Original Article

Effects of Neuromobilization Maneuver on Clinical and Electrophysiological Measures of Patients with Carpal Tunnel Syndrome

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Abstract. [Purpose] The aim of this study was to investigate the efficacy of neuromobilization combined with routine physiotherapy in patients with carpal tunnel syndrome through subjective, physical, and electrophysiological studies. [Subjects and Methods] Twenty patients with carpal tunnel syndrome (totally 32 hands) were assigned two groups: treatment and control groups. In both groups, patients received the routine physiotherapy. In addition to the routine physiotherapy, patients in the treatment group received neuromobilization. The symptoms severity scale, visual analogue scale, functional status scale, Phalen's sign, median nerve tension test, and median nerve distal sensory and motor latency were assessed. [Results] There were significant improvements in the symptoms severity scale, visual analogue scale, median nerve tension test, and Phalen's sign in both groups. However, the functional status scale and median nerve distal motor latency were significantly improved only in the treatment group. [Conclusion] Neuromobilization in combination with routine physiotherapy improves some clinical findings more effectively than routine physiotherapy. Therefore, this combination can be used as an alternative effective non-invasive treatment for patients with carpal tunnel syndrome.
Key words: Carpal tunnel syndrome, Neuromobilization, Electrophysiological measures

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INTRODUCTION

Carpal tunnel syndrome (CTS) is the most well-known entrapment neuropathy in the upper extremity. In CTS the median nerve is compressed in the wrist[1)]. It is characterized by pain, tingling, numbness, and motor weakness distal to the wrist in severe CTS, particularly in the first three digits, which is enhanced at night[1–4)]. CTS is more commonly found in individuals who perform repetitive hand activities[2)]. Furthermore, the sensory symptoms often appear in prolonged activities of the finger and wrist flexor muscles. Patients with CTS rarely complain of actual weakness of the affected hand[3, 4)]. The evaluation of CTS is mainly based on the clinical findings, i.e., those of subjective and physical examination, and electrophysiological studies[3, 4)].

According to the high prevalence and medical cost of treating patients with CTS[5)], its diagnosis and timely treatment are very important both for physicians and patients. Often, a non-invasive treatment protocol including medica-

tion, modifications to occupation and activities of daily living, rest splint, and physiotherapy are recommended for patients with mild to moderate CTS[6)]. Some efficacy has been reported of CTS treatments using physiotherapy modalities such as low power laser therapy, transcutaneous electrical nerve stimulation (TENS), therapeutic ultrasound, rest splint, etc[6–10)]. Some findings in CTS pathophysiology, including reduced gliding and motion of the median nerve in the carpal tunnel, abnormal strain on the median nerve during upper extremity movements, and possible peripheral adhesion of the median nerve or even fibrosis of intranerve connective tissue, have provided new insights into how CTS can be effectively treated[11, 12)]. It has been observed that the median nerve glides longitudinally during upper extremity movements[13–15)]. However, in entrapment neuropathies, e.g. CTS, the longitudinal gliding of the nerve is partially limited[16, 17)]. In addition, adhesion, fibrosis and possible scar tissue, namely nerve pathophysiological problems, may cause difficulty for peripheral nerve adaptation in certain postures and movements. This, in turn, may lead to limitation of nerve trunk motions relative to surrounding compartments as well as a reduction in the normal gliding of nerve fibers and fascicles relative to each other and connective tissues[12, 18)].

It seems that the immobilization of the wrist with a splint, or physiotherapy modalities in order to reduce pain,

swelling, and inflammation are of important modalities of CTS treatment. However, they are unlikely to restore the normal function of the median nerve[11].

Neuromobilization maneuver has recently been used to treat nerve entrapment syndromes. It consists of a series of therapeutic active and passive movements aimed at restoring the normal mechanical properties of the nerve in common postures and during extremity movements[11, 12, 19]. Among the studies of non-invasive CTS treatment, only a limited number have used neuromobilization maneuvers to relieve the symptoms of CTS, and these studies have reported contradictory results. Rozmaryn et al. reported the efficacy of tendon and nerve gliding exercises in the treatment of CTS[20]. However, Akalin et al., did not observe any significant difference in the splint vs. the combination of splint, tendon and nerve gliding exercise[21]. Therefore, there is no consensus on the efficacy of neuromobilization maneuvers in CTS.

