LYMPHATIC RESEARCH AND BIOLOGY
Volume 00, Number 00, 2018

DOI: 10.1089/lrb.2018.0011

Original Article

Is Complex Decongestive Physical Therapy Safe for Median Nerve at the Level of Carpal Tunnel in Breast Cancer Related Lymphedema?

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Abstract

Background: Multilayer bandaging used in complex decongestive therapy (CDT) may increase tissue pressure resulting in nerve entrapments. The aim of this study was to discover if median nerve damage is a consequence of CDT in patients with breast cancer-related lymphedema (BCRL).
Methods and Results: Eighty-two arms of 41 patients with BCRL were included. Mean age was 56.05 (8.16) years and all stages of lymphedema were equally included. Fifteen sessions of CDT was applied to all patients. The calculated volume of extremities, the quality of life (cancer adaptation of Ferrans-Powell), neuropathic pain (NP; Douleur Neuropathique 4), and disability (quick disabilities of arm, shoulder, and hand [Q-DASH]) tests were recorded before and after therapy. Skin and subcutaneous tissue thicknesses of volar and dorsal sides and median nerve cross-sectional area (CSA) at the level of carpal tunnel were measured using ultrasonography (US), before and after therapy. Carpal tunnel syndrome (CTS; 41.37%) and polyneuropathy (10.34%) were common findings confirmed by electromyography. Neuropathic pain profile was also found in 34.14% of patients. The arm volume of affected side, quality of life, and skin and subcutaneous tissue thicknesses were improved after therapy ($p < 0.05$). However, median nerve CSA, the NP, and Q-DASH scores were not changed after therapy.
Conclusions: Although lymphedema is a painless condition, NP and CTS should not be ignored in patients with BCRL. US is an alternative, precise, and high technological method for evaluating treatment response. CDT is an effective and safe treatment according to volumetric calculations, US measurements of tissue thicknesses, and median nerve size.

Keywords: breast cancer-related lymphedema, complex decongestive therapy, quality of life, ultrasonography, electromyography, median nerve

Introduction

Lymphedema is a chronic, progressive, and disabling disease leading to significant impairments in the quality of life for affected individuals. In the developed countries, the highest incidence of lymphedema is observed following breast cancer surgery, particularly among those who undergo radiation therapy following axillary lymph node surgery.[1,2] More than one in five women with breast cancer will develop breast cancer-related lymphedema (BCRL).[3,4] Many factors influence the development of BCRL, including obesity,[5,6] hypertension,[7] infection, type of cancer treatment,[8] and individual lymphatic drainage.[9] Lymphedema frequently develops slowly, often with preclinical symptoms and signs, such as heaviness, transient swelling, and slight volume changes compared with preoperative values. Early detection is essential for a treatment program during the initial stages of lymphedema before the development of elephantiasis.[1,2]

Complex decongestive therapy (CDT) is frequently used for the treatment of BCRL. CDT is a fourfold conservative treatment, which includes two phases with manual lymph drainage (MLD), compression therapy (consisting of

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compression bandages, compression sleeves, or other types of compression garments), skin care, and lymph-reducing exercises. Phase 1 of CDT is to reduce swelling applied by health professionals; phase 2 is to maintain the reduced swelling by caregivers.[10]

The lifelong compression therapy of the affected extremity is an essential component of the lymphedema management since the lymphatics are never normal again after lymphedema and the skin elasticity may never be regained completely.[2,10] Without the benefits provided by compression therapy, successful treatment of lymphedema would be impossible.

It is well known that compression therapy increases the pressure in the tissues.[1,2] Chronic compression by short stretch bandages or compression garments may lead to entrapment of median nerve, especially at the level of the carpal tunnel, as the most reported area of compression. However, this possible association is based on limited and poor-quality data, including retrospective study or case report.[11,12] To the best of our knowledge, there was no study to evaluate the size of the median nerve before and after compression therapy.

The aim of this study was to evaluate the possible adverse effects of the compression therapy on the median nerve using ultrasonography (US) and EMG. We also aimed to show the changes of skin thickness, volumes, upper extremity function, quality of life, and neuropathic pain (NP) scores before and after therapy in patients with BCRL.

Materials and Methods

All patients were recruited in a single center dedicated to the treatment of lymphedema between 2014 and 2016. The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. All patients signed written informed consents and ethics approval was obtained from the Local Ethics Committee.

All patients had undergone modified radical mastectomy because of invasive ductal cancer of the breast. Totally, the 82 arms of 41 patients with BCRL were included after giving informed consent.

The inclusion criteria were patients having unilateral lymphedema following their breast cancer surgery, more than 5% difference in volume between the two arms.

