional abilities, further long term studies to confirm the general efficacy of PEMF are recommended.

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