Any pathology that reduces the nerve motion and normal strain may produce an abnormal tension in the corresponding nerve in common postures and during extremity movements[11]. The key point in the management of CTS is that the treatment protocol should consider all relevant structures surrounding the nerve[11]. Accordingly, a successful neuromobilization maneuver for treatment of CTS would consist of specific neuromobilization techniques, widening of the carpal tunnel, and flexor tendon gliding exercises, and these additional interventions might have been ignored by previous studies. Thus, taking this into account, it would appear that neuromobilization maneuvers help to restore longitudinal motion of the affected nerve[11, 12, 16, 19]. To the best of our knowledge, no previous study has considered neuromobilization maneuvers for the treatment of CTS with regard to basic principles: removing structural obstacles, i.e., widening the carpal tunnel and stretching the transverse carpal ligament; applying an oscillatory neuromobilization technique (not sustained) to the elbow joint (not to the wrist) with the median nerve relatively stretched;, and passively performing neuromobilization at wrist adhering to the basic use of neuromobilization, i.e., first performing neuromobilization more proximally from the wrist and then proximal to the wrist[5, 11, 12, 19]. Therefore, in the present study we investigating the efficacy of a neuromobilization maneuver combined with routine physiotherapy and compared the results with those of routine physiotherapy in patients with CTS through subjective, physical, and electrophysiological examinations.

SUBJECTS AND METHODS

In a randomized clinical trial, registered in IRCT with the number of 138903094052N1, 20 patients with mild to moderate CTS (totally 32 hands) ranging from of 18 to 65 years old were recruited. Diagnosis of CTS was confirmed by both clinical and electrophysiological findings. The latter included a median nerve distal motor latency > 4.4 ms and a median nerve distal sensory latency > 3.7 ms[22] prior to the intervention. Patients were excluded from the study if they met any of the following criteria: a positive compression test at the proximal area, systemic peripheral neuropathy, a history of carpal tunnel release, metabolic disorders such as diabetes or thyroid diseases, pregnancy, previous steroid injection into the carpal tunnel, or atrophy of the thenar muscle. The qualifying subjects were first informed of the study purpose and the protocol. Written, informed consent was then obtained from all of the subjects, and the protocol was approved by the Tabriz University of Medical Sciences Ethics Committee. Individual characteristics such as age, sex, weight, height, duration of disease, and history of any underlying diseases were recorded prior to the intervention.

Twenty patients (32 hands) were randomly assigned to the control group (n = 16 hands), which received routine physiotherapy including rest splint, TENS, and therapeutic ultrasound, or the treatment group (n = 16 hands), which received a neuromobilization maneuver in addition to the routine physiotherapy.

For the control group, a short cock-up splint was applied with the wrist in a neutral position (0°). The patients were instructed to wear the splints at night and during the day for a period of 4 weeks, as much as possible. TENS was administered for 20 min each session, 3 days a week at a frequency of 80 Hz, with a pulse duration of 60 μs, and at an intensity that produced a comfortable tingling sensation. Therapeutic ultrasound was administrated to the palmar carpal tunnel area for 5 min per session, 3 days a week at a frequency of 1 MHz, with an intensity of 1 W/cm^2, and a duty cycle of 20%.

In addition to the aforementioned routine physiotherapy, patients in the treatment group received the neuromobilization maneuver as described below.

Preliminary stage: transverse wrist extension mobilization was applied along with thumb extension and radial abduction (Fig. 1) and followed by finger flexor tendon gliding exercise. It was passively applied 3 times in each session, for 30 sec each time, 3 days a week. Patients receiving this maneuver were positioned so that there was no tension on the median nerve, i.e., head and neck placed in a neutral position and the affected arms positioned at the subjects' side. As the intervention progressed, the maneuver was applied in a position with increasing tension on the nerve.

