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Original Article

Skeletal Status in Women With Carpal Tunnel Syndrome—A 1-Yr Prospective Study

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Abstract

Functional deterioration due to carpal tunnel syndrome (CTS) may influence the bone status of the forearm and hand. The aim of this prospective study was to establish whether CTS has an impact on bone status at distal parts of the upper limb and to monitor the longitudinal changes of that status during a 1-yr follow-up after surgical treatment. Fifteen women with CTS at mean age of 55.13 ± 9.3 yr, mean weight of 79.18 ± 20.37 kg, and mean height of 157.8 ± 6.17 cm were enrolled into the study. All women had unilateral CTS that negatively affected upper limb function and were qualified to surgical treatment. Functional status was established at baseline using Levine's scale, motor latency, and nerve conduction velocity in electrophysiologic examinations. Bone status was established using densitometric measurements (Hologic Explorer, Bedford, MA) at the forearm, spine, and hip (bone mineral density [BMD], g/cm^2) and with quantitative ultrasound measurements (amplitude-dependent speed of sound, m/s) at hand phalanges (DBM Sonic, IGEA, Carpi, Italy). Longitudinal changes were established for Levine's scale score and for forearm and phalanges measurements at 3, 6, and 12 mo after surgery. Levine's scale results improved significantly over a period of observation ($p < 0.0001$). Longitudinal BMD measurements for ultradistal forearm have shown a decrease only for measurement at 6 mo vs baseline result (0.386 ± 0.08 g/cm^2 vs 0.375 ± 0.08 g/cm^2, $p < 0.05$) with onward increase. Amplitude-dependent speed of sound did not differ over the period of observation. Correlation analysis has shown that functional status expressed by Levine's scale was most strongly related to the longitudinal BMD measurements for ultradistal forearm at 6 mo ($r = -0.52$, $p < 0.05$). Successful surgery in patients with CTS does not lead to permanent deterioration in bone status within the affected upper limb in a 1-yr longitudinal observation.

Key Words: carpal tunnel syndrome; densitometry; functional status; quantitative ultrasound.

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment peripheral neuropathy. The first description of the disease was made by Paget in 1853 *(1)*. In general, population incidence is estimated in wide range between 0.1% and 9.2% *(2,3)*. The disturbance occurs most often in women in their sixth and seventh decades of life *(4)*. Many disorders such as diabetes mellitus, amyloidosis, sarcoidosis, or rheumatoid arthritis may predispose to CTS. The carpal tunnel is composed of the carpal bones and the transverse carpal ligament. It also contains 9 flexor tendons and a median nerve. Intracarpal pressure in neutral wrist position is 2.5 mm Hg. The pressure is constantly higher than 20 mm Hg in patients with CTS *(5,6)*.

The symptoms of CTS are paresthesia and dysesthesia in the 1–3 digits and pain that often awakens patients at

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night. At the advanced stage of CTS, clumsiness, dropping of objects, and hand weakness may occur.

Physical examination reveals defects of sense on a palmar side of the 1–3 digits and positive provocative tests results by using the Tinel's sign or Phalen's sign.

A useful tool for the assessment of severity of symptoms and outcome of treatment is the Levine's questionnaire (Boston Questionnaire, Carpal Tunnel Questionnaire). By using the questionnaire, subjective patient's evaluation is transposed into the score (7–10).

The most common examination describing the nerves' function in CTS is neurography (ENG). ENG sensitivity ranges from 49% to 84% (mean: 70%), and the specificity of the method is 95%. Results of the ENG such as sensory nerve conduction velocity (m/s) and distal motor latency (ms) are employed in the neurophysiologic grading scale for CTS (11–13).

Median nerve structure, shape, and size inside and outside the carpal tunnel can be obtained by sonography or magnetic resonance imaging (14).

Conservative treatment of the CTS includes anti-inflammatory drugs, rehabilitation, and manual therapy. However, operative treatment is the most effective. Efficiency of the carpal tunnel release depends on good surgical technique and degree of nerve impairment due to compression. Failure of surgical treatment affects 1%–3% of patients (6,15). Untreated CTS damages neuromuscular structures and decreases hand dexterity. Generally, it is not established if CTS affects the upper limb skeletal system.