The cases with bilateral breast cancer, stage IV breast ca, previous history of compressive therapy, the presence of diabetes or adhesive capsulitis of the shoulder, continuing radiotherapy and/or chemotherapy, active infection, arterial or venous disease, active rheumatic disease such as rheumatoid arthritis, ulcers in the affected arm, congestive heart failure and uncontrolled hypertension, and those using any medications that affect the body fluid and electrolyte balance were excluded from the study.

The demographic features of the patients, including age, duration of the lymphedema, and the number of chemotherapy and radiotherapy sessions were recorded.

Lymphedema measurements

The International Society of Lymphology staging was used for determining the lymphedema stage[13] as follows:

Stage 1: mild edema that is reversible with appropriate limb position, may pit.
Stage 2: moderate edema that is not reversible with limb elevation. Pitting is present, except in late stage 2 when more fibrosis occurs.
Stage 3: Lymphostatic elephantiasis with trophic skin changes.

Truncated cone method was used to calculate estimated volumes for upper arm and forearm. Right and left arm circumferences were measured at 4-cm intervals, starting from the carpometacarpal joint. The volume of each limb was calculated from the circumference using the truncated cone formula. The reliability and specificity of the calculated volume has been established.[14]

The extremity volumes (V) of normal (N) and lymphedema (LE) sides were calculated before and after therapy. Both side-to-side (VL-VN, before and after therapy) and same side (VLE-VLE or VN-VN, before and after therapy) volume differences as milliliters were also recorded.[15] Percentage of difference was recorded as side-to-side [(VLE-VN/VN$\times$100)%], before and after therapy. The change of percentages was also evaluated and formulated as %(side-to-side percentage of differences before therapy) − (side-to-side percentage of differences after therapy)/(side-to-side percentage of differences before therapy)$\times$100.

Therapy

All patients underwent CDT, which included 30–45 minutes MLD, intermittent pneumatic compression pump, multilayer compression bandaging using Rosidal® lymphedema upper extremity bandaging set, lymphedema remedial exercises, and skin care.[2]

The same experienced therapist applied standard CDT protocol to the patients for 2 hours a day, 5 days a week for 3 weeks, totally15 sessions. The MLD was performed by certified physical therapists in a proximal to distal lymphatic direction with light skin massage.[2,16] Nonelastic multilayer compression bandages were applied and changed daily. All patients were educated on appropriate skin care, such as skin hygiene, applying moisturizer daily, avoiding mechanical, thermal, and barotrauma. The patients were also performed remedial lymphedema exercise program, such as diaphragmatic breathing exercise, and neck and shoulder stretching exercises for helping facilitate lymphatic flow. All circumferential measurements and volumetric calculations were recorded at the beginning and end of the therapy.

Self-reported outcomes

All clinical measurements were done before CDT and end of the 15 treatment sessions by the same physician. The presence of NP was evaluated using DN4 (Douleur Neuropathique 4) test before and after therapy.[17] The DN4 is one of the questionnaires that can be useful in helping to diagnose NP. It has components of how the pain feels to the patient, but also requires the examining health professional to assess whether there is reduced sensation (hypoesthesia) to touch or pinprick, and whether light brushing increases or causes pain (allodynia). If the score is 4 or higher, then the pain is likely to be NP.

Quick disabilities of arm, shoulder, and hand (Q-DASH) self-reported questionnaire was selected for the evaluation of

upper extremity disability, before and after therapy.[18] The purpose of the Q-DASH is to use 11 items to measure physical function and symptoms in people with any or multiple musculoskeletal disorders of the upper limb. The Q-DASH decreases responder and data entry burden while maintaining a high degree of correlation to the original length DASH. The Q-DASH is scored in two components: the disability/symptom section (11 items, scored 1–5) and the optional high-performance sport/music or work modules (4 items, scored 1–5). To calculate a Q-DASH score, at least 10 of the 11 items must be completed. Similar to the DASH, each item has five response options and, from the item scores, scale scores are calculated, ranging from 0 (no disability) to 100 (most severe disability).

Ferrans and Powers quality of life index (QLI) with permission was used to measure quality of life in terms of satisfaction with life in the present study. Quality of life is defined by Ferrans as ''a person's sense of well-being that stems from satisfaction or dissatisfaction with the areas of life that are important to him/her''.[19] The QLI measures both satisfaction and importance of various aspects of life. Importance ratings are used to weigh the satisfaction responses, so that scores reflect the respondents' satisfaction with the aspects of life they value. Items that are rated as more important have a greater impact on scores than those of lesser importance. The instrument consists of two parts: the first measures satisfaction with various aspects of life and the second measures importance of those same aspects. Importance ratings are used to weigh satisfaction responses, so that scores reflect satisfaction with the aspects of life that are valued by the individual. The QLI produces five scores: quality of life overall and in four domains (health and functioning, psychological/spiritual domain, social and economic domain, and family).

