

Detection of carpal tunnel syndrome by infrared thermography

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Abstract – The aim of this study is to approach the possibilities of stimulated infrared thermography to the carpal tunnel syndrome diagnosis. Eleven patients were studied. Six of them were affected by the carpal tunnel syndrome. The five others were healthy. The study consists in exciting the patients' hands and in analyzing their thermal response. The infrared thermograms obtained show that the hands infected by the carpal tunnel syndrome give a different thermal response.

Key words: Carpal tunnel syndrome / diagnosis / stimulated infrared thermography / non-destructive testing / median nerve

1 Introduction

The carpal tunnel syndrome is the result of the median nerve compression [1]. At first, the pain from carpal tunnel syndrome comes with a loss of feelings in the first three fingers (thumb, index finger, and the middle finger). Actually the front of those three fingers corresponds to the median nerve innervation (Fig. 1)

The syndrome often settles in a progressive manner. The first signs appear at night and during manual works, but they easily go away by gently hand shaking. As for the loss of feeling, it can be clinically reproduced by tests as Tinel's, Phalen's and Phalen reverse [2–5]. The evolution of the pathology makes those signs permanent. Moreover, those manifestations can be strengthened by a difficulty to hold objects; this means that the motor region of the nerve is affected. In this case, an electromyogram is often prescribed because it should bring a medico-legal evidence to attempt a surgery. But this is an invasive technique and appears to give no additional reliable diagnosis [6–8]. In the statistics of the professional troubles entitled to compensation, the carpal tunnel syndrome is the most frequent with a rate of 37% in 2002 for occupational disease referenced [9, 10]. Even if in 50% of the case, the syndrome is idiopathic, some of the traumatic and micro-traumatic causes can be caused by professional attitudes such as typing, for a long time, repeated fingers movements and the usual use of vibrating tools [11]. As the objectification of the carpal tunnel syndrome by

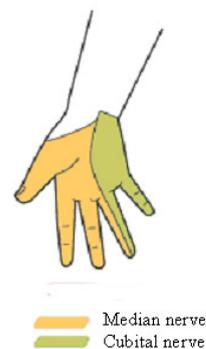


Fig. 1. The different sensitive areas of the anterior face of the hand and corresponding nerves.

electromyogram is invasive and no more trustworthy than usual clinical tests, it seems interesting to explore other potential diagnosis ways. The infrared thermography is a non-destructive testing already widely used to support medical diagnosis [12–23]. With this in mind, the aim of this tool is to detect any human body thermal changes. For a carpal tunnel syndrome, a lot of experimentation proves that the sympathetic nervous system quota related to the median nerve is the first to be injured [24, 25]. It creates vasomotor troubles in the hand and so, potentially, local thermal variations. It seems then that using infrared thermography is a good candidate to analyze these variations [26–33]. Furthermore, the carpal tunnel syndrome first injures the non myelinated nerve fibers

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and this type of fiber cannot be detected by an electromyogram, which can only find the myelin sheath of the neurons [34]. This means that the infrared thermography should be able to detect the syndrome earlier. To finish, this control method is non-destructive and analysis allows remote-control without contact. For all those reasons we thought it was interesting to explore the possibilities towards detecting carpal tunnel syndrome given by the infrared thermography. Our presentation is composed of four parts, to begin with, we will explain the way we recruited the patients, then we will expose the experimental protocol, next we will present the results. Finally, we will draw conclusions.

2 Experimental conditions required

2.1 Choice and recruitment of patient cohort who participated in the study

We contacted health professionals (neurologist, generalists, and rheumatologists from Paris's region and from the Osteopathic Clinic of the "Osteopathic superior school") that could encounter people suffering from a carpal tunnel syndrome. First of all we informed them with a written paper about the goal of the research and the way the study would take place. Then, we gave them a document to inform their patient that would be susceptible to correspond to our need. At the term of this first phase, which lasted for a month, six pathological patients contacted us. All patients met the selection criteria that we set. These are: the carpal tunnel syndrome should be diagnosed by electromyography (EMG). Patients should not have mobility problem, because these patients may have venous return trouble related to hypomobility. Patients should perform normal activities. Patients should not suffer from anxiety, depression and have no social problem. Patients had to have no pathology associated with carpal tunnel syndrome to analyze the disease only. We then listed the following diseases: infections with febrile syndrome, metabolic disorders, hormonal diseases, rheumatoid arthritis, tuberculosis, syringomyelia, multiple sclerosis, cervical radiculopathy, lateral sclerosis, neck amyotrophy, Raynaud's disease, cancer, unconsolidated fracture, trauma for less than three weeks. Patients had to be in the central nervous system (taking neuroleptics or benzodiazepines) drug treatment, so as not to disrupt the distribution of body temperature. Patients could not have peripheral nervous system medication (vasodilator, antihypertensive) in order not to disrupt the sympathetic vasoconstrictor response and thus again the human body temperature medication. Patients could not be under osteopathic treatment as leading again, by disruption of the central and peripheral nervous systems, to a change in body temperature. Patients could not be in menstruation process, so as not to alter with hormonal modification the body temperature. Patients could not have been taking anti-inflammatory drugs orally or by infiltration for less than three months, as these treatments lead to a reduction of the signs of carpal tunnel syndrome, which

