Infrared Thermography as a Screening Method for Carpal Tunnel Syndrome Diagnosis

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Abstract. *The presented study deals with thermographic (IRT) diagnosing of the Carpal Tunnel Syndrome (CTS). It is considered to be an approach to screening thermal manifestations of the difference between the physiological temperature distribution in the skin of dorsal hands and pathophysiological temperature distribution in hands affected by CTS. We created a database of 356 thermal images of dorsal and palmar side of 162 healthy (n_{RS}= 162) and 16 pathological hands (n_{CTS}=16) with clinically diagnosed CTS of 9 patients. Pre-surgical thermograms of the hands with CTS of each subject were taken and stored using IRT (Thermocamera Fluke Ti55/20). We observed the temperature distribution in the entire hand and partial temperatures of the center point of carpals (D1/P1) as well as the area of distal phalanges on middle fingers (D5/P5). The Index of Median Nerve ($_DMI=(T_{D1}-T_{D5})$; $_PMI=(T_{P1}-T_{P5})$) was determined based on resulting data. Test results obtained from measurements of the two points on the dorsal side of hands showed that the temperature of CTS hands is typically higher in the phalanges as opposed to the wrist ($_DMI<0$, 62.5%), while the temperature is the lowest in distal phalanges (D5) of healthy hands ($_DMI\geq0$, 81.5%). The sensitivity of IRT diagnostic test in our diagnostic process of CTS was calculated to be 0,625.*

Keywords: Thermography, Carpal Tunnel Syndrome, Index of Median Nerve

1. Introduction

The goal of the presented paper is to discuss the role of medical thermography in the diagnostics of neuro-vascular diseases of the human body such as the Carpal Tunnel Syndrome (CTS). Main issues include limits to investigating the median nerve area, diagnostic importance of measurements, etc.

Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS), or median neuropathy in the wrist, is a medical condition in which the median nerve is compressed at the wrist, which leads to paresthesia, numbness and muscle weakness in the hand. As a result of these predisposing factors, the finger flexor tendons cause friction as they move over one another and the generated heat causes local inflammation. This inflammation irritates the nerve and the resulting pain is what patients experience when they have CTS. The reason there is so much pain associated with CTS is because there is a lot of pressure on the Median Nerve.

CTS can be diagnosed with special tests and EMG, which is the only imaging diagnostic method. This method is based on myodynamia, but results from EMG are not always clear. In addition, EMG uses electrodes either in contact with the body or invasive electrodes. Modern medicine seeks to be contactless and noninvasive, which also makes thermography a suitable diagnostic method. A nerve conduction study, inflammation and temperature distribution may be of benefit to clarifying the diagnosis and this is the goal of this study. [1], [2], [3], [4], [10]

2. Subject and Methods

Contactless, noninvasive and painless infrared thermography (IRT) was used during these examinations. Skin temperature of the dorsal and palmar side of hands from our database (n= 356) was measured with an infrared camera (ThermaCam Fluke Ti55/20, Fluke, USA). This thermographic camera generates a matrix (representing image points) of temperature values. They feature 320 x 240 (76 800 pixels) detectors with industry leading thermal sensitivity (≤0.05 °C; 50 mK NETD) for high resolution. The camera works in the spectral range from 8 to 14 μm (human body infrared radiation is the highest in the spectral range around 9.66 μm) and the calibrated temperature range from -20 to 100 °C. Data were obtained through high-speed (60Hz) analysis.

Emissivity of the skin was set up 0.98 in the camera, the ambient temperature was measured with an infrared (laser) thermometer (Pyrometer Testo 810) and a contact multimeter (Almemo Multimeter 2690, Ahlborn, Germany) was used for verification. The camera was calibrated using the system's internal calibration process before each recording. All thermograms (n=356) were processed using special software (SmartView 2.1, FLUKE, USA).