Ultrasonography

A specialist (H.G.) with 5 years of musculoskeletal US experience performed the US examinations by using a 14–8-MHz (General Electric, Logic 5 ultrasonography) linear array transducer. The subjects were seated facing the examiner with their arms extended, their wrists resting on a flat surface, their forearms supine, and their fingers semiextended. Large amount of gel was applied into the skin without compression of probe for skin and subcutaneous tissue imaging.

Volar and dorsal skin thickness measurements at six different points at the hand (the base of thumb), the forearm, and the arm, were done before and after therapy. The six points were defined as follows: (1) hand, the thenar eminence of hand at the level of the base of the thumb; (2) forearm, 10 cm distal to the elbow point along the line of the radial and ulnar styloid processes between the midpoint of the medial and lateral epicondyles; and (3) arm, 10 cm proximal to the elbow point along the line of the humerus and the bicipital groove between the midpoint of the medial and lateral epicondyles.[20] All skin and subcutaneous tissue thickness measurements were performed at the volar and dorsal sides; in affected and unaffected arms; before and after therapy. Images of skin and subcutaneous tissue measurement are shown in Figure 1.

Transverse US section of the median nerve from the distal forearm to the outlet of the carpal tunnel was also performed. The measurements of the maximal median nerve cross-sectional area (CSA) were obtained: The carpal tunnel CSA measurement was obtained at the level of the maximal nerve shape change from the proximal to the distal carpal tunnel.[21] The carpal tunnel CSA measurement was recorded in the affected and unaffected side, before and after therapy. Figure 2 shows the US image of the median nerve CSA measurement.

Electromyography

Median and ulnar nerve conduction studies (NCSs) were performed using Nihon Kohden Neuropack M1 (Tokyo, Japan). The same specialist (B.M.K.) with 5 years of EMG experience was the examiner. Room temperature was set at 25°C while hand temperature was maintained at min 32°C. During the NCS, F-wave latency for both median nerves, median motor, median and ulnar sensory NCSs were examined. Median motor NCS and F-wave latency for median nerve were recorded with surface electrodes from abductor pollicis brevis muscle. The standard distance between stimulation at the wrist and recording electrode was 8 cm. Median motor nerve proximal and distal latencies, motor nerve conduction velocities, compound muscle action potential amplitudes, and F-wave latency were measured. Median sensory NCS was recorded from the second digit as antidromical with standard distance of 13 cm. Ulnar sensory NCS was recorded from fifth digit with standard distance of 13 cm. For all sensory NCSs, distal latency, sensory nerve action potential amplitude, and sensory nerve conduction velocity were measured. The severity of carpal tunnel syndrome (CTS) was defined as mild, moderate, or severe electrophysiological CTS according to AANEM guidelines.[22]

Statistical analysis

Statistical analysis was performed using SPSS version 15.0 for Windows (SPSS, Inc., Chicago, IL). Descriptive analyses were used for the demographic data, Spearman's rank correlation coefficient for finding the relationship between variables. The categorical variables were analyzed by Chi-square test. The student's t-test for continuous variables was used to evaluate the values before and after the treatment within the group. The level of statistical significance was set at $p < 0.05$.

Results

The main characteristics of the 41 female patients with the BCRL were shown in Table 1. All patients underwent modified radical mastectomy. Most of them had a history of chemotherapy and radiotherapy. Lymphedema duration when the patient was referred to the lymphedema unit was 54.5 ± 65.6 (range 1–300) months.

The changes of self-reported outcomes

The changes of upper extremity pain scores (NP and Q-DASH) and QLI are shown in Table 2.

The NP profile was detected in 14 patients (33.3%) according to the DN4 test.

Neuropathic pain scores tend to increase, but does not reach a statistically significant level after therapy ($p = 0.063$). There was no difference in the percentage of volumetric change in patients with and without NP. Neuropathic

