Journal of Medicine in Scientific Research

Volume 4 | Issue 3 Article 5

Subject Area: Rheumatology

Comparison between the effect of single-dose radial extracorporeal shock wave and local corticosteroid injection in treatment of patients with carpal tunnel syndrome

Abeer H. Ismaiel
Ahmed Maher Teaching Hospital

Lamis S. Ahmed
Ahmed Maher Teaching Hospital, lamissafwat25@gmail.com

Nahed H. Taha
Ahmed Maher Teaching Hospital

Recommended Citation

Ismaiel, Abeer H.; Ahmed, Lamis S.; and Taha, Nahed H. (2021) "Comparison between the effect of single-dose radial extracorporeal shock wave and local corticosteroid injection in treatment of patients with carpal tunnel syndrome," *Journal of Medicine in Scientific Research*: Vol. 4: Iss. 3, Article 5.
DOI: https://doi.org/10.4103/jmisr.jmisr_1_21

Comparison between the effect of single-dose radial extracorporeal shock wave and local corticosteroid injection in treatment of patients with carpal tunnel syndrome

Lamis S. Ahmed[b], Abeer H. Ismaiel[a], Nahed H. Taha[c]

Departments of [a]Physical Medicine Rheumatology and Rehabilitation, [b]Departments of Physical Medicine Rheumatology & Rehabilitation, Ahmed Maher Teaching Hospital, [c]Department of Physiotherapy- Ahmed Maher Teaching Hospital Cairo, Egypt

Abstract

Objective

To evaluate the efficacy of radial extracorporeal shock wave therapy (rESWT) compared with local corticosteroid injection (LCsI) in reducing pain and improving the function of patients with mild and moderate carpal tunnel syndrome (CTS) over 6 months.

Patients and methods

We studied 40 patients with mild and moderate CTS, where 20 patients received single-dose rESWT and the second group was treated with LCsI. Both groups had been assessed at baseline and at 1, 3, and 6 months after treatment using Boston self-assessment questionnaire (BQ) and visual analog scale (VAS) and at baseline and after 3 months using neurophysiological studies. Our prospective study compared efficacy in relieving pain and improving clinical function between single-dose rESWT and LCsI over 6 months. We subdivided our patients into mild and moderate groups and comparing improvement in outcome variables after treatment with rESWT and LCsI.

Results

There was a significantly higher improvement in symptom severity scores, functional scores, and BQ scores and decrease in VAS at 3 and 6 months, with significant improvement in sensory nerve conduction parameters at 3 months in the rESWT group compared with the LCsI group. When compared with the baseline, there was a significant reduction of VAS and functional score, symptom severity scores, BQ scores at third and sixth months, and electrophysiologic parameters at third month in the rESWT group. The LCsI group had no statistically significant improvement in all outcome variables at sixth month. Moreover, there were highly positive significant correlations between peak sensory latency of median nerve and the clinical outcomes (VAS and BQ score) at the sixth month after rESWT and between motor latency of median nerve and BQ score in mild and moderate CTS groups.

Conclusion

Single-dose rESWT is a noninvasive and convenient method for treating mild and moderate CTS with long-term beneficial effect lasting up to 6 months compared with LCsI.

Keywords: Carpal tunnel syndrome, extracorporeal shock wave, steroid injection

Introduction

Carpal tunnel syndrome (CTS) is a clinical syndrome caused by compression of the median nerve at the wrist [1]. It is the most common entrapment neuropathy in adults. Previous studies have reported population prevalence estimates from 2.7 to 14.4%, with a higher incidence in females than males among the elderly [2].

Clinical features of CTS include nocturnal pain, numbness, and tingling sensation in the median nerve dermatome, and

Correspondence to: Lamis S. Ahmed, MD, Department of Physical Medicine Rheumatolog and Rehabilitation, Ahmed Maher Teaching Hospital, Cairo 12556, Egypt
Tel: 01010425137 E-mail: lamissafwat25@gmail.com

Access this article online

Quick Response Code:

Website: www.jmsr.eg.net

DOI: 10.4103/jmisr.jmisr_1_21

Submitted: 02-Jan-2021 **Revised:** 09-Jan-2021 **Accepted:** 13-Jan-2021 **Published:** 17-Sep-2021

How to cite this article: Ahmed LS, Ismaiel AH, Taha NH. Comparison between the effect of single-dose radial extracorporeal shock wave and local corticosteroid injection in treatment of patients with carpal tunnel syndrome. J Med Sci Res 2021;4:202-9.

the diagnosis is confirmed using electrodiagnostic studies [3]. Repetitive wrist movements, obesity, rheumatoid arthritis, diabetes mellitus, and menopause are known risk factors of CTS [4].