The aims of the study were (1) to examine whether CTS influences the bone status of the forearm and hand phalanges, (2) to determine the factors with possible influence on bone status, and (3) to follow up bone status of the hand and forearm during a 1-yr longitudinal observation.

Materials

Fifteen women with 1-sided CTS at mean baseline age of 55.13 ± 9.3 yr, mean weight of 79.18 ± 20.37 kg, and mean height of 157.8 ± 6.17 cm were enrolled into the prospective study.

At baseline, 23 women gave their permission to be included in the study. They were selected from 191 patients suffering from CTS. The group of 168 patients excluded from the study comprises men, women who did not give their consent to participate in the study, and women with previous osteoporotic fractures at the upper limbs or spine. Patients with previous surgical treatment of the carpal tunnel syndrome and with chronic diseases or other risk factors for fast essential deterioration of bone mineral density (BMD), such as rheumatoid arthritis, chronic kidney or liver disease, or inflammatory bowel disease, and patients on prolonged glucocorticoids, anticonvulsants, heparin, or oral anticoagulant administration, and long-term immobilized subjects were excluded from the study. Rigorous exclusion criteria allowed us to assume that any essential 1-yr changes in BMD value (if found) could had been assigned with highest probability to the influence of the disease and its surgery but not to other factors.

Additionally, collected data in 8 of 23 women who started the study were not complete, so these subjects were neither taken under consideration.

All patients studied presented with positive results of the Levine's questionnaire and ENG at baseline examination.

The local ethics committee gave the permission for the study. All women participating in the study gave a written informed consent.

Methods

Functional Status

Functional status was established at baseline using the Levine's scale. Longitudinal changes were expressed by Levine's scale with repeated assessment at 3, 6, and 12 mo after surgery.

A self-administered Levine's questionnaire consists of 2 parts: (1) a functional status scale with 8 questions and (2) a severity symptoms status scale with 11 questions.

The overall score is the sum of the mean of functional score and severity symptoms score. Minimum score, which indicates the lack of symptoms, is 2. Maximum score is 9.36 (16).

Neurography

Selected ENG parameters such as sensory nerve conduction velocity (in m/s) and distal motor latency (in ms) were used to evaluate patients using the Bland's scale as follows:

Grade 0—normal
Grade 1—very mild, CTS demonstrable only with most sensitive tests
Grade 2—mild, sensory nerve conduction velocity slow on finger/wrist measurement, normal terminal motor latency
Grade 3—moderate, sensory potential preserved with motor slowing, distal motor latency to abductor pollicis brevis (APB) <6.5 ms
Grade 4—severe, sensory potentials absent but motor response preserved, distal motor latency to APB <6.5 ms
Grade 5—very severe, terminal latency to APB >6.5 ms
Grade 6—extremely severe, sensory and motor potentials effectively undetectable (surface motor potential from APB <0.2 mV amplitude).

Bone Measurements—Densitometry

Skeletal status was assessed using bone densitometry (dual energy X-ray absorptiometry [DXA]). All DXA measurements were performed by 1 experienced operator using device Explorer Hologic (Bedford, MA). BMD (g/cm^2) was measured at the lumbar spine and proximal femur (femoral neck and total hip [TH]) to establish baseline general bone status. Longitudinal local bone changes related to functional disturbances resulting from CTS were followed by DXA measurements at both forearms performed at baseline and after 3, 6, and 12 mo after surgery. The following longitudinal measurements of the forearm skeletal sites were measured: one-third forearm, middle forearm, ultradistal forearm, and total forearm.

Coefficient of variation for the lumbar spine, femoral neck, TH, and forearm were 1.6%, 1.8%, 2.4%, and 1.6%, respectively.

Bone Measurements—Quantitative Ultrasound

Quantitative ultrasound (QUS) measurements were performed using DBM Sonic 1200 (IGEA, Carpi, Italy). The device measures amplitude-dependent speed of sound (Ad-SoS) at distal metaphyses of proximal phalanges II−V and is expressed as mean of 4 measurements in m/s. The QUS measurements were performed at baseline and monitored longitudinally at 3, 6, and 12 mo after surgery. Coefficient of variation for Ad-SoS was 0.64%.