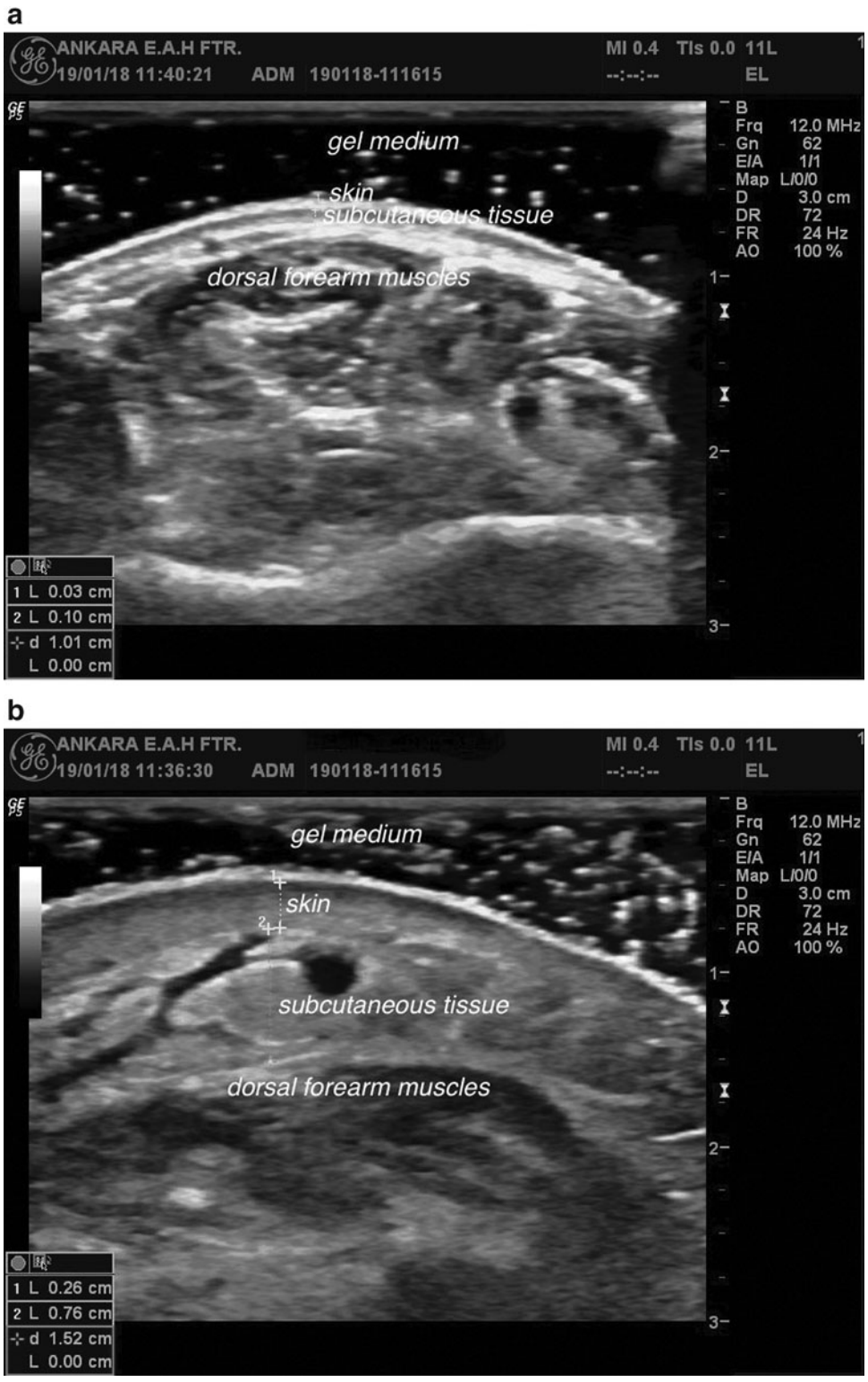

FIG. 1. **(a,b)** The US images in skin and subcutaneous tissue of affected and normal dorsal forearm (with written permision of patient). US, ultrasonography

pain score was positively correlated with Q-DASH score ($r = 0.486$, $p = 0.001$).

The changes of Q-DASH score tend to lower, but does not reach a statistically significant level after therapy ($p = 0.191$).

The overall quality-of-life scores and health-related quality-of-life scores were statistically significantly improved after therapy ($p = 0.025$ and $p = 0.049$). The overall quality-of-life score negatively correlated with NP score ($r = -0.314$, $p = 0.043$) and lymphedema extremity volume ($r = -0.375$, $p = 0.017$).