Among the variety of optional treatments for CTS, local corticosteroid injection (LCsI) is widely used in mild to moderate cases and achieves improved symptom scores within 1 week [5]. Other studies have reported greater symptom improvement 1 month after injection compared with placebo and significantly improved clinical outcomes compared with oral corticosteroids for up to 3 months. Other publications have shown that LCsI provides benefits in terms of pain reduction and functional scores in patients with CTS [6].

Recent studies demonstrated significant improvement in pain and symptom severity scores in patients with CTS using focused extracorporeal shock wave therapy (fESWT). At 3 months, however, symptom relief was not different from LCsI [7]. Several later studies have focused on the effect of radial extracorporeal shock wave therapy (rESWT), where patients with CTS receiving three sessions of rESWT and showed better clinical symptom improvement for 12–14 weeks compared with patients receiving sham ESWT [8].

rESWT can decrease inflammation of the carpal tunnel, reduce the perineural pressure, and can improve symptoms by stimulation of endothelial nitric oxide (NO) synthase in inflamed tissue, leading to NO accumulation, which subsequently decrease release of inflammatory mediators, so we suggest the use of a single-dose rESWT as a recent efficient modality for CTS. We compared the efficacy of that treatment with LCsI up to the mid-term mark (week 24) to reduce the period of time that a patient needs to repeat rESWT to improve patient compliance, which can affect the success of treatment.

Aim

Our work aim was to study the efficacy of a single-dose rESWT for CTS and to compare that treatment with LCsI treatment up to week 24.

Patients and methods

The study protocol was approved by the Ethnic Committee of GOTHI. It included 40 patients with nocturnal numbness and tingling on the hand or hands, being accepted as CTS, with age between 20 and 50 years, who were recruited from the rheumatology outpatient clinic of Al-Mataria Teaching Hospital.

Full medical history and clinical examination were done. All patients were divided into two groups: one group was treated with a single dose of radial extracorporeal shock therapy, and the second group was treated with local steroid injection. We compared the efficacy of the two methods of treatment for both groups regarding outcome variables, which are relieving pain, assessed by visual analog scale (VAS), improvement in clinical function evaluated by Boston questionnaire (BQ) [9], and electrodiagnostic parameters. Evaluations at baseline and at 4, 12, and 24 weeks after treatment were performed using BQ and VAS, and also the evaluation using neurophysiological study was done at baseline and Materia after 12 weeks.

Inclusion criteria

Individuals with age between 20 and 50 years showing nocturnal numbness and tingling of one hand or both hands were diagnosed clinically as having CTS and were included.

Exclusion criteria

The exclusion criteria for both groups of patients were as follows: patients with underlying metabolic disorders, such as diabetes mellitus; genetic disorders; upper limb surgery; peripheral polyneuropathy; traumatic nerve injury; blood coagulation disorder while using anticoagulants; pregnancy; thrombosis; cancer or previous surgical treatment for cancer; treatment with ultrasound, cryo-ultrasound, oral steroids or NSAIDs within 7 days before enrollment; or local injection of corticosteroid for CTS in the previous year were excluded. Patients with severe CTS diagnosed according to neurophysiologic examination criteria were excluded as well.

Radial extracorporeal shock wave therapy

A total of 20 patients with CTS received shock waves, of continuous frequency and intensity (4 Bar, 15 Hz frequency, 5000 shocks, BTL-6000 SWT, radial shock wave mode). The probe was oriented perpendicular to the patient's palm between the distal wrist crease and Kaplan's cardinal line; ultrasound gel was used as a coupling agent. The duration of treatment was 5–8 min. A cold pack was applied for 15 min after rESWT [10].

Local corticosteroid injection

We used 1 ml of triamcinolone 10 mg mixed with 1 ml of 1% lidocaine in a 3-ml disposable syringe. The injection was performed using a 25-G needle applied 1 cm proximal to the wrist flexion crease and 1 cm medial to the palmaris longus and flexor carpi radialis tendons. The angle of the needle was about 45° distally and was advanced 1 cm, where it penetrated the flexor retinaculum. We advanced 1 cm at a time until the solution was injected. After injection, we instructed the patient to use their hand freely without splinting. Each patient was injected only once.