obviously distort the measurements. Patients could not participate at the time of analysis to an other biomedical research, so as not to cause interference and false diagnoses. Finally, patients had to agree to comply with the study constraints. At the end of the recruitment phase, we selected eleven patients. Of these, six patients met our selection criteria and had a carpal tunnel syndrome diagnosed by electromyography. The other five were healthy subjects, showing no entrapment.

2.2 Preliminary constraints imposed to patients

Before the thermography examination, and in order not to create interference, we had to propose constraints to the patients:

- Not to apply topical skin medication where the analysis should be performed.
- Not to smoke in the hours before the examination.
- Not to take a big meal for a few hours before the examination.
- Not to drink large amounts of coffee or tea in the hours before examination.
- Not to wear tight clothes.
- Not to perform an intense exercise for a few hours before the test.
- Not to have received physiotherapy (electrotherapy, ultrasound, thermotherapy, cryotherapy, massage and hydrotherapy): treatments with cutaneous thermal effects that can last 4–6 h after administration.

2.3 Experimental protocol followed

2.3.1 Environmental conditions selected for the study

The experimental protocol we followed is the one usually used for medical analysis by infrared thermography [12–21]. First of all, to avoid vasomotion phenomena we set the temperature of the room at 22 °C (+/– 1 °C). In fact, the temperature of the examination room is an important element for influencing the state vascularization of skin [22]. We ensured that the experimental area was subjected to a low air exchange. We verified that humidity was maintained to a comfort zone that is to say between 40% and 70%. In our study, it was typically around 50%. We also sought to develop our analysis in part of sufficient dimensions, allowing some thermal stability. In our case study, these were about 10 m × 8 m × 2.5 m. Finally, for patients' comfort and therefore to avoid generating disruptive thermal stress, we put a comfortable chair placed beside the analysis table on which the patient sat with both dorsal side hands on the table (Fig. 2).

2.3.2 Choice and implementation of infrared thermography camera

At this point of the study, we had to choose the type of camera using infrared thermography and equipment



Fig. 2. Layout of the experimental area.



Fig. 3. The infrared camera of thermography used.

to associate. To do this, we first considered the radiative properties of human skin [35]. A literature study shows that human skin has a maximum emissivity in a wavelength band between $7 \mu\text{m}$ and $10 \mu\text{m}$. This value is approximately 0.95. As also the temperature of the scanned object is close to room temperature, it is therefore natural to a thermography camera “long waves” that we chose. In addition, the thermal phenomenon being studied rather slowly, it seemed sufficient to implement a bolometer array camera. So this is a camera-type A320 series27 that was used for this study (Fig. 3).

This infrared camera of thermography was mounted on a tripod of studio, to allow easy adjustment and reproducibility tests. The distance camera-hand was fixed at 90 cm beginning of the day and to have images of radiometric quality, we took care to put on the camera thirty minutes before the first study. Thus, during the study the camera was in thermal equilibrium with its environment. Regarding the area taken, we standardized as done for example in radiology. It was attached to a square area of 50 cm side. The camera position was chosen to take advantage of the isotropic emission of the skin. So we set the camera perpendicularly to the analyzed hand. The support on which hands were placed was chosen polymethylmethacrylate (Plexiglas). Indeed, this material is low effusive thermally, so it will not disrupt the low temperature distribution in the hands analyzed. Moreover, it also provides a solid background that allows better reading thermograms.