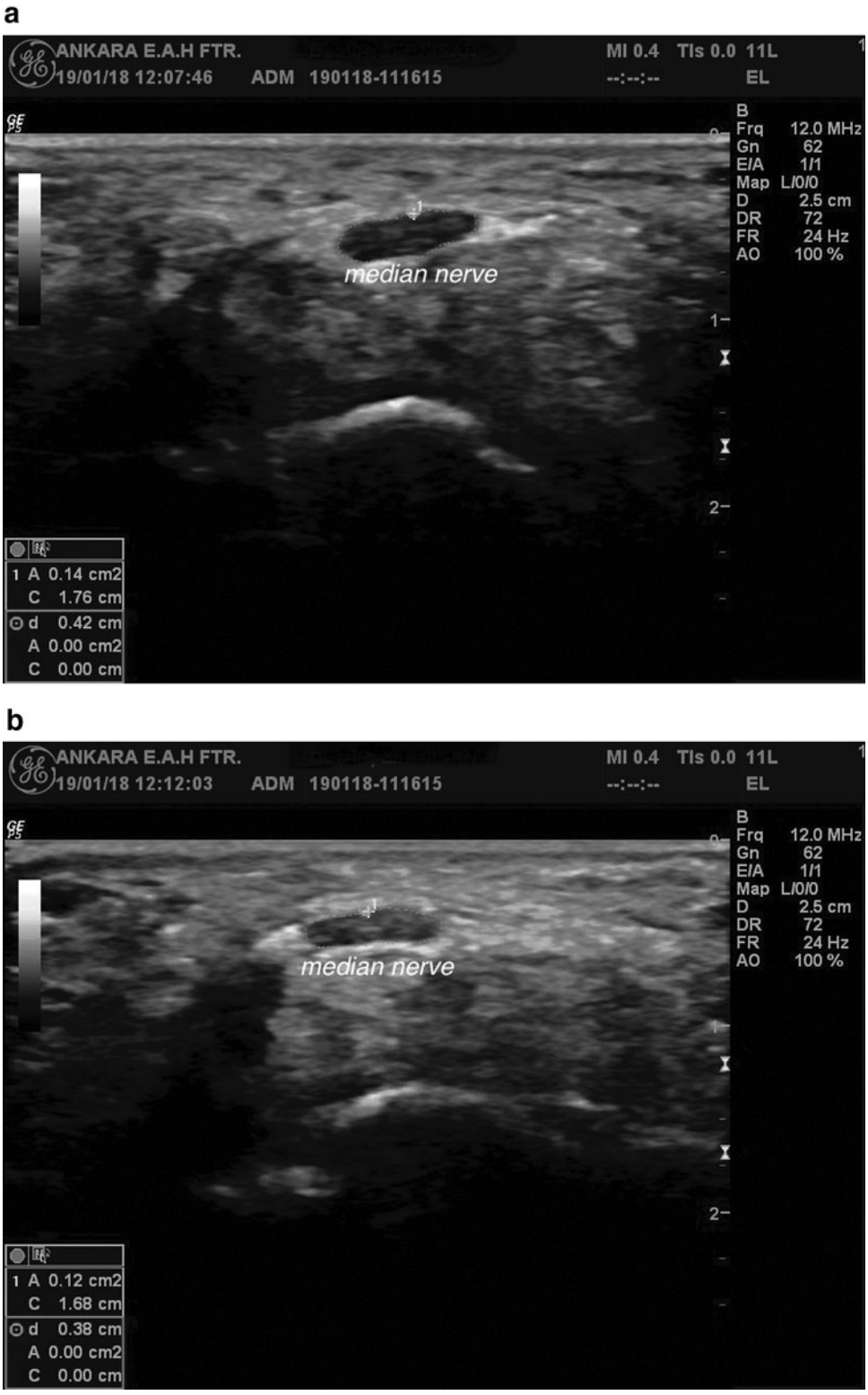

FIG. 2. (**a,b**) The US images for median nerve at the level of carpal tunnel in affected and normal sides (with written permision of patient).

The changes of skin US measurements

All US measurements of skin and subcutaneous tissue thicknesses in both volar and dorsal sides were decreased after therapy in the arm with lymphedema ($p < 0.001$). Interestingly, the skin and subcutaneous tissue thicknesses of the dorsal forearm, and dorsal arm were also decreased in the normal upper extremity ($p < 0.05$). The US measurements are also shown in Table 3.

Table 1. The Main Characteristics of the Patients

Age (years), mean (SD) (min–max)	56.05 (8.16) (38–70)
Lymphedema duration (months), mean (SD) (min–max)	50.00 (62.50) (1–300)
Dominant hand, right, *n* (%)	38 (92.68)
Dominant side lymphedema, *n* (%)	23 (56.09)
Lymphedema stage, *n* (%)	Stage 1: 13, 31.7% Stage 2: 13, 31.7% Stage 3: 15, 36.6%
The dissected axillary lymph node, mean (SD) (min–max)	19.08 (7.17) (6–34)
The positive axillary lymph node, *n* (%) (min–max)	None (10, 24.39%) (0–25) 1–3 (18, 43.90%) ≥4 (14, 34.14%)
Adjuvant therapy, *n* (%)	
Radiotherapy	36 (87.80)
Chemotherapy	38 (92.68)
Neurological findings, *n* (%)	
Neuropathic pain	14 (34.14)
CTS	12 (41.37)
Polyneuropathy	3 (10.34)

CTS, carpal tunnel syndrome.

The US-detected median nerve CSA did not change before and after therapy in both affected and unaffected sides ($p > 0.05$).