The database consists of reference thermograms (*RT*; n_{RT}=324) and pathological (*CTS*) thermograms (*CTS*; n_{CTS}=32). They are divided into dorsal (D_{RT}, $_Dn_{RT}$=162; D_{CTS}, $_Dn_{CTS}$=16) and palmar (P_{RT}; P_{CTS}) thermograms. Current (thermographic) research focuses on the dorsal side of hands. Therefore our calculations focus on thermograms of dorsal hands (D_{RT}, $_Dn_{RT}$=162; D_{CTS}, $_Dn_{CTS}$=16).

Conditions of Measurement

Measurements were carried out under the same conditions, always in the same room with the ambient temperature at 20 °C (±2°C). The blinds in the room were drawn in order to eliminate the impact of solar radiation and the room was air-conditioned to keep the same temperature during each measurement. [5], [6]

The Index of Median Nerve

We identified five points in the lines of the median nerve (on dorsal and palmar side of hand), on which we measured the temperature. For the dorsal side of hands, there are the center point of carpals (D_1), the center point of metacarpals (D_2) and the fingertips of the middle finger from proximal phalanges (D_3), the intermediate phalanges (D_4) to the distal phalanges (D_5). (see Fig.1)

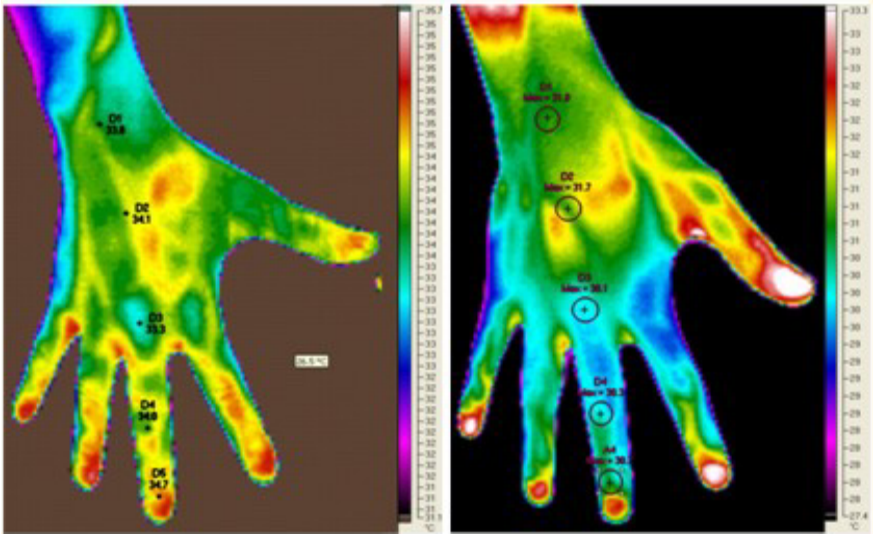

Fig. 1. Location of points Di, the left thermogram shows a hand with CTS (D_{CTS}), the right one shows a hand from reference thermograms (D_{RT})

3. Results

The data showed that the skin temperatures of median nerve distribution area on dorsal hands varied significantly between CTS and the control group. Results will be confirmed by further termal screening of a statistically significant group of patients.

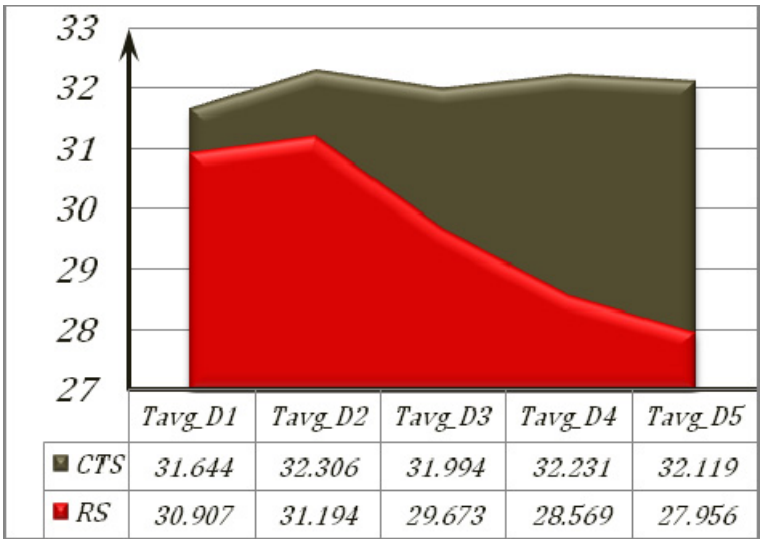

Fig. 2. Arithmetic average of the temperature of hands on the dorsal side of hand (line of median nerve)