2.3.3 Patient management

The progress of the experiment was as follows: first the patient was invited to read the experimental protocol, and then to sign in duplicate. This step was to build confidence and thus reduce temperature changes potentially generated by stress. It also aimed to verify that the patient had not consumed stimulant (coffee, tea, soda) or smoked tobacco within two hours before the experiment. He was then invited to wash his hands with soap with a neutral pH. The objective of this phase was to remove a potential greasy film covering the hands, which can lead to local emissivity variations. The hands were then wiped with paper towels. Obviously, the patient was asked after this step not to touch anything. The patient was then asked to sit in the analysis room, positioning his hands on the analysis table, dorsal side on the table on a plate of polymethylmethacrylate, on which markers were placed to help an accurate and reproducible positioning of the hands. The table height was adjusted to the patient so that it was comfortable. This was to prevent an additional stress and a possible back pain onset. The height of the camera was then adjusted to meet the distance camera-hand defined by the protocol. Finally, the thermography recording could take place. Once the previously mentioned precautions taken, the recording could begin. The experimental protocol was then as follow: immediately after washing and drying hands, the patient was asked to place his hands on the plate of polymethylmethacrylate. To assist in good positioning of the latter, reference points were marked on the plate. This initial phase was a learning stage aimed to learn the actions to be followed in the analysis. A first thermogram named t_0 was acquired at this point. This phase, as showing the progress of the analysis, was also intended to reassure the patient. Then, the patient was asked to place the palmar surface of both hands on ice blocks for 60 s. This analysis phase aimed to cause sympathetic nerve stimulation. This type of excitation has been used by Nabel et al. [36] to study coronary arteries vasomotion. It seemed to us a possible use for this study. After this stimulation phase the patient was asked to put his hands on the analysis table. A succession of taking infrared views was then developed. These were spaced about 30 s. The first is denoted t_1 in the remainder of this article, the second t_2 and so on until t_{22} to analyze the longest.

3 Experimental results

At first, we studied a healthy patient cohort. They were five. In the Figure 4, we present thermograms obtained thanks to one patient’s analysis. The first thermogram was made just after washing and drying the hands. It shows two thermal signatures rather symmetrical. For both hands hypothenar areas are warmer than the thenar areas. Moreover, the fingertips also seem warmer than the first phalanges of these (it may be slightly warmer for the right hand). The following thermograms correspond to moments 0 s, 30 s, 60 s, 90 s, 120 s, 150 s and 180 s after

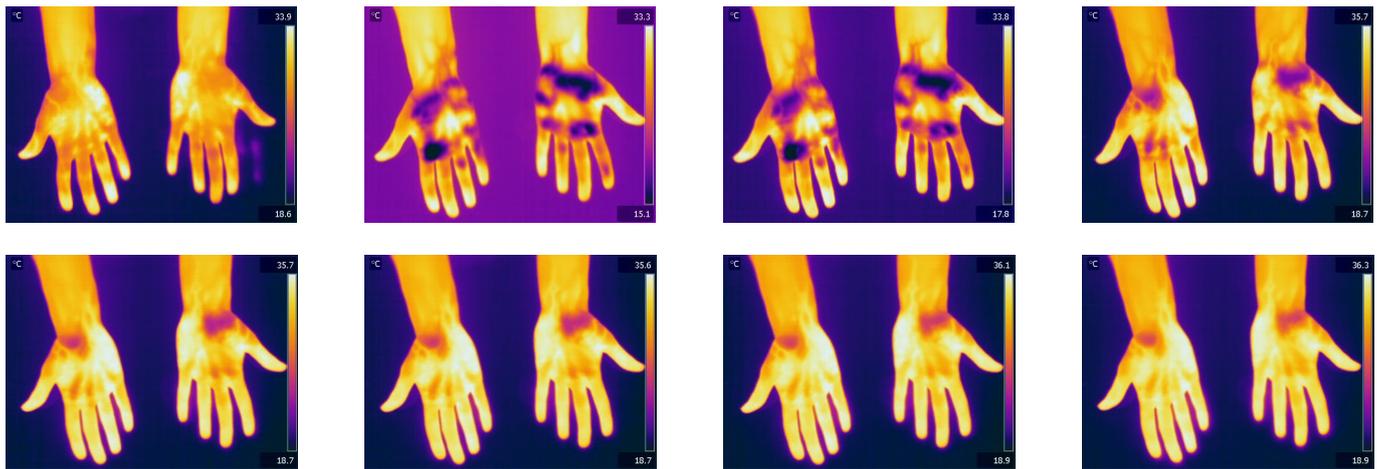


Fig. 4. Thermograms obtained in the study of healthy subjects, after washing hands, after contact with the ice blocks then 30 s, 60 s, 90 s, 120 s, 150 s and 180 s after it.



Fig. 5. Thermograms obtained in the study of healthy subjects, 180 s after contact with the ice blocks.

contact with the ice blocks. We show first that this contact has resulted in a decrease of temperature of parts of the hands that were in good contact with the ice. Here, it is especially the hands palms. They show then a gradual warming in these areas, but always symmetrically for both hands.