The changes of volumetric measurements

The mean arm volumes were 3254.56 ± 869.87 mL versus 2455.60 ± 691.66 on both sides. The percentage of difference or baseline lymphedema severity was $37.20\% \pm 23.90$. Analysis on an intention-to-treat basis, after 15 sessions of CDT program, the percentage of difference decreased to $25.36\% \pm 19.00\%$ ($p = 0.0001$). The arm volume of the lymphedema side and side-to-side volume differences tend to decrease as statistically significant ($p = 0.0001$). The changes of volumetric parameters and percentage of changes are shown in Table 4.

EMG results

Electromyography protocols for CTS and polyneuropathy were performed in 29 patients (69.0%) using surface electrodes. The remaining patients did not accept these EMG procedures. Bilateral CTS were detected in six patients, two of them had mild and four of them had moderate CTS. Unilateral mild CTS was found in two normal sides and one lymphedema side of total three patients. Bilateral severe CTS was detected in three patients. The remaining three patients had polyneuropathy on EMG. EMG findings were in normal limits in 14 patients. There was no difference in median and ulnar NCSs and the severity of CTS between both affected and unaffected sides. The EMG results are shown in Table 5.

There was no difference in the percentage of volumetric change in patients with and without CTS or with and without polyneuropathy. The severity of CTS was not related with the severity of lymphedema ($p = 0.636$).

Conclusions

We found that the phase 1 or intensive phase of CDT has no effect on the size of median nerve at the level of carpal tunnel, NP score, and arm disability. One of each of the three patients had NP and one of two patients had abnormal EMG findings, including CTS or polyneuropathy in the present study. However, the improvement of percentage of volume difference after therapy was not affected with the presence of NP or CTS.

There were important improvements in the affected extremity volumes, and skin and subcutaneous tissue thicknesses after therapy. The overall quality of life and health-related quality of life were also improved after phase 1 therapy.

It is well known that compression therapy increases the pressure in the tissues.[1,2] Compression therapy may also lead to entrapment of upper extremity nerves in BCRL. Lymphedema has long been considered a risk factor for median nerve compression at the wrist. However, this possible association is based on limited and poor-quality data, including retrospective study or case report.[11,12]

To the best of our knowledge, there was no study to evaluate the size of the median nerve before and after phase 1 CDT. We found no change in US-measured median nerve CSA after therapy. US-measured volar skin and subcutaneous tissue thicknesses of hand, forearm, and arm were

Table 2. The Changes of Neuropathic Pain Score, Disability Level, and Quality-of-Life Score, Before and After Therapy

	Before therapy	*After therapy*	
	Mean (SD) [min–max]	*Mean (SD) [min–max]*	p
DN4 score	3.09 (2.54) [0–8]	3.46 (2.28) [0–8]	0.063
Quick-DASH score	43.12 (47.30) [0–31.8]	39.03 (18.53) [0–70.5]	0.100
Quality-of-life score			
Overall[a]	23.48 (4.11) [6.83–28.94]	24.10 (3.97) [6.83–28.94]	0.025
Health	22.48 (5.16) [5.15–29.42]	23.47 (4.99) [5.15–29.42]	0.049
Socioeconomic	21.70 (5.58) [5.07–30]	22.29 (5.15) [5.07–28.93]	0.286
Psychological	27.20 (3.43) [18–30]	26.95 (3.44) [18–30]	0.356
Family	25.99 (5.27) [2–30]	26.25 (4.86) [2–30]	0.352

[a]Statistically significant differences ($p < 0.05$).
DN4, Douleur Neuropathique 4.

Table 3. The Changes of Ultrasonography Measurements in Normal and Lymphedema Sides Before and After Therapy

