Research Article

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Thermography in the diagnosis of carpal tunnel syndrome

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Abstract

Introduction – Carpal tunnel syndrome (CTS) is a condition caused by chronic compression of the median nerve. The diagnosis is made mainly on the basis of clinical image and confirmed with electrodiagnostic testing (electromyography and nerve conduction study); however, these methods do not always aid in reaching the diagnosis of CTS. Moreover, they are invasive examinations, unpleasant for the patient and have to be performed by a qualified physician.

Aim – An evaluation of the usefulness of dynamic thermography in the diagnosis of CTS.

Material and methods – Forty patients were included in the study group. CTS was diagnosed based on clinical examination and electromyography. Forty healthy volunteers were included in the control group. Each of the participants was examined thrice with dynamic thermography. The patient’s hands were first cooled down and then a thermal camera measured their return to normal temperature. The measurement was repeated on the dorsal and volar aspects of each hand.

Results – The results obtained in the study show that a relief of symptoms after carpal tunnel release does not correlate with thermal image. Moreover, the return to normal hand temperature was faster in the control group. In patients with unilateral CTS, no difference was observed in thermographic images of the affected and healthy hands.

Conclusions –
1. Dynamic thermography can be useful in confirming CTS diagnosis.
2. Dynamic thermography does not allow for objective assessment of patient’s complaints in the postoperative period.
3. This method has currently limited clinical application. Due to complexity, it presently serves mainly scientific purposes.

Keywords: dynamic thermography, sympathetic system, carpal tunnel

1 Introduction

Carpal tunnel syndrome (CTS) is caused by chronic compression of the median nerve within the carpal tunnel. It is one of the most common peripheral mononeuropathies and the most common upper extremity neuropathy. Prevalence in general population is estimated at 0.1–1%.

Risk factors include female gender and physical labour. Ten percent of patients have bilateral CTS [1–3].

Clinical presentation is not always obvious. In some cases, one group of symptoms can dominate for years. There are patients with considerable motor deficits without pain or sensitivity impairment and patients with positive
electrophysiological results who, despite being in severe pain for years, have no muscle atrophy. This varying clinical image could be a result of overlap syndromes, multifocal compression on the median nerve (“double crush” syndrome) or substitution of lost median nerve functions by the ulnar nerve [8].

Electrodiagnostic testing plays a key role in diagnosing peripheral nerve disorders. Nerve conduction study (NCS) and electromyography (EMG) are mostly used when CTS is suspected. NCS directly measures the sensory and motor fibre conduction speed and amplitude, while with EMG it is possible to register and assess the function of thenar muscles (it has a lower sensitivity than NCS). Many clinicians consider these electrodiagnostic examinations as gold standard to diagnose CTS; however, it has been proved that approximately 18% of patients with clinical signs of median nerve compression have unimpaired nerve conduction in a classic NCS examination. Both NCS and EMG are invasive, unpleasant for the patient and a qualified physician must perform them. Moreover, according to many authors, they are not more sensitive than physical examination combined with medical history [8–11].

In search of new objective CTS diagnostic tests, researchers have recently taken interest in thermography. Infrared thermography (IRT, IR) records a map of surface temperature of an examined area. Skin temperature indirectly reflects blood supply to a given area, which changes in response to various stimuli. Such measurements are easy, non-invasive, inexpensive and quick. These features make IRT a promising diagnostic test [12–14] (Tables 1 and 2).

Few studies evaluating thermography in CTS have been published. Furthermore, no measurement standard is presently available [15].

2 Aim

An evaluation of the usefulness of dynamic thermography in the diagnosis of CTS.

3 Material and methods

3.1 Material

Out of 84 patients who underwent carpal tunnel release in our department in years 2014–2016, 40 were included in the study group – 32 females and 8 males aged 32 to 68 (mean age 54 years). Diagnosis was based on clinical examination and EMG. Symptoms had to present for a minimum of one year, mean duration was 21 months. Ten patients had bilateral CTS. Right hand was affected in 29 cases, left hand in 11 patients. Thirty-two patients were right-handed, 8 patients left-handed.

Control group consisted of 40 healthy volunteers: 25 women and 15 men aged 27 to 63, mean age was 49 years. The right hand was dominant in 34 people, the left hand in 6. No member of the control group complained on any hand, cervical or thoracic spine disorders.

3.2 Methods

Study protocol was approved by the Pomeranian Medical University Ethics Committee (KB-0012/94/13). Patients included in the study had no significant comorbidities. Smokers and patients with carpal release or carpal tunnel injections were excluded from the study. Each patient was examined with dynamic thermography thrice. First examination was performed one day prior to the surgery, second a day after surgery and the third one 2 weeks after surgery.