Main stage: a neuromobilization maneuver including oscillatory elbow flexion-extension was carried out. In order to increase tension on the median nerve, the position of the arm-forearm-wrist-elbow was altered during the neuromobilization maneuver, depending on the patients (Fig. 2). The maneuver was applied 3 times in each session, with 15 repetitions of oscillatory elbow flexion-extension each time, 3 days a week.

The electrophysiological measurements and clinical examinations, consisting of the Boston questionnaire, Phalen's test, visual analogue scale (VAS), and median nerve tension test (MNTT), were carried out for all patients before and after the 4 weeks of the intervention program. The study was double blinded: the participants were not aware of the details of the intervention in the groups. Also the staff performing the electrophysiological measurements and analyzing the outcome measures were also blinded to the group allocations.

Fig. 1. Transverse wrist extension mobilization along with thumb extension and radial abduction

A commercially available EMG recorder (Medelec Synergy, Viasys 2005) was used for electrophysiological studies. Distal sensory latency (milliseconds; DSL) was measured in the standard way, in which the examined wrist was stimulated and the peak latency was recorded 14 cm away in the middle finger. Distal motor latency (milliseconds; DML) was measured from the wrist to the abductor pollicis brevis muscle. The environmental temperature was kept constant for all measurements. Electrophysiological measurements were performed by the same physiatrist for all patients.

The Boston questionnaire consists of a symptoms severity scale (SSS) and a functional status scale (FSS), and it was answered by the patients. SSS is evaluated by 11 questions concerning pain, tingling, night symptoms, numbness, and hand weakness and responses range from no symptoms (1 point) to symptoms too severe to perform activity (5 point). The average of these 11 scores was used to quantify the severity of patients' symptoms. FSS consists of 8 questions concerning functional activities and responses range from functional activities with less deficiency (1 point) to functional activities with high deficiency (5 point). The average of these 8 scores was used to quantify the patients' functional status. VAS was used to quantify the pain. Pain was rated from 0 to 10, which indicated no pain and maximum pain, respectively.

For Phalen's test, the patients' affected hand was passively flexed at the wrist and kept flexed for 60 seconds. Phalen's test is considered positive if patients report increased sensory symptoms in less than 60 seconds in the first three digits. Phalen's test was performed once for each patient. MNTT was also performed for the patients[11]. With the patients in the supine position and their elbows kept at 90° flexion, MNTT was carried out with consecutive motions as follows: 1) the shoulder girdle was slightly depressed downward, 2) the arm was abducted slightly more than 90°, 3) the forearm was fully supinated and the shoulder externally rotated, 4) the wrist and fingers were extended, and 5) the elbow was slowly extended (Fig 2). The test was stopped if the signs or symptoms of CTS (including pain, tingling, or numbness) appeared or increased in the thumb or the first three digits, and the elbow extension angle was then measured. MNTT was conducted three times, and the average measurement was used in the analysis. The tests were separated by a 2-min rest interval. When the first four stages had been completed, the elbow was moved through the range of extension, and the elbow extension angle was measured using a goniometer at the time of reproduction or increase in hand symptoms.

Fig. 2. Median nerve tension test (MNTT) for a representative subject: Shoulder depression (1), Shoulder abduction (2), Forearm supination and shoulder external rotation (3), wrist and finger extension (4), and elbow extension (5)

The mean, standard deviation, and percentage improvement in outcomes were calculated for all patients in the control and treatment groups. Statistical analysis was performed using Statistical Package for Social Sciences, version 17.0 (SPSS, Chicago, Illinois, USA). The data for each group were tested for the normal distribution with the Kolmogorov-Smirnov test. The outcome measures of each group before and after the intervention were compared within and between groups using the paired t-test and the independent t-test, respectively. The improvement in each outcome measure after the intervention was normalized to the corresponding value prior to the intervention and used to compare the outcomes between groups. The McNemar test was used to compare Phalen's sign before and after the intervention within and between groups. Significance was accepted for values of $p < 0.05$ in all analysis.