Assessment of outcomes

(1) BQ, the most commonly used instrument to assess improvement of clinical symptoms and functional recovery of patients with CTS, consisted of 11 questions covering symptom severity and eight questions to evaluate functional status (functional score), which rate the level of difficulty to perform activities in daily life. The rating scale ranged from 1 to 5, with 5 being the most difficult.
(2) VAS was used to evaluate the intensity of pain at rest on a 10 cm scale. The patient marked the scale on which the start point represented no pain and the endpoint represented maximum or intolerable pain.
(3) Electrodiagnostic evaluation was done using Dantec key point, USA, for measuring median peak sensory

latency in millisecond (ms), distal motor latency in millisecond (ms), sensory nerve action potential (SNAP) amplitude in microvolt (μV), and compound muscle action potential (CMAP) amplitude in millivolt (mV), which were the parameters used in this study. The normal reference values are motor distal latency less than or equal to 4.2 ms, motor conduction velocity more than or equal to 49 m/s, and the motor amplitude more than or equal to 4 mV. Peak sensory latency is less than or equal to 3.2 ms, sensory conduction velocity more than or equal to 50 ms, and sensory amplitude more than or equal to 20 μV [11].

We specified classification of cases according to the proposed scheme of the American Association of Neuromuscular and Electrodiagnostic Medicine [12] as follows:

Mild CTS: prolonged (relative or absolute) sensory latency or mixed nerve action potential distal latency (orthodromic, antidromic, or palmar)±SNAP amplitude below the lower limit of normal.

Moderate CTS: abnormal median sensory latencies as above and (relative or absolute) prolongation of median motor distal latency.

Severe CTS: prolonged median motor and sensory distal latencies, with either an absent SNAP or mixed nerve action potential, or low amplitude or absent thenar CMAP. Needle examination often reveals fibrillations, reduced recruitment, and motor unit potential changes (to be excluded in our study).

Statistical analysis

All tabulated data were expressed as mean ± SD. Comparisons between patients and control groups were done by using the Student *t* test. For all statistical tests, significance was done using the correlation coefficient (*r*) test, in which significance is defined as level of probability, where *P* value less than 0.05 was considered significant. Computations were done using an SPSS statistical program, version 21 (SPSS Inc., Chicago, Illinois, USA) and graphs were assessed using Microsoft excel XP version.

Results

We studied 40 patients with CTS recruited from the rheumatology outpatient clinic of Al-Mataria Teaching Hospital. There were no statistically significant differences between the groups in terms of demographic characteristics (age, sex, height, and lesion site) or in clinical characteristics (baseline of pain, symptom and functional score, and severity determined by electrodiagnostic measurement) (Tables 1 and 2).

There was significant improvement in electrodiagnostic parameters including reduction in peak sensory distal latency, increased in amplitude on SNAP, and in sensory conduction velocity at month 3 in both groups compared with baseline. The improvement was highly significant in the rESWT group.

As we found a significant improvement in electrophysiologic parameters at month 3, we continued to assess the functional improvement using VAS and BQ 3 months later, and we found that there was a significant reduction of VAS and functional scores, symptom severity score, and BQ score in the rESWT group at not only 1 and 3 months but also at month 6 compared with baseline. Moreover, there was a significant change for the LCsI group at 1 and 3 months compared with baseline (Table 3).

There was a significant decrease in VAS, symptom severity score, functional score, and BQ score at week 24, with significant improvement in sensory nerve conduction parameters at week 12 in the rESWT group compared with the LCsI group (Table 4).

Our results showed significant improvement in both sensory neurophysiological parameters and in motor distal latency in patients with mild CTS treated with rESWT, whereas in patients with moderate CTS, there was significant improvement only in peak sensory latency. Patients with mild CTS treated with LCsI showed significant improvement in sensory nerve neurophysiologic parameters and distal motor latency, whereas in patients with moderate CTS, there was improvement in all

Table 1: Demographic data and severity of both groups

Data	rESWT group (*n*=20)	LCsI group (*n*=20)	*P*
Age (mean±SD)	51±6	49±8	>0.05
Sex [*n* (%)]			
Male	4 (20)	5 (25)	>0.05
Female	16 (80)	15 (75)	>0.05
Height	155±8	152±7	>0.05
Lesion site [*n* (%)]			
Unilateral	18 (90)	17 (85)	>0.05
Bilateral	2 (10)	3 (15)	>0.05
Severity [*n* (%)]			
Mild	11 (55)	10 (50)	>0.05
Moderate	9 (45)	10 (50)	>0.05

LCsI, local corticosteroid injection; rESWT, radial extracorporeal shock wave therapy.