All measurements were taken in a room with a steady temperature of 22°C and 65% humidity. Patient’s hands were placed on a table 20 cm away from the camera and fan, which acted as a cooling device. Hands were cooled down for 20 s. A FLIR T335 camera was used to obtain thermal images after the fan was stopped. Measurements were sampled every 5 s for 3 min. The dorsal aspect was assessed first, then after re-cooling, the volar side. To analyse the thermographic images, FLIR Research IR programme was used. Temperature values were sampled from the fingertips (on the volar side) and nails (on the dorsal side) of fingers I–III. Capillary circulation efficiency was measured as area under curve in a graph that showed temperature change in time.

4 Results

Patients from the study group had undergone carpal tunnel release. At 24 h postoperatively, 37 patients reported spontaneous pain mitigation (which previously woke them up), while 3 patients did not report any improvement. At 14 days postoperatively, symptoms subsided in 39 patients, while one reported an exacerbation of pain.
Table 1: Skin temperature change in the study group (volar and dorsal side) on days −1, 1 and 14 after 3 min cold exposure expressed as area under the curve

| Study group | Left (L) | Right (R) | Volar aspect (V) | Dorsal aspect (D) |
|-------------|---------|-----------|-----------------|------------------|
| Day −1 [cm²] Day 1 [cm²] Day 14 [cm²] | Day −1 [cm²] Day 1 [cm²] Day 14 [cm²] | Day −1 [cm²] Day 1 [cm²] Day 14 [cm²] |
| Right (R) | Left (L) | Right (R) | Left (L) |
| 573.7871 | 7407.9383 | 5139.8895 | 5588.9585 |
| 6696.8626 | 6618.3152 | 6134.609 | 6148.8008 |
| 7077.037 | 6919.94 | 6981.5185 | 7094.2211 |
| 7005.7044 | 7346.557 | 7493.6902 | 7381.5325 |
| 709.701 | 7397.985 | 7515.416 | 7735.987 |
| 6678.5851 | 7295.9813 | 6926.9649 | 6494.2285 |
| 709.701 | 7397.985 | 7515.416 | 7735.987 |
| 634.5163 | 7515.998 | 4194.0041 | 6437.497 |
| 6590.219 | 6295.712 | 5788.669 | 6324.852 |
| 7333.7067 | 6258.4961 | 5720.772 | 6524.31 |
| 7333.7067 | 6258.4961 | 5720.772 | 6524.31 |
| 7024.157 | 6579.372 | 5720.772 | 6524.31 |
| 7438.845 | 6579.372 | 5720.772 | 6524.31 |
| 7641.064 | 6579.372 | 5720.772 | 6524.31 |
| 7636.349 | 6579.372 | 5720.772 | 6524.31 |
| 7465.357 | 7229.305 | 7940.297 | 7451.362 |
| 7536.542 | 7232.347 | 7385.472 | 7451.362 |
| 7343.36 | 7578.313 | 7383.942 | 7451.362 |
| 7358.729 | 7383.942 | 7383.942 | 7451.362 |
| 7375.246 | 7352.746 | 7352.746 | 7451.362 |
| 7634.632 | 5518.511 | 6959.144 | 6959.144 |

Thermography in the diagnosis of carpal tunnel syndrome
During dynamic thermography, it was observed that after the cold stimulus had been withdrawn, temperature rose during the first 2 min and then stopped. Therefore, only data gathered during these first 2 min were included in the statistical analysis (Figure 1).

5 Discussion
In patients with median nerve compression, it appears natural that apart from motor and sensory fibre damage, autonomic nerve fibres can also be affected. Clinical examination and electrophysiological testing both measure the extent of motor and sensory function loss. Some patients, however, complain about symptoms resembling Raynaud’s phenomenon. Trophic changes to the skin are rare, although possible [16,17]. Literature data show that even as many as 50% of patients with CTS may suffer from sympathetic dysfunction [18]. In the study group, 75% of patients reported symptoms related to the sympathetic system: sweating, dryness, pallor, rubor, swelling, or cyanosis. Literature reveals many papers where the extent of sympathetic damage in CTS is evaluated by plethysmography, capillaroscopy, or Doppler ultrasound. Another method is sympathetic skin response (SSR), where the electric potential of the skin varies depending on surface temperature, which reflects the activity of sweat glands controlled by the sympathetic nervous system [19–24].