	Before therapy	*After therapy*	
	Mean (SD) [min–max]	*Mean (SD) [min–max]*	p
Volar hand (mm)			
LE skin[a]	0.062 (0.03) [0.03–0.14]	0.059 (0.07) [0.03–0.48]	0.001
LE subcutis[a]	0.22 (0.14) [0.10–0.71]	0.16 (0.09) [0.09–0.45]	0.0001
N skin	0.04 (0.01) [0.02–0.10]	0.04 (0.02) [0.02–0.10]	0.052
N subcutis	0.15 (0.08) [0.07–0.44]	0.14 (0.07) [0.05–0.42]	0.081
Volar forearm (mm)			
LE skin[a]	0.19 (0.07) [0.06–0.37]	0.19 (0.17) [0.07–0.17]	0.0001
LE subcutis[a]	1.12 (0.48) [0.20–2.67]	0.94 (0.37) [0.15–2.03]	0.0001
Normal skin	0.14 (0.06) [0.05–0.32]	0.140 (0.06) [0.05–0.29]	0.092
Normal subcutis	0.80 (0.40) [0.14–2.00]	0.79 (0.38) [0.14–2.00]	0.362
Volar arm (mm)			
LE skin[a]	0.18 (0.06) [0.07–0.33]	0.16 (0.05) [0.06–0.31]	0.0001
LE subcutis[a]	1.89 (0.69) [0.19–2.90]	1.67 (0.53) [0.34–2.79]	0.0001
Normal skin	0.14 (0.06) [0.03–0.28]	0.13 (0.06) [0.04–0.27]	0.139
Normal subcutis[a]	1.29 (0.51) [0.16–2.74]	1.20 (0.46) [0.15–2.13]	0.009
Dorsal hand (mm)			
LE skin[a]	0.07 (0.051) [0.02–0.24]	0.06 (0.05) [0.03–0.26]	0.0001
LE subcutis[a]	0.32 (0.43) [0.05–2.20]	0.25 (0.29) [0.05–1.19]	0.0001
Normal skin	0.04 (0.02) [0.02–0.13]	0.04 (0.02) [0.02–0.12]	0.097
Normal subcutis	0.13 (0.06) [0.02–0.43]	0.12 (0.04) [0.05–0.32]	0.521
Dorsal forearm (mm)			
LE skin[a]	0.17 (0.07) [0.05–0.31]	0.15 (0.05) [0.07–0.30]	0.004
LE subcutis[a]	1.06 (0.70) [0.11–2.82]	0.88 (0.52) [0.28–2.48]	0.001
Normal skin[a]	0.12 (0.05) [0.04–0.27]	0.12 (0.04) [0.07–0.25]	0.030
Normal subcutis[a]	0.74 (0.43) [0.05–2.00]	0.71 (0.38) [0.16–1.59]	0.016
Dorsal arm (mm)			
LE skin[a]	0.16 (0.06) [0.07–0.31]	0.16 (0.11) [0.07–0.74]	0.0001
LE subcutis[a]	1.83 (0.63) [0.70–3.38]	1.60 (0.51) [0.68–2.78]	0.0001
Normal skin[a]	0.12 (0.03) [0.07–0.24]	0.11 (0.03) [0.07–0.18]	0.002
Normal subcutis[a]	1.21 (0.41) [0.45–2.03]	1.11 (0.35) [0.45–1.83]	0.001
Median nerve (cross-sectional area, cm^2)			
LE-CSA	0.11 (0.02) [0.06–0.18]	0.10 (0.02) [0.07–0.14]	0.087
Normal-CSA	0.10 (0.02) [0.07–0.19]	0.10 (0.02) [0.07–0.18]	0.686

[a]Statistically significant differences ($p < 0.05$).
CSA, cross-sectional area; N, normal; LE, lymphedema.

decreased after therapy, similar to previous reports.[20,23,24] We measured both dorsal and volar skin and subcutaneous tissue thicknesses on both sides. These measurements were also decreased in the normal arm after therapy. It may be related to increasing body lymphatic flow because of therapy effects.

The quality of life improved after phase 1 therapy in the present study. A number of prospective studies have found that CDT is associated with volume reduction in the affected limb as well as improved quality of life,[25,26] as we found. The quality of life was affected negatively by NP and lymphedema extremity volume in the present study.

Some studies reported that neurological complications, such as NP and chemotherapy-induced peripheral neuropathy (CIPN), are frequent in patients with breast cancer, and NP remained the major contributor to the burden of these conditions among survivors.[27,28] Fontes et al. reported a follow-up study, including first and third years after breast cancer diagnosis. They found that one in five patients had NP (21.1% in first year and 23.6% in third year) and it was associated with

Table 4. The Changes in Volumes (mL) and Percentage of Differences Before and After Therapy

	Before therapy, mean (SD) [min–max]	*After therapy, mean (SD) [min–max]*	p
N volume (mL),	2455.60 (691.66) [1318–4827]	2552.20 (641.50) [1565–4431]	0.122
LE volume (mL)[a]	3254.56 (869.87) [2009–5439]	3078.90 (748.80) [1755–4816]	0.01
Side-to-side difference (mL)[a]	879.21 (556.41) [77–2251]	621.20 (404.49) [19–1609]	0.0001
Percentage of differences[a]	37.2% (23.9%) [7.40–107]	25.36% (19.00%) [1.1–90.40]	0.0001
Change of percentages		29.43 (31.13) [–62.50–87.15]	

[a]Statistically significant differences ($p < 0.05$).