Table 2: Comparison between both groups as regard pretreatment clinical and electrophysiological parameters

Parameters	rESWT group (mean±SD)	LCsI group (mean±SD)	*P*
VAS	4.46±1.09	4.48±1.2	0.95
Symptom severity score	21.25±6.5	22.0±6.4	0.90
Functional score	20.7±5.62	20.6±5.9	0.96
Boston questionnaire score	42.9±11.4	42.6±11.6	0.93
Peak sensory distal latency	3.8±0.38	3.7±0.44	0.6
SNAP amplitude	21.4±6.4	23.07±7.9	0.46
Sensory conduction velocity	44.8±1.2	43.5±9.3	0.33
Motor distal latency	4.5±0.5	4.4±0.7	0.21
CMAP amplitude	6.8±1.7	7.5±1.6	0.21
Motor conduction velocity	54.8±3.6	56.0±4.2	0.61

CMAP, compound muscle action potential; LCsI, local corticosteroid injection; rESWT, radial extracorporeal shock wave therapy; SNAP, sensory nerve action potential; VAS, visual analog scale.

Table 3: Comparison between pretreatment and posttreatment as regard outcomes variables and electrophysiologic parameters

Parameters	rESWT group (mean±SD)	*P*	LCsI group (mean±SD)	*P*
VAS baseline (months)	4.4±1		4.5±1.2	
1	2.24±0.5	0.007	2.1±0.8	0.00
3	2.3±0.6	0.001	3.2±0.8	0.01
6	2.27±0.6	0.00	4.08±0.7	0.23
Symptom severity score baseline (months)	22.2±6.5		22.0±6.3	
1	13.4±4.8	0.02	12.1±3.9	0.00
3	16.1±4.1	0.00	17.8±3.9	0.02
6	15.3±3.9	00.0	18.4±4.7	0.053
Functional score baseline (months)	20.7±5.6		20.6±5.9	
1	12.2±3.9	0.009	11.8±4.9	0.00
3	13.1±3.6	0.00	14.2±4.2	0.00
6	12.8±3.4	0.00	21.9±6.2	0.48
Boston questionnaire score baseline (months)	42.9±11.4		42.6±11.6	
1	25.4±7.6	0.00	23.9±8.2	0.00
3	28.8±6.3	0.00	31.9±6.9	0.01
6	27.9±5.5	0.00	37.3±4.9	0.14
Peak sensory distal latency baseline (months)	3.8±0.3		3.7±0.4.4	
3	3.0±0.19	0.00	3.2±0.14	0.002
SNAP amplitude baseline (months)	21.3±6.3		20.0±5.9	
3	28.6±4.2	0.002	24.6±6.1	0.03
Sensory conduction velocity baseline (months)	44.8±1.2		43.6±9.3	
3	49.1±4.2	0.002	51.5±6.8	0.004
Motor distal latency baseline (months)	4.5±0.5		4.4±0.8	
3	4.4±0.5	0.74	4.1±0.8	0.66
CMAP amplitude baseline (months)	6.8±1.8		7.6±1.7	
3	6.9±1.9	0.91	7.7±2.6	0.76
Motor conduction velocity baseline (months)	54.8±3.5		56.0±4.2	
3	56.0±3.3	0.28	57.3±4.6	0.37

CMAP, compound muscle action potential; LCsI, local corticosteroid injection; rESWT, radial extracorporeal shock wave therapy; SNAP, sensory nerve action potential; VAS, visual analog scale.

sensory and motor parameters but not statistically significant after 3 months of treatment (Table 5).

Our results showed significant relieving of pain assessed by VAS and improvement in clinical function assessed by BQ more in patients with mild than moderate CTS after 6 months of treatment with rESWT. However, there was no significant improvement in outcome variables in patients with mild and moderate CTS after 6 months of treatment with LCsI (Table 6).

In our study, we found that there were highly positive significant correlations between peak sensory latency of median nerve and clinical outcomes (VAS and BQ score) (r = 0.34 and r = 0.54, respectively; $P < 0.05$) after rESWT and between motor latency of median nerve and BQ score (r = 0.45 and r = 0.67, respectively; $P < 0.05$) in mild and moderate groups at sixth month.

Discussion

rESWT is a noninvasive technique that has been used for the treatment of several painful inflammatory soft tissue conditions including mild and moderate CTS, with an acceptable successful outcome [13]. It relieves the pain of peripheral nerve damage and enhances local arterial remodeling and cellular regeneration [14].