Graph (Fig. 2) illustrates the relationship between points of line of the median nerve from D_{RT} ($_{D}n_{RT}$=162) and D_{CTS} ($_{D}n_{CTS}$=16).

The cumulative averages of temperature distribution, which were taken from reference and pathological thermograms on the dorsal side of the line of the median nerve, show a big difference between healthy and CTS hands. To be precise, there were 4°C between average temperatures which were taken from $_{CTS}D_5$ and $_{RT}D_5$. This difference was the main reason to establish the Index of Median Nerve. The following equation is used to calculate the Index of Median Nerve on the dorsal side of hands (MI; Graph 2, 3, 4):

$$_{D}MI = T_{D_1} - T_{D_5} \qquad (1)$$

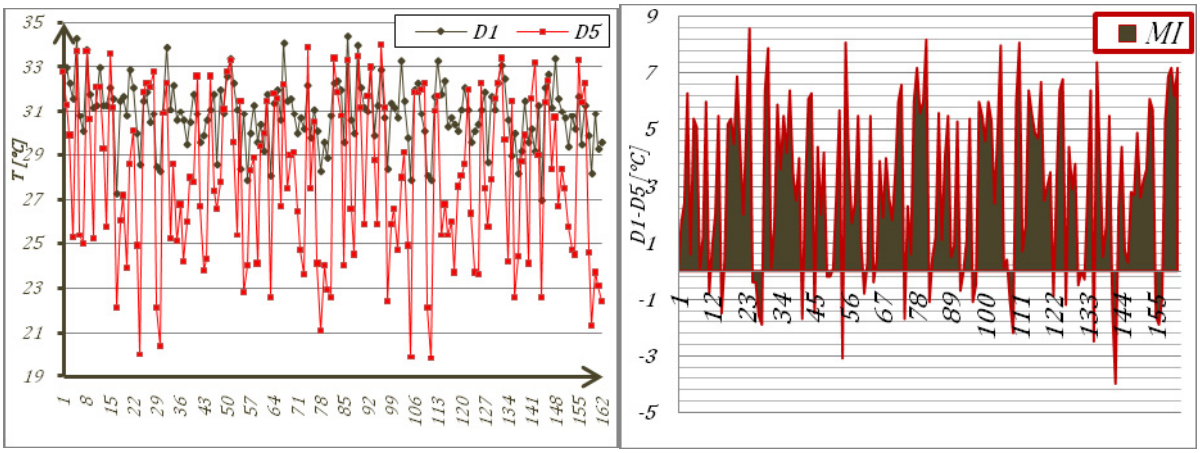

Fig. 3. Index of the Median Nerve ($_{D}MI_{RT}$) from D_{RT} ($_{D}n_{RT}$=162)

A negative difference D_1-D_5 ($_{D}MI<0$) from D_{RT} ($_{D}n_{RT}$=162) was detected in 30 healthy hands which account for 18.5% of total normal thermograms from the dorsal side of D_{RT}, see Fig. 3.