All DXA forearm and QUS hand measurements were done on operated and nonoperated sides.

Surgical Technique

All patients were operated in 1 hospital by the same experienced surgeon (AK). The patient's hand was positioned on the operating table in the supine position and anesthetized using 4−7 mL of 1% lignocaine solution. Operations were performed using forearm tourniquet inflated with pressure of 20 mm Hg higher than the patient's systolic blood pressure. About 2-cm-long skin incision was made in the distal wrist line. Antebrachial fascia was cut. The external and internal layers of the transverse carpal ligaments were then separated. Transverse ligaments were cut using small scissors and median nerve protector. Then complete release control and bleeding control after releasing tourniquet were made.

Skin was closed and elastic bulky dressing was placed over the wound. All patients were instructed to keep their operated hand up. The stitches were removed after 7−10 d. The patients were allowed to do activities of daily living carefully after 14−20 d. They were allowed to be back at work after 2−3 mo.

Statistics

All analyses were performed using the Statistica software (StatSoft, Tulsa, OK). Descriptive statistics are presented as means and standard deviations. The normality of distribution of the analyzed data was checked by the Shapiro-Wilk test. The differences between measurements obtained at baseline and at follow-up, as well as the differences between the operated and nonoperated sides, were assessed using the *t* test for dependent variables or the Wilcoxon signed-rank test, whichever was appropriate according to data distribution. Longitudinal changes in bone densitometric and QUS variables over the whole period of observation were additionally analyzed with repeated measures analysis of variance. Correlation analysis between skeletal and functional (Levine's score and ENG) parameters was obtained by Spearman's correlation test. p Values lower than 0.05 were considered statistically significant.

Results

Functional Status

Baseline results for Levine's scale, distal motor latency, and sensory nerve conduction velocity were 6.4 ± 1.71 ms, 4.71 ± 1.64 ms, and 34.67 ± 7.26 m/s, respectively. Levine's scale has shown a significant improvement after 3, 6, and 12 mo in comparison with the baseline value ($p < 0.000001$). Longitudinal changes of the mean values of Levine's scale score are presented in Fig. 1. The difference between assessment in Levine scale after 3 and 6 mo was also significant ($p < 0.05$), whereas the change noted between 6 and 12 mo after surgery was no longer significant.

Spine and Hip DXA Measurements

Mean spine BMD at baseline was 1.000 ± 0.251 g/cm^2, mean T-score was −0.41 ± 2.22. For 3 women (20%), the T-score was below −2.5.

Mean hip BMD at baseline measured for femoral neck was 0.828 ± 0.198 g/cm^2 (with mean T-score −0.193 ± 1.791), and for TH, it was 0.987 ± 0.196 g/cm^2 with mean T-score 0.453 ± 1.766.

Forearm—Baseline Results

At baseline, forearm BMD at all analyzed projections did not differ between the affected and healthy sides.

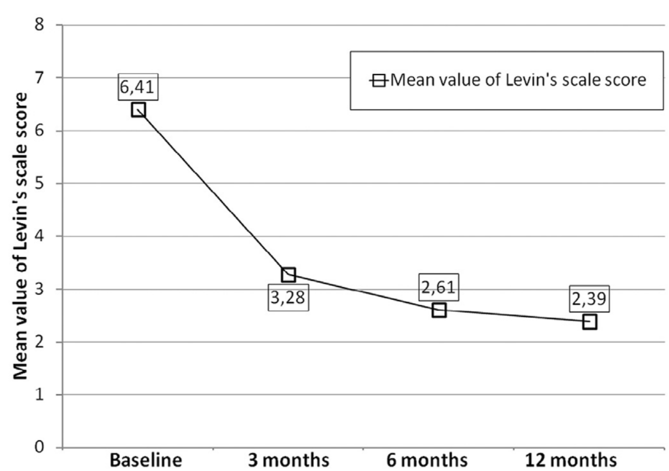

Fig. 1. Longitudinal changes of the mean values of Levine's scale score.