As inflammation leads to decrease in NO, the anti-inflammatory effect by shock therapy is by stimulation of endothelial NO synthase in inflamed tissue leading to NO accumulation, which modulates NF kappa B activation, which in turn may prevent lipopolysaccharide/interferon-gamma-elicited induction of the inflammatory process. Decreased inflammation of the carpal tunnel can reduce the perineural pressure and can improve symptoms [15].

In this study, we found the improvement in clinical symptoms and functional outcomes after a single dose rESWT session of higher frequency and longer duration compared with other previous studies, which achieved similar results but after obtaining multiple rESWT sessions per week, lasting for around 3–4 weeks, which will affect patients' compliance regarding the treatment [16].

The evaluation of the efficacy of a single-dose rESWT was done in the absence of other treatment modality and lasted for 6 months. However, in most previous studies, follow-up was carried out in a period limited to 3 months only, and the

Table 4: Comparison between both groups after 1, 3, and 6 months of treatment as regard outcome variables and electrophysiological assessment parameters

Parameters	rESWT group (mean±SD)	LCsI group (mean±SD)	*P*
VAS 1 month	2.24±0.54	2.17±0.8	0.75
3 months	3.2±0.58	3.2±0.8	0.64
6 months	2.27±0.6	4.08±0.7	0.00
Symptom severity score 1 month	13.45±4.8	12.1±3.9	0.34
3 months	16.0±4.06	17.8±3.9	0.16
6 months	15.3±3.9	18.4±4.7	0.028
Functional score 1 month	12.0±3.9	11.35±4.5	0.63
3 months	13.0±3.6	14.15±4.2	0.36
6 months	12.8±3.4	21.9±6.1	0.00
Boston questionnaire score 1 month	25.45±7.6	23.45±7.7	0.41
3 months	28.8±6.3	31.9±6.9	0.15
6 months	27.9±5.5	37.8±7.9	0.00
Peak sensory distal latency 3 months	3.09±0.19	3.2±0.14	0.02
SNAP amplitude 3 months	28.6±4.2	24.6±6.1	0.02
Sensory conduction velocity 3 months	49.1±4.2	51.4±6.8	0.001
Motor distal latency 3 months	4.4±0.5	4.1±0.8	1.84
CMAP amplitude 3 months	6.9±1.91	7.7±2.6	0.24
Motor conduction velocity 3 months	56.0±3.3	57.2±4.5	0.33

CMAP, compound muscle action potential; LCsI, local corticosteroid injection; rESWT, radial extracorporeal shock wave therapy; SNAP, sensory nerve action potential; VAS, visual analog scale.

Table 5: Comparison between effect of pretreatment and posttreatment with radial extracorporeal shock wave therapy and local corticosteroid injection (after 3 months of treatment) on neurophysiological parameters in patients with mild and moderate carpal tunnel syndrome

Neurophysiological parameters	rESWT group		Mean±SD	*P*	LCsI group		Mean±SD	*P*
Peak sensory distal latency	Mild	Pre	3.4±0.2		Mild	Pre	3.4±0.14	
		Post	3.1±0.1	0.00		Post	3.1±0.13	0.04
	Moderate	Pre	4.1±0.3		Moderate	Pre	4.2±0.5	
		Post	3.1±0.1	0.00		Post	3.3±0.9	0.03
SNAP amplitude	Mild	Pre	24.2±4.3		Mild	Pre	25.3±5.1	
		Post	33.1±5.2	0.00		Post	33.5±13.9	0.04
	Moderate	Pre	22.5±5.4		Moderate	Pre	22.7±5.1	
		Post	24.7±4.1	0.4		Post	24.4±5.6	0.42
Sensory conduction velocity	Mild	Pre	49.5±4.3		Mild	Pre	47.8±6.0	
		Post	54.0±4.5	0.02		Post	54.6±4.3	0.02
	Moderate	Pre	45.7±6.0		Moderate	Pre	33.7±8.2	
		Post	49.0±4.3	0.26		Post	44.1±5.8	0.3
Motor distal latency	Mild	Pre	4.0±0.2		Mild	Pre	4.0±0.2	
		Post	3.5±0.22	0.01		Post	3.5±0.2	00.0
	Moderate	Pre	5.05±0.5		Moderate	Pre	5.3±0.3	
		Post	4.95±0.5	0.72		Post	5.1±0.7	0.3
CMAP amplitude	Mild	Pre	7.5±0.2		Mild	Pre	8.4±1.1	
		Post	9.7±1.8	0.01		Post	9.2±1.7	0.15
	Moderate	Pre	5.7±1.8		Moderate	Pre	4.4±0.4	
		Post	5.9±1.7	0.8		Post	4.6±0.5	0.6
Motor conduction velocity	Mild	Pre	51.0±3.3		Mild	Pre	55.7±3.6	
		Post	57.4±4.3	0.00		Post	57.4±4.2	0.24
	Moderate	Pre	53.1±1.1		Moderate	Pre	54.8±3.4	
		Post	54.1±2.9	0.4		Post	56.86±2.1	0.13