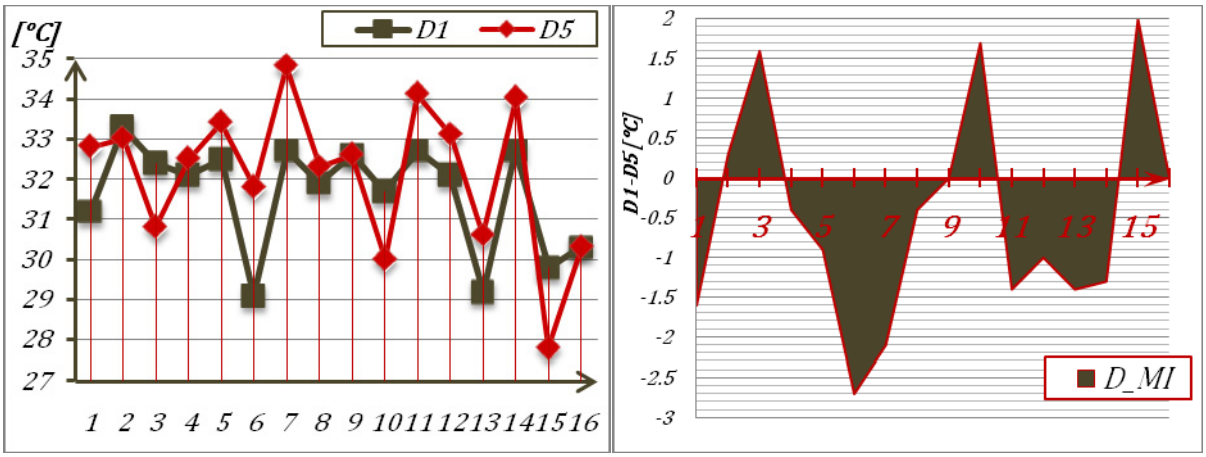

Fig. 4. Index of the Median Nerve ($_{D}MI_{CTS}$) from D_{CTS} ($_{D}n_{CTS}$=16)

A negative difference $_{D}MI_{CTS}$ ($_{D}MI<0$) from D_{CTS} ($_{D}n_{CTS}$=16, dorsal side of hands from CTS patients) was detected in 10 cases (that is 62.5% from D_{CTS}), see Fig. 4, Fig. 5.

Table 1. The Index of Median Nerve ($_{D}$MI).

The Index of Median Nerve (MI)		
$_{D}MI = T_{D_1} - T_{D_5}$	[°C] ± SD	$_{D}$MI<0 [%]
D_{CTS}	- 1,165 ± 2,944	62,5%
D_{RT}	2,937 ± 2,936	18,5%

Estimation of index test results

The diagnostic test performance includes consideration of validity and reliability of the test (infrared thermography). (See table 2).

Table 2. Assessment of validity of a diagnostic test

		Reference test [EMG]	
		Positive	Negative
Diagnostic test [Thermography]	Positive	a = 10	b = 30
	Negative	c = 6	d = 132
Total sample size		n_1 = 16	n_2=162

Based on Tab.3 above, measures of validity and 95% confidence intervals were calculated confidence interval for sensitivity: $0.625_{\pm 0.237}$ and confidence interval for specificity: $0.815_{\pm 0.060}$.

4. Discussion

Calculated sensitivity (0.625) and specificity (0.815) of diagnostic test showed that thermography could be the promising method in diagnostic process of CTS, but we need more pathological thermograms for study for evidence. From our results thermogram of dorsal side of the hand has more significant importance for diagnostic process than the palmar side of hand what correlates with other studies in the world. [1], [2], [3], [4], [8]

5. Conclusions

Sensitivity and specificity of thermographic diagnostic tests were realized on 162 healthy hands (${}_{D}n_{RT}$=162) whose dorsal side was scanned (D_{RT}) and 16 pathological hands (${}_{D}n_{CTS}$=16) whose dorsal side was also scanned (D_{CTS}). An EMG diagnostic method was applied as a referential test. Sensitivity and specificity were calculated using standart formulas and argument ${}_{D}MI = (T_{D1}-T_{D5})$ from the database of dorsal scans. The calculated sensitivity of diagnostic test (0.625) with the confidence interval $0.625_{\pm 0.237}$ and specificity of diagnostic test (0.815) with the confidence interval $0.815_{\pm 0.060}$ showed that thermography could be a promising method in the diagnostic process of CTS, its advantages being its non-invasiveness and contactlessness. More statistically significant measurements are required to confirm obtained results.

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