Table 1: Continued

| Study group | Dorsal aspect (d) | Volar aspect (v) |
|-------------|------------------|-----------------|
|             | Right (R) | Left (L)    | Right (R)    | Left (L)    |
|             | Day −1 [cm²] | Day 1 [cm²] | Day 14 [cm²] | Day −1 [cm²] | Day 1 [cm²] | Day 14 [cm²] | Day −1 [cm²] | Day 1 [cm²] | Day 14 [cm²] |
| 36          | 6926.741    | 7192.663     | 7193.323     | 6628.539    | 7448.668     | 7266.991     | 7091.038    | 7361.571     | 7425.18    |
| 37          | 6928.644    | 7192.663     | 7193.323     | 7028.173    | 7303.756     | 7498.523     | 7421.219    | 6441.04      | 7516.028   |
| 38          | 6607.199    | 6805.185     | 6896.199     | 5655.211    | 6185.663     | 6499.905     | 6386.031    | 7575.476     | 6100.129   |
| 39          | 5617.811    | 6222.673     | 6986.948     | 5754.189    | 5641.753     | 5198.507     | 5922.529    | 7862.005     | 6047.83    |
| 40          | 5505.797    | 5240.434     | 6184.999     | 5572.637    | 5892.825     | 5199.465     | 5368.412    | 7594.724     | 6065.676   |
Table 2: Skin temperature change in the control group (volar and dorsal side) on days −1, 1 and 14 after 3 min cold exposure expressed as area under the curve

| No | Right (R) | Dorsal aspect (d) | Left (L) | Volar aspect (V) |
|----|-----------|-------------------|----------|------------------|
| Day −1 [cm²] | Day 1 [cm²] | Day 14 [cm²] | Day −1 [cm²] | Day 1 [cm²] | Day 14 [cm²] |
| 1 | 7931.789 | 8018.725 | 7992.002 | 7944.69 | 8021.499 | 8001.998 |
| 2 | 7420.906 | 7807.555 | 7549.036 | 7517.381 | 7746.42 | 7730.55 |
| 3 | 7375.576 | 7242.062 | 7417.303 | 7285.791 | 7331.754 | 7442.08 |
| 4 | 7496.062 | 7470.305 | 7660.607 | 7506.423 | 7573.31 | 7666.501 |
| 5 | 7838.856 | 7801.766 | 7567.021 | 7282.60 | 7777.997 | 7605.85 |
| 6 | 7841.396 | 7797.629 | 7802.432 | 7831.478 | 7830.348 | 7830.986 |
| 7 | 7939.365 | 7956.175 | 8003.475 | 7902.297 | 7933.434 | 7974.1 |
| 8 | 7785.669 | 7395.189 | 5898.385 | 7814.308 | 7497.196 | 5924.191 |
| 9 | 7847.208 | 7481.591 | 6979.941 | 7851.236 | 7499.11 | 7029.309 |
| 10 | 8122.939 | 7690.557 | 7379.837 | 8006.076 | 7628.321 | 7241.683 |
| 11 | 5484.605 | 6107.246 | 5430.307 | 5578.629 | 6284.529 | 6148.846 |
| 12 | 7614.6 | 6932.045 | 6589.296 | 7349.413 | 6972.879 | 6887.417 |
| 13 | 5475.814 | 5996.919 | 5927.656 | 5434.092 | 6087.442 | 5353.354 |
| 14 | 7521.972 | 7581.084 | 7577.265 | 7556.966 | 7598.959 | 7548.54 |
| 15 | 7256.842 | 7289.844 | 0 | 7192.58 | 7216.869 | 6171.461 |
| 16 | 7938.222 | 8006.154 | 0 | 7936.055 | 8003.07 | 0 |
| 17 | 7347.619 | 7810.582 | 7524.392 | 7047.287 | 7680.187 | 7691.496 |
| 18 | 5426.226 | 6037.146 | 5431.891 | 5520.76 | 6188.335 | 6262.346 |
| 19 | 7484.808 | 7475.43 | 7519.076 | 7493.637 | 7551.137 | 7526.288 |
| 20 | 7809.787 | 7750.991 | 7578.268 | 7884.112 | 7692.559 | 7567.222 |
| 21 | 7838.235 | 7819.318 | 7817.969 | 7838.25 | 7809.712 | 7794.23 |
| 22 | 7933.339 | 7914.865 | 8006.161 | 7916.831 | 7931.969 | 7957.458 |
| 23 | 7791.83 | 7048.545 | 8635.373 | 7808.404 | 7457.39 | 5828.169 |
| 24 | 7836.506 | 7447.504 | 6963.893 | 7791.804 | 7434.288 | 6945.826 |
| 25 | 8127.872 | 7681.88 | 7438.169 | 8095.436 | 7627.691 | 7347.806 |
| 26 | 7424.791 | 6589.296 | 6703.144 | 7033.306 | 6652.372 | 6710.664 |
| 27 | 7334 | 7250.992 | 7461.055 | 7421.676 | 7362.357 | 7411.68 |
| 28 | 7836.506 | 7447.504 | 6963.893 | 7791.804 | 7434.288 | 6945.826 |
| 29 | 5452.463 | 5983.178 | 5907.96 | 5353.154 | 6054.229 | 5218.644 |
| 30 | 7542.093 | 4577.265 | 7523.255 | 7458.5 | 7567.339 | 7516.741 |
| 31 | 7290.9382 | 7252.433 | 6430.989 | 7513.462 | 7514.4 | 6097.15 |
| 32 | 7983.932 | 7998.098 | 7930.323 | 7789.432 | 8009.213 | 8013.3344 |
| 33 | 7400.433 | 7840.211 | 7398.321 | 7418.321 | 7534.432 | 7723.212 |
| 34 | 7349.234 | 7238.245 | 7381.23 | 7361.321 | 7382.234 | 6990.321 |
| 35 | 7564.423 | 7423.44 | 7790.21 | 7440.221 | 7543.133 | 7612.309 |
included into the study group, the sensitivity, however, was lowered. In our study, most patients were diagnosed with moderate CTS (stage II, according to NCS). Papez also observed during his study that the sensitivity of the examination was higher on the dorsal side of the hand. [25–27]. Similar conclusions were made by Zivcak et al. [28]. Some authors examined only the volar aspect of the hand [29–31]. In our study, both the volar and dorsal sides of the hand were evaluated, and the results show a significant difference in blood flow for both sides between the study and the control group.