CMAP, compound muscle action potential; rESWT, radial extracorporeal shock wave therapy; LCsI, local corticosteroid injection; SNAP, sensory nerve action potential.

improvement was evaluated after using other concomitant treatment methods [17].

The pain relief benefit and the improvement outcomes of rESWT in this study, appeared at the first month, and lasted

Table 6: Comparison between effect of pretreatment and posttreatment with radial extracorporeal shock wave therapy and local corticosteroid injection (after 6 months) on outcome variables in patients with mild and moderate carpal tunnel syndrome

Outcome variables	rESWT group		Mean±SD	*P*	LCsI group		Mean±SD	*P*
VAS	Mild	Pre	2.9±0.6		Mild	Pre	2.9±0.6	
		Post	2.2±0.5	0.00		Post	2.7±0.6	0.4
	Moderate	Pre	3.9±0.5		Moderate	Pre	3.9±0.8	
		Post	3.4±0.5	0.04		Post	3.5±0.3	0.15
Symptom severity score	Mild	Pre	19.1±4.6		Mild	Pre	16.9±4.4	
		Post	10.5±4.3	0.00		Post	15.2±3.0	0.32
	Moderate	Pre	22.5±3.2		Moderate	Pre	19.1±0.7	
		Post	18.4±3.5	0.02		Post	18.5±0.8	0.09
Functional score	Mild	Pre	17.1±4.3		Mild	Pre	18.9±4.3	
		Post	13.7±3.8	0.00		Post	16.2±4.7	0.2
	Moderate	Pre	22.5±5.3		Moderate	Pre	13.9±4.3	
		Post	12.4±3.3	0.00		Post	11.2±4.7	0.19
Boston questionnaire score	Mild	Pre	36.2±8.9		Mild	Pre	35.8±8.7	
		Post	24.2±8.1	0.00		Post	31.4±7.7	0.24
	Moderate	Pre	45.0±8.5		Moderate	Pre	33.0±5.0	
		Post	29.8±8.6	0.00		Post	29.7±4.5	0.13

CMAP, compound muscle action potential; rESWT, radial extracorporeal shock wave therapy; LCsI, local corticosteroid injection; SNAP, sensory nerve action potential; VAS, visual analog scale.

for 6 months compared with baseline, whereas in LCsI, pain reduction was observed for the first 3 months. However, disappeared gradually till no pain reduction by the sixth month. Similar results were observed by previous studies, where they found that the effect of pain reduction, symptom severity, and functional outcomes from session rESWT seemed to begin early [18]. However, another study disagrees with our outcomes, where the benefit of session rESWT seemed to begin at a later period, in the third month [10]. The differences may be owing to the duration of treatment with shock therapy, as we used 5–8 min whereas they used 3–7 min per session.

Regarding electrodiagnostic parameters, there was a significant reduction in peak sensory distal latency and increase in amplitude on SNAP and in sensory conduction velocity at the third month in both groups compared with baseline. The improvement was highly significant in the rESWT. These results were also suggested by other authors where they reported a significant increase in sensory nerve conduction velocity between baseline and 12th week with rESWT [18]). However, one study detected no difference between the baseline and the 12th week results for all electrodiagnostic parameters in an fESWT group [7], whereas the other study reported a significant decreased in not only peaked SNAP latency but also in distal latency of CMAP between baseline and the 12th week in an ESWT group [19].

Our study demonstrated that single rESWT provided greater benefits in term of symptom severity reduction and functional improvement compared with LCsI during and after the sixth month. A previous paper demonstrated similar results [10].

rESWT produces a shock wave with relatively low energy, which is dispersed through the applicator tip and has a less penetrative depth [14]. A recent meta-analysis comparing radial and fESWT reported that rESWT has the potential advantage of treating a larger area, lesser need for precise focusing, and low cost [18].