RESULTS

A total of 32 hands of 20 patients with CTS were studied. The patients had a mean (±SD) age of 46.7±11 years and duration of CTS symptoms of 19.6±15.9 months, and they all completed the 4-week intervention protocol. The outcome measure showed a normal distribution in both groups. The comparison of the mean values of the outcome measures between before and after the intervention in the control group showed that there were significant decreases in SSS, VAS, MNTT, and Phalen's sign ($p < 0.05$). However, there was no significant change in FSS, distal sensory latency, or

Table 1. Comparison of the means of subjective, physical, and electrophysiological measures between before and after the intervention and between the control and treatment groups

Outcome	Control		Treatment	
	Mean±SD (before)	Mean±SD (after)	Mean±SD (before)	Mean±SD (after)
SSS	2.28±0.9	1.7±0.72*	2.55±0.7	1.53±0.53*
FSS	2.12±0.7	1.92±0.67	2.64±0.6	1.76±0.43*
VAS	4.43±2.5	3.31±3.05*	5.56±1.9	2.68±1.62*
Phalen's sign (%)	75	31*	69	19*
MNTT (deg)	25.4±10.4	18.41±11.6*	31.1±11.6	9.04±9.6*
DSL (ms)	3.05±0.9	3.27±1.04	3.53±0.6	3.54±0.66
DML (ms)	5.08±1.5	4.63±1.15	5.14±1.2	4.81±1.08*

SSS, symptom severity scale; FSS, functional status scale; VAS, visual analogue scale; MNTT, median nerve tension test; DSL, distal sensory latency; DML, distal motor latency
* $p < 0.05$

Table 2. Percentage improvement in outcome measures of the control and treatment groups

Outcome	Control (%)	Treatment (%)
SSS	23	37
FSS	6	31*
VAS	23	45
Phalen's sign	58	72
MNTT	23	69*
DSL	−14	0
DML	6	6

SSS, symptom severity scale; FSS, functional status scale; VAS, visual analogue scale; MNTT, median nerve tension test; DSL, distal sensory latency; DML, distal motor latency
* $p < 0.05$

distal motor latency in the control group (Table 1, $p > 0.05$).

Except for the distal sensory latency ($p > 0.05$), significant improvements were found in all of the outcome measures after the intervention in the treatment group (Table 1, $p < 0.05$). Prior to the intervention, Phalen's sign was positive in 75% and 69% of the patients in the control and treatment groups, respectively.

The comparison of outcome measures between the two groups revealed that the percentage of improvement in MNTT ($p = 0.001$) and FSS ($p = 0.004$) in the treatment group was significantly greater than those of the control group. However, there was no significant difference between the two groups for the other outcome measures (Table 2, $p > 0.05$).

DISCUSSION

The present study revealed that both routine physiotherapy (rest splint, TENS, and therapeutic ultrasound) and neuromobilization maneuver in combination with the routine physiotherapy improved SSS, VAS, MNTT, and Phalen's sign in patients with CTS at the end of the 4-week intervention. The improvement in these outcomes may be attributable to the physiotherapy modalities having decreased pain and in inflammation or edema in the carpal tunnel. The effectiveness of physiotherapy modalities for pain relief and sensory symptoms in patients with CTS has been reported by some studies[7–9, 23, 24]. Previous studies have reported that splints keep the wrist in a low pressure position for the carpal tunnel, that TENS activates the gate control mechanism, and that therapeutic ultrasound decreases inflammation resulting in improvements in SSS, VAS, and Phalen's sign in patients with CTS[7, 8, 10, 23]. In the present study, improvement in MNTT may also be ascribed to the effect of physiotherapy modalities which have not been reported in the previous studies.

We did not observe any improvement in the hand functional status scale in the control group, possibly indicating that hand function is affected by several factors, such as sensory signs and symptoms (pain, tingling, and numbness), nerve tension and gliding capabilities, nerve conduction and muscular strengths.