Table 1
Operated Side: Ultradistal, Middle Distal, 1/3, and Total BMD of the Forearm at Baseline and After 3, 6, and 12 Mo (Mean, SD)

BMD measurements	Baseline	After 3 mo	After 6 mo	After 12 mo	p Value[a]
UD BMD (g/cm^2)	0.386 ± 0.08	0.380 ± 0.08	0.375 ± 0.08[b]	0.379 ± 0.08	NS
MID BMD (g/cm^2)	0.555 ± 0.09	0.555 ± 0.09	0.548 ± 0.09	0.546 ± 0.09	NS
1/3 BMD (g/cm^2)	0.658 ± 0.1	0.663 ± 0.1	0.656 ± 0.09	0.624 ± 0.18	NS
Total BMD (g/cm^2)	0.534 ± 0.09	0.533 ± 0.09	0.527 ± 0.9	0.527 ± 0.9	NS

Abbr: BMD, bone mineral density; MID BMD, longitudinal BMD measurements for the middle forearm; NS, not significant; SD, standard deviation; UD BMD, longitudinal BMD measurements for the ultradistal forearm.
[a]Time-effect based on repeated measures analysis of variance.
[b]Transient significant decrease in comparison with baseline examination; $p < 0.05$.

Detailed results are given together with presentation of longitudinal changes in Tables 1 and 2, respectively.

Forearm—Follow-Up

Operated Side

Longitudinal BMD measurements for the ultradistal forearm (UD BMD) have shown a decrease only for measurement at 6 mo (0.386 ± 0.08 g/cm^2 vs 0.375 ± 0.08 g/cm^2, $p < 0.05$). Other BMD measurements did not differ over a period of observation. These results are shown in Table 1.

Nonoperated Side

Longitudinal BMD measurements for 1/3 forearm have shown an increase only for measurement at 3 mo (0.653 ± 0.07 g/cm^2 vs 0.668 ± 0.08 g/cm^2, $p < 0.05$). Other BMD measurements did not differ over a period of observation. These results are shown in Table 2.

Ultrasound Measurements—Baseline Results

Baseline Ad-SoS at operated and nonoperated sides were 2010.1 ± 80.6 and 2012.6 ± 66.2 m/s, respectively, and did not differ significantly.

Ultrasound Measurements—Follow-Up

Longitudinal QUS measurements performed at the operated hand at 3, 6, and 12 mo after surgery were 2003 ± 90, 2011 ± 77, and 2004 ± 69 m/s, respectively, and did not show significant changes in comparison with the baseline value.

Correlation Analysis

At baseline, distal motor latency correlated with UD BMD ($r = 0.51$, $p < 0.05$), electroneurography staging with middle forearm BMD ($r = 0.52$, $p < 0.05$), UD BMD ($r = 0.66$, $p < 0.001$), and total BMD ($r = 0.57$, $p < 0.05$).

Levine's scale did not correlate with baseline upper limb BMD and QUS variables.

Discussion

The most important finding of the present prospective study is an observation that CTS does not influence bone status at distal part of the affected upper limb. At baseline, skeletal status assessed by DXA at forearm and by QUS at hand phalanges did not deteriorate in comparison with the healthy side. Also, a 1-yr follow-up did not reveal any negative influence on the local skeletal status besides temporary decrease in UD BMD after 6 mo with onward

Table 2
Nonoperated Side: Ultradistal, Middle Distal, 1/3, and Total BMD of the Forearm at Baseline and After 3, 6, and 12 Mo (Mean, SD)

BMD measurements	Baseline	After 3 mo	After 6 mo	After 12 mo	p Value[a]
UD BMD (g/cm^2)	0.390 ± 0.08	0.396 ± 0.08	0.393 ± 0.08	0.386 ± 0.07	NS
MID BMD (g/cm^2)	0.559 ± 0.08	0.565 ± 0.09	0.564 ± 0.08	0.559 ± 0.09	NS
1/3 BMD (g/cm^2)	0.653 ± 0.07	0.668 ± 0.08[b]	0.665 ± 0.09	0.663 ± 0.09	NS
Total BMD (g/cm^2)	0.537 ± 0.08	0.544 ± 0.08	0.543 ± 0.8	0.537 ± 0.8	NS

Abbr: BMD, bone mineral density; MID BMD, longitudinal BMD measurements for the middle forearm; NS, not significant; SD, standard deviation; UD BMD, longitudinal BMD measurements for the ultradistal forearm.
[a]Time-effect based on repeated measures analysis of variance.
[b]Transient significant increase in comparison with baseline examination; $p < 0.01$.

improvement. Parallel, the functional status has significantly improved after successful surgery. Such observations indicate that female patients with CTS are not at risk of developing osteoporosis at the involved hand, and perhaps do not need special attention with regard to increased future forearm fracture risk.