The mechanism of rESWT in an entrapment neuropathy, such as CTS, remains controversial. However, two main effects, the anti-inflammatory and neuronal regeneration effects, are potential mechanisms. The anti-inflammatory effect is similar to the mechanism of action noted in other musculoskeletal problems treated with rESWT [20].

After treatment with rESWT, neuronal regeneration may be induced by accelerating the healing of the injured axon, increasing Schwann cells proliferation, and increasing axonal regeneration in animal experiments [21]. Improvement of electrophysiologic parameters, as observed in our review, might be explained by these mechanisms.

The efficacy of rESWT depends on the dose intensity, duration, and number of attempts. A recent study reported a longer lasting effect with multiple-session attempts compared with a single dose [10]. Our single-dose rESWT protocol had a higher dose intensity than previous study (5–8 min 4 Bar, frequency: 15 Hz, number of shocks: 5000 shocks VS 4 Bar, frequency: 5 Hz, number of shocks: 2000 shocks) [15]. Our rESWT protocol provided a long-lasting effect, up to 24 weeks, without multiple-session attempts. Atthakomol *et al*. [10] used a single session rESWT of 5000 shocks to improve patient compliance and reported a significant effect.

No serious complications in terms of severe pain or progression of symptoms occurred with single-dose rESWT. In contrast, corticosteroid injection potentially has more risks than ESWT. Needle injection can lead to infection or median nerve injury,

and corticosteroids can weaken the tendon by inhibiting activity of the tenocyte [22]. For this reason, unlike rESWT, corticosteroid injections cannot be used repeatedly for treating CTS.

Our results showed significant improvement in both sensory and motor neurophysiological parameters in patients with mild CTS treated with rESWT, whereas in patients with moderate CTS, there was significant improvement only in peak sensory latency. Patients with mild CTS treated with LCsI showed significant improvement in sensory nerve neurophysiologic parameters and distal motor latency, whereas in patients with moderate CTS, there was improvement in both motor and sensory parameters but not statistically significant. These results were in agreement with a recent study which revealed that an improvement in electrophysiological findings (motor latency, peak sensory latency, motor and sensory amplitudes, and sensory nerve conduction velocity) of median nerve after rESWT more in mild than in moderate groups [23].

In our study, we found that there were highly positive significant correlations between peak sensory latency of median nerve and the clinical outcomes (VAS and BQ score), at the sixth month after rESWT and between motor latency of median nerve and BQ score in mild and moderate CTS groups. Similarly, other studies revealed a highly significant correlations between electrophysiological and clinical variables after rESWT in mild and moderate CTS groups. Moreover, significant correlations were observed among cross-section area (CSA) with clinical symptoms (lateral pinch and VAS) and CSA with nerve conduction studies. So, the authors suggested that CSA of the median nerve can be used as a screening tool for detection as well as discrimination of different severities of CTS. In addition, VAS and lateral pinch can be used for detection and assessment of the efficacy of treatment in CTS [24].

This study has a few limitations. The first is that the patients were limited to those with mild to moderate CTS, because the primary option for treatment of severe cases with motor weakness is surgical treatment. Studies examining the effect of rESWT on severe CTS would be lacking. However, if the efficacy and mechanisms of rESWT are clear and evident, it will be necessary to examine whether this technique can also be used in the management of severe CTS or not. Second, there is a lack of data on the long-term effects of rESWT. The follow-up duration of the included trials ranged from 12 to 24 weeks. So, we recommend to prolong the duration of the follow-up in the future research studies up to 1 year.