Table 5. The Side-to-Side Comparisons of Median and Ulnar Nerve Conduction Studies

	Lymphedema side, mean (SD) [min–max]	*Normal side, mean (SD) [min–max]*	p
Median motor latency (msec)	3.65 (1.41) [2.60–9.78]	3.53 (0.94) [2.28–6.68]	0.822
Median motor NCV (m/sec)	51.72 (6.21) [33.80–62.90]	50.43 (10.86) [0.00–62.20]	0.936
Median motor amplitude (mV)	14.70 (5.15) [3.80–23.66]	15.14 (5.15) [6.44–26.80]	0.785
Median F-latency	27.76 (3.09) [22.65–34.70]	27.62 (2.44) [23.63–33.11]	0.988
Median sensory latency (msec)	1.80 (0.98) [0–3.16]	2.16 (0.84) [0–3.16]	0.110
Median sensory NCV (m/sec)	41.06 (21.95) [0–60.00]	44.13 (16.73) [0–60.40]	0.864
Median sensory amplitude (μV)	18.59 (14.54) [0–55.50]	21.36 (13.07) [0–48.40]	0.350
Ulnar sensory latency (msec)	1.97 (0.61) [0–3.00]	1.91 (0.94) [0–5.58]	0.243
Ulnar sensory NCV (m/sec)	47.82 (14.43) [0–59.30]	46.58 (18.02) [0–69.00]	0.834
Ulnar sensory amplitude (μV)	15.75 (9.88) [0–40.00]	18.61 (10.84) [0–46.60]	0.263
EMG final report	n = *29 (100%)*		
Normal EMG	14 (48.27%)		
Bilateral mild CTS	2 (6.89%)	2 (6.89%)	
Unilateral mild CTS	1 (3.44%)	2 (6.89%)	
Bilateral moderate CTS	4 (13.79%)	4 (13.79%)	
Bilateral severe CTS	3 (10.34%)	3 (10.34%)	
Polyneuropathy	3 (10.34%)	3 (10.34%)	

NCV, nerve conduction velocity.

axillary lymph node dissection, and chemotherapy. CIPN was decreased from 14.1% to 12.6% in this study and strongly associated with Taxane-based chemotherapy. Pereira et al. also reported oncological-related neurological complications, including NP (30.8%) and CIPN (16.8%) at the first after diagnosis.[28] All of our patients underwent modified radical mastectomy and more than ninety percent of them received chemotherapy, including taxane. Possibly, because of this intensive treatment, one of three patients had NP. Neuropathic pain scores of patients were not changed after therapy. It may depend on short follow-up period, small sample size, or chronic nature of NP. In addition, there was no difference in percentage of volumetric change in patients with and without NP. To the best of our knowledge, there was no study to evaluate NP after CDT. Therefore, no comparison could be made for this result.

In contrast to the improvement of quality-of-life scores, NP and arm disability were not improved after phase 1 therapy. In addition, NP was positively correlated with Q-DASH. It may depend on short follow-up period, small sample, or the lack of resistance training exercises in our study. Do et al. reported that resistance training added to CDT demonstrated improvement in the DASH score and muscular strength compared with the CDT-only group after 8 weeks.[29] The absence of resistance training in the present study may be responsible for this failed result for disability.

Previously, Ganel et al. reported that brachial plexus entrapment and CTS should be added to the list of complications following mastectomy, with lymphedema playing an active part in their development.[30] Lymphedema was associated with brachial plexus entrapment and CTS in 30 patients with BCRL in Ganel et al.'s study. Twenty-eight percent of the patients had CTS, and 28% suffered from brachial plexus entrapment of the arm on the mastectomy side, as compared with 8% and 5%, respectively, on the nonoperated side. On the contrary, Stubblefield et al. reported no association between the presence of lymphedema and CTS or between lymphedema severity and CTS severity in 19 patients with BCRL,[11] as we found. They also concluded that lymphedema was not an etiologic factor in the pathogenesis of CTS.

The main limitation of the present study was the relatively small sample size. Despite this small sample size, CTS and NP were common findings in patients with BCRL in the present study. CTS may be treated surgically in women with BCRL.[31] Although lymphedema volume increased transiently, it remained stable with compression therapy over long-term follow-up, with no local complications reported in these 32 patients.

As a conclusion, CDT is a safe and effective therapy according to the US-measured median nerve CSA at the level of the carpal tunnel, skin and subcutaneous tissue thicknesses, and volumetric calculations of both affected and unaffected arms in patients with BCRL. Quality of life improved also immediately after therapy, but not effective for NP and disability at short term. We suggested that the addition of NP and CTS evaluation are commonly seen problems in patients with BCRL. US for skin thickness measurements is a precise technique for follow-up due to imaging of the target tissues in patients with BCRL. It is also simple, safe, noninvasive, easy, but an operator-dependent technique for experienced hands.

Acknowledgment

Special thanks to Burcu Duyur Cakit, MD, for the cooperation and the counseling of statistical analyses.

Author Disclosure Statement

No competing financial interests exist.

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