Fracture risk is connected with 2 main issues: osteoporosis, which weakens bone strength, and a functional status decrease leading to falls. In the present study, we assessed the potential risk of osteoporosis as a consequence of CTS, and a preliminary thesis was not proven. Forearm fractures are very common in the female population from the RAC-OST-POL study *(16)* so an observation that women with CTS are not at increased risk of fracture has a significant value. This observation derived from longitudinal observation was shown using DXA, a *gold standard* in the assessment of bone health that supported the practical significance of the present study. One should also remember that biomechanic bone competences are also related to bone quality features such as microarchitecture or elasticity. QUS at hand phalanges was proven to have an ability to follow quality features of bone tissue so this method provides additional information *(17)*. The lack of changes for Ad-SoS at baseline and follow-up indicates that not only bone quantity (e.g., calcium content) expressed by BMD measurement but also bone quality had not deteriorated in the course of CTS. In several published studies, hand QUS measurements were able to discriminate between fractured and nonfractured individuals, suggesting that fracture risk is connected also with bone quality *(18–20)*.

The efficiency of the hand depends on cooperation of the skeletal, muscle, and nervous system. We hypothesized that peripheral neuropathy such as CTS impairs function in the region much bigger than the area of the damaged part of nerve innervation.

In CTS, the intracarpal pressure may be 4–10 times higher than the physiologic (depending on the position of the hand) *(21–23)*. It is very interesting if high pressure around bones could affect the status of bone tissue directly. However, it is extremely troublesome to verify that assumption, as the direct influence of increased intracarpal pressure is limited to small wrist bones only and there are no standardized diagnostic tools for quantitative assessment of mineralization in that selected area. On one hand, it is well proven that mechanical load (e.g., during physical exercises) has a positive impact on the bone structure *(24,25)*, but on the other hand, it is highly probable that constant high pressure around bones makes a totally different stimulus than dynamic mechanical load during physical activity.

In our study, we aimed to check if there are changes in the skeletal status of bones located either proximally or distally to carpal tunnel, which could be interpreted as secondary to muscle weakness or atrophy caused by CTS because it is known that disability of the limb causes its bone loss (so-called disuse osteoporosis) *(26,27)*. In other words, we studied the potential indirect impact of pathologically increased intracarpal pressure resulting in compressive median nerve neuropathy on the upper limb bones, which are available for assessment by standard tools (DXA and QUS). Therefore, we measured parameters of the bones located outside the carpal tunnel, but in the area of median nerve innervation.

Carpal ligament stabilizes the wrist. Surgical treatment makes temporary destruction of it. An advantage of this treatment is nerve decompression, but the consequence is temporary hand mobility and muscle strength restriction. In a short-time observation, this fact may be relevant. It was proven that upper limb disability after stroke leads to negative consequences for bone status *(28,29)*, whereas active use of the limb straightens bones *(30,31)*.

A similar study was performed by Schorn et al in 1978. In this project, bones of the hands were assessed by X-ray examination before and after CTS decompression. The authors found the increase of the bone density after operation at 1 and 3 metacarpals and at proximal phalanges 2, 3, and 4 *(32)*. The limitations of Schorn's study were the short follow-up time (range: 3–10 mo) and the small group of the patients ($n = 10$).

The present study has some limitations. Eight patients dropped out because some data were lacking. We investigated only females and longitudinal observation was limited to 1 yr. The inclusion of females only is a limitation of the study, but it guarantees the homogeneity of the group and reflects the epidemiology of CTS (at the prescreening step of our study the number of females with CTS was much greater than the number of males).

However, a very good response to therapy and fast improvement in functional status suggest that further problems related to hand functional status and possible side effects on bone status are not very probable.

In conclusion, successful surgery in patients with CTS in a 1-yr observation does not lead to permanent deterioration in bone status.

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