Conclusion

Treatment of CTS using single-dose rESWT has a beneficial effect on the pain relief and improvement in symptom severity and functional outcomes on both mild and moderate cases, and we confirm that single-dose rESWT is a noninvasive and convenient method for treating mild and moderate CTS with long-term of beneficial effect lasting up to 6 months compared with LCsI.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Olney RK. Carpal tunnel syndrome: complex issues with a ‘simple’ condition. Neurology 2001; 56:1431–1432.
2. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. JAMA 1999; 282:153–158.
3. Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies. Obes Rev 2015; 16:1094–1104.
4. Cartwright MS, White DL, Demar S, Wiesler ER, Sarlikiotis T, Chloros GD, *et al*. Median nerve changes following steroid injection for carpal tunnel syndrome. Muscle Nerve 2011; 44:25–29.
5. Marshall S, Tardif G, Ashworth N. Local corticosteroid injection for carpal tunnel syndrome. Cochrane Database Syst Rev 2007; 2:CD001554.
6. Atroshi I, Flondell M, Hofer M, Ranstam J. Methylprednisolone injections for the carpal tunnel syndrome: a randomized, placebo-controlled trial. Ann Intern Med 2013; 159:309–317.
7. Seok H, Kim SH. The effectiveness of extracorporeal shock wave therapy vs. local steroid injection for management of carpal tunnel syndrome: a randomized controlled trial. Am J Phys Med Rehabil 2013; 92:327–334.
8. Wu YT, Ke MJ, Chou YC, Chang CY, Lin CY, Li TY, *et al*. Effect of radial shock wave therapy for carpal tunnel syndrome: a prospective randomized, double-blind, placebo-controlled trial. J Orthop Res 2016; 34:977–984.
9. Upatham S, Kumnerddee W. Reliability of Thai version Boston questionnaire. J Med Assoc Thail 2008; 91:1250–1256.
10. Atthakomol P, Manosroi W, Phanphaisarn A, Phrompaet S, Iammatavee S, Tongprasert S. Comparison of single-dose radial extracorporeal shock wave and local corticosteroid injection for treatment of carpal tunnel syndrome including mid-term efficacy: a prospective randomized controlled trial. BMC Musculoskeletal Disorders 2018; 19:32.
11. Cranford CS, Ho JY, Kalainov DM, Hartigan BJ. Carpal tunnel syndrome. J Am Acad Orthop Surg 2007; 15:537–548.
12. Stevens JC. AAEM minimonograph #26: the electrodiagnosis of carpal tunnel syndrome. American Association of Electrodiagnostic Medicine. Muscle Nerve 1997; 20:1477–1486.
13. Lee JH, Cho SH. Effect of extracorporeal shock wave therapy on denervation atrophy and function caused by sciatic nerve injury. J Phys Ther Sci 2013; 25:1067–1069.
14. Vahdatpour B, Kiyani A, Dehghan F. Effect of extracorporeal shock wave therapy on the treatment of patients with carpal tunnel syndrome. Adv Biomed Res 2016; 5:120.
15. Ciampa AR, de Prati AC, Amelio E, Cavalieri E, Persichini T, Colasanti M, *et al*. Nitric oxide mediates anti-inflammatory action of extracorporeal shock waves. FEBS Lett 2005; 579:6839–6845.
16. Ke MJ, Chen LC, Chou YC, Li TY, Chu HY, Tsai CK, Wu YT. The dose dependent efficiency of radial shock wave therapy for patients with carpal tunnel syndrome: a prospective, randomized, single-blind,

placebo controlled trial. Sci Rep 2016; 6:38344.
17. Graham B, Peljovich AE, Afra R, Cho MS, Gray R, Stephenson J, *et al*. The American Academy of Orthopaedic Surgeons evidence-based clinical practice guideline on management of carpal tunnel syndrome. J Bone Joint Surg Am 2016; 98:1750–1754.
18. Raissi GR, Ghazaei F, Forogh B, Madani SP, Daghaghzadeh A, Ahadi T. The effectiveness of radial extracorporeal shock waves for treatment of carpal tunnel syndrome: a randomized clinical trial. Ultrasound Med Biol 2017; 43:453–460.
19. Kim CJ, Jung HS, Lee US, Lee YS. Effect of extracorporeal shockwave therapy on carpal tunnel syndrome. A systematic review and meta-analysis of randomized controlled trials. Medicine 2019; 98:e16870.
20. Russo S, Suzuki H. Extracorporeal shock waves: from lithotripsy to anti inflammatory action by NO production. Nitric Oxide 2005; 12:89–96.
21. Hausner T, Nogradi A. The use of shock waves in peripheral nerve regeneration: new perspectives? Int Rev Neurobiol 2013; 109:85–98.
22. Gelberman RH, Aronson D, Weisman MH. Carpal-tunnel syndrome. Results of a prospective trial of steroid injection and splinting. J Bone Joint Surg Am 1980; 62:1181–1184.
23. Rashad MU, Nirmeen AK, Mansour TW, Amani MN, Khalil SA, Helmy H, Zayed KT. Effect of extracorporeal shock wave therapy on different severities of carpal tunnel syndrome. J Egypt Neurol Psychiatry Neurosurg 2020; 56:48.
24. El Habashy HR, El Hadidy RA, Ahmed SM, El Sayed BB, Ahmed AS. Carpal tunnel syndrome grading using high-resolution ultrasonography. J Clin Neurophysiol 2017; 34:353–358.