Secondly, do thermographic images of the unaffected hand in CTS patients in three examinations (a day before the surgery, one day after the surgery and 14 days after the surgery) differ among each other? In unilateral CTS, thermographic images of the unaffected hands did not differ in consecutive examinations. Similarly, 3 examinations of control group volunteers did not show any differences. Such stable thermographic images confirm the reproducibility of the method.

Thirdly, does the relief of symptoms during the first day after surgical carpal tunnel release correlate with changes in thermographic images?

Immediate relief of nocturnal pain after carpal tunnel release is seen in most patients with CTS. In this study, a similar postoperative observation was made in nearly all patients. It did not, however, correlate with thermographic images captured in 24 hours and 14 days after the surgery. In literature, there is scarce information on changes in blood circulation in patients with CTS after surgical release. A similar study had been conducted by Z. Ming and J. Sivola in 2007. Static thermography had been used to evaluate capillary flow. The diagnosis of CTS was made purely on NCS, without taking the clinical image into consideration. The first thermographic image was captured prior to the surgery, the second 6 months after. In our study, carpal tunnel was diagnosed mainly on signs and symptoms with NCS results only to confirm the diagnosis. A lack of NCS result with a clear clinical image of CTS did not exclude a patient from the study. Ming et al. in their study showed that an improvement in circulation follows a carpal tunnel release within 6 months. Immediate relief of nocturnal symptoms is related to an increase of blood flow to the nerve itself, while full healing is achieved after 6 months due to reinnervation [29].

Lastly, does a thermal image of the affected and unaffected hand differ in the same patient with CTS?

A comparison of the affected and unaffected hand in the same patient with CTS did not reveal statistically significant differences in hand temperature. This may

| No | Control group |
|----|---------------|
| Day −1 (cm²) | Day 1 (cm²) | Day 14 (cm²) |
| Right (R) | Left (L) | Right (R) | Left (L) | Right (R) | Left (L) |
| 38 | 7203.646 | 7319.735 | 7504.495 | 7539.907 | 7556.488 | 7570.203 | 7579.385 | 7817.696 | 7800.021 | 7817.696 |
| 37 | 5430.307 | 6068.343 | 5415.601 | 6294.398 | 5523.639 | 6948.864 | 5541.175 | 6688.674 | 6441.046 | 6745.145 |
| 36 | 7203.646 | 7319.735 | 7504.495 | 7539.907 | 7556.488 | 7570.203 | 7579.385 | 7817.696 | 7800.021 | 7817.696 |
| | | | | | | | | | | |
be a result of many overlapping factors. CTS is diagnosed with clinical image. NCS is an additional examination to confirm the already suspected diagnosis and to evaluate the extent of nerve damage. Healthy limbs in patients with CTS were described as those showing no clinical symptoms, not ones with a negative NCS result. Out of 40 study group patients, as few as 12 people had a bilateral NCS, and in that group, only 2 patients had CTS excluded. Literature data estimate the prevalence of bilateral CTS at 50%. Not all symptoms of early CTS could be noticed by a patient. Thus, it may be possible that among 23 healthy limbs, some may be in an early stage of the disease. Most researchers compared hands with confirmed CTS with healthy limbs from the control group. Few authors focused on looking upon both hands of the same patient. The majority assessed the temperature difference of two corresponding points on the volar and dorsal aspect and then compared the results to the control group [25–28].

6 Results

Our research shows that:
1. Dynamic thermography can be useful in confirming CTS diagnosis.
2. Dynamic thermography does not allow for objective assessment of patient’s complaints in the postoperative period.
3. This method has currently limited clinical application. Due to complexity, it presently serves mainly scientific purposes.

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