Owing to differences in CTS severity, the number of the treatment sessions, and the duration of symptoms in patients with CTS, different results have been reported regarding the effects of physiotherapy modalities on electrophysiological parameters. In a study on CTS patients with 8 months duration of symptoms, who were treated with ultrasound in 20 sessions, there was significant improvements in median nerve distal sensory and motor latencies[7]. However, in another study of CTS patients with 48 months duration of symptoms, there were no significant improvements in electrophysiological measures after 10 sessions of therapeutic ultrasound[10]. The presence of abnormal electrophysiological findings may indicate that the underlying pathology causes pysiological and structural damages such as demyelination and axonic damage[18]. The control group in our present study demonstrated no significant improvement in electrophysiological parameters, suggesting that electrophysiological parameters might not be affected by physiotherapy modalities alone. It seems that other factors, not considered in the present study, such as age at CTS onset, duration of CTS, ergonomy, and occupation might influence the effectiveness of routine physiotherapy on electrophysiological parameters.

In addition to finding significant improvements in SSS, VAS, MNTT, and Phalen's sign in patients with CTS in the treatment group, this study also found significant improve-

ments in the FSS and distal motor latency, indicating that the neuromobilization maneuver improved hand function. A literature review of the effects of tendon and nerve gliding exercises for the treatment of CTS revealed that rest splint along with exercises involving gliding of the median nerve significantly improve Phalen's sign, grip, pinch, muscle strength, FSS, VAS, and SSS[21, 24]. In another study, intracarpal tunnel pressure was decreased after 1 minute of active hand and wrist exercises[25], which might in turn lead to an improvement in clinical findings due to regulation in venous return and distribution of edema in the nerve[26].

In the present study, contrary to the tendon and nerve gliding exercises described by Totten and Hunter[27], we used transverse wrist extension mobilization along with thumb extension and radial abduction, followed by finger flexor tendons gliding, and then by oscillatory elbow flexion-extension. The possible mechanism behind the effectiveness of the neuromobilization maneuver on CTS symptoms might be associated with decreases in intracarpal tunnel pressure and intra- and extra-median nerve edema, improvement in axoplasmic circulation, and release of nerve adhesion[11, 12, 24, 26].

The significant reductions in MNTT and FSS in the treatment group, compared with the control group (Table 2), suggest that adaptation mechanisms occurred in the patients who received the neuromobilization maneuver, as they could place the affected limb in the median nerve stretched position without any symptoms at the end of the 4-week intervention. The reduction in MNTT and FSS may also be associated with a decrease in median nerve tension during movements and upper limb activities. We expected to observe a great decrease in median nerve tension after the neuromobilization maneuver intervention, because the stretched position of the median nerve in each session formed the basis for performing the neuromobilization maneuver. This newly formed position might have had an adaptation effect on the patients, resulting in an improvement in hand function.

It needs to be pointed out that although SSS, VAS, and Phalen's sign were not significantly different between the two study groups, their improvement percentages were higher in the treatment group than in the control group. Furthermore, these improvements may be sustained for a long period of time by the patients who received the neuromobilization maneuver compared with the routine physiotherapy[20]. However, this could not be verified in the present study because we did not perform a follow up.

There are several limitations of this study that should be considered in future studies. First, we used two CTS hands in patients with bilateral CTS due to the limited number of participants enrolled in our study. In other words, we recommend investigating only one hand in each CTS patient. Second, we did not follow up the patients to monitor the consistency of the treatment effects. Further research is needed to study the systemic effects of the neuromobilization maneuver on different aspects of CTS considering the above mentioned limitations, including greater numbers of patients, and a wider range of CTS severity based on the electrophysiological measurements.

In conclusion, routine physiotherapy including rest splint, TENS, and therapeutic ultrasound seems to improve the symptom severity scale, visual analogue scale, median nerve tension test, and Phalen's sign in patients with CTS. On the other hand, the neuromobilization maneuver in combination with routine physiotherapy improved the functional status scale and the median nerve distal motor latency. Therefore, this combination can be used as an effective non-invasive treatment for patients with CTS.

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