In Figure 6, we have a thermogram of the five healthy patients after they put their hands on ice cubes for 240 s. We can clearly see that the temperature of the patient is symmetrical in all results.

For the second part of the testing, we called the patients that presented the carpal tunnel syndrome, we had six of them. On Figure 7, we present the results we had thanks to those patients. In this case, the patient presented the carpal tunnel syndrome on the right hand. He told us that he was suffering from nightly paresthesia in the two first fingers (thumb and index). We recall that if the patient is healthy, the temperature in both hand is rather symmetrical, then the thermal excitation shows

some cooler spots at the contact between hand and ice. Here we notice that at the extremity of thumb and index, the cold was *getting* slower than on the other fingers. This result helps us to prove that a carpal tunnel syndrome can cause a vasomotion trouble in the first two fingers, that is to say where the paresthesia is felt.

After we had those results with a patient suffering from a carpal tunnel syndrome, localized in the first two fingers because of the anatomical variation of the median nerve. We decided to present an other patient that presented an other anatomical variation of that same nerve. This variation is more common and implies the first three fingers. The results are in the fifth and sixth pictures. Figure 8 shows all the thermal kinetics during the study. Picture 9 is concentrated on the 90th s. Figure 9 shows rather symmetrical thermal hands and then the thermal influence with the ice cube contact. Finally it enlightens the fact that the three fingers have different answers to get their normal temperature again. This is where the carpal tunnel syndrome was diagnosed. Thanks to those two patients we can deduce that the infrared technique is sensitive to the median nerve variation.

At last, we had to determine criteria to differentiate the patient suffering from the carpal tunnel syndrome from the healthy one. With that in mind, we first had to calculate the hands' basic temperature. This temperature is the one equal to the temperature of the thumb and the index, from which we subtract the temperature of the ring and last fingers. In the case of a healthy hand, the temperature is approximately 0 °C and quite homogeneous. If the patient presents a carpal tunnel syndrome, the difference increases because the thermal behaviour of the hand is different. Figure 10 is a table where we show the results for the eleven patients we had. We can see that the variation of the temperature is weak for healthy patients and increases for pathological patients. It also proves that the variation of temperature should be above or under 0 °C. It corresponds to a vasoconstriction or vasodilatation of the veins.

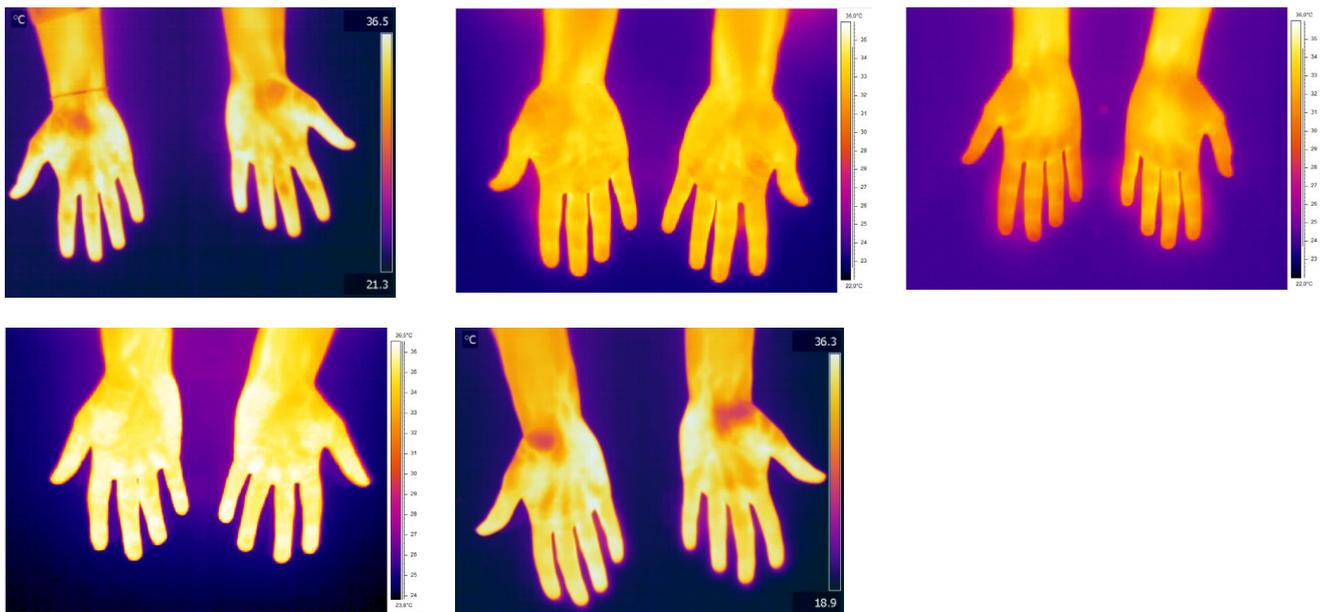


Fig. 6. Thermograms obtained after the patients hands were on the ice for 240 s.

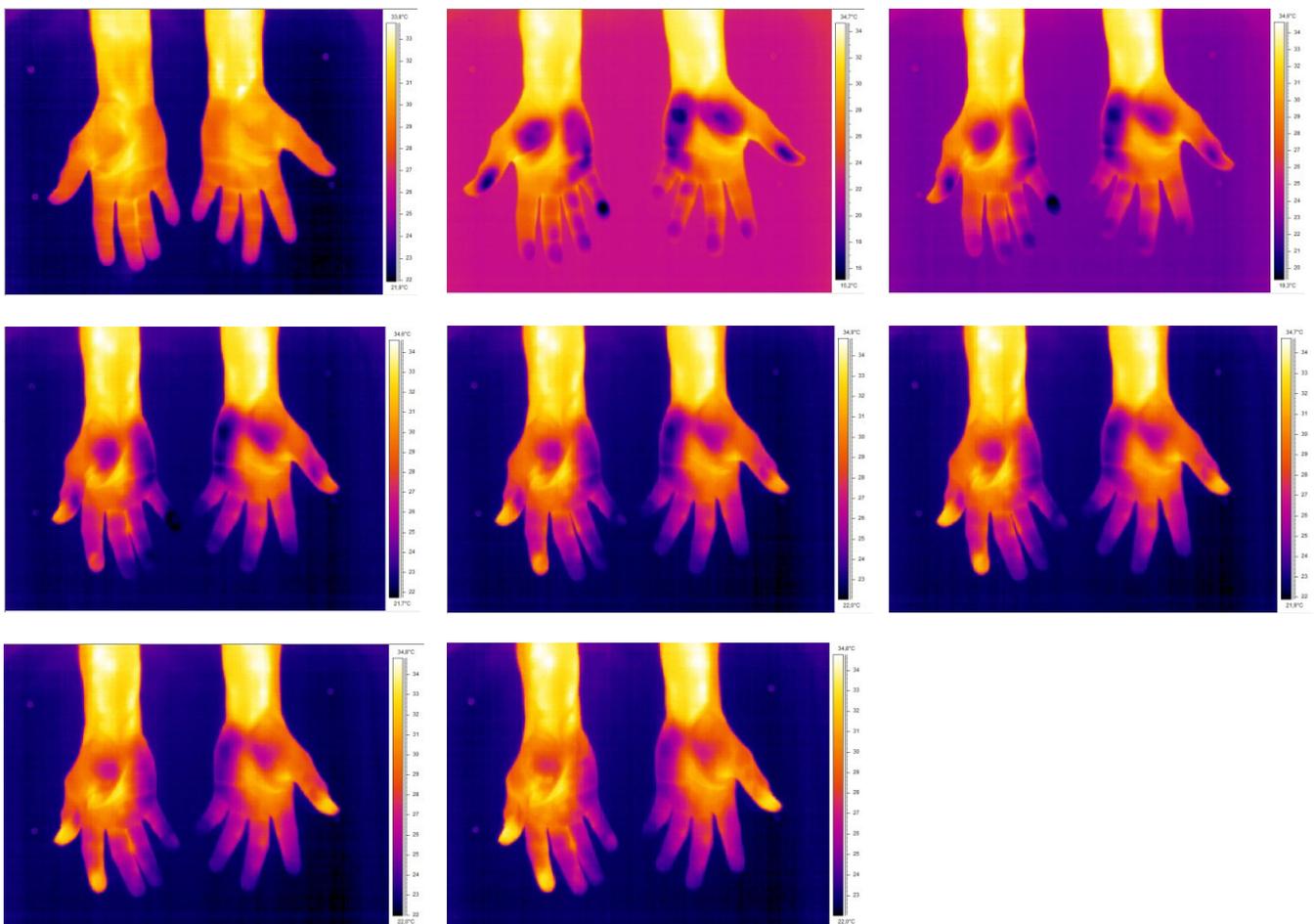


Fig. 7. Thermograms obtained with a patient suffering from a carpal tunnel syndrome in the right hand, after he washed his hands and put them on ice cubes; then pictures were taken at 30 s, 60 s, 90 s, 120 s, 150 s, 180 s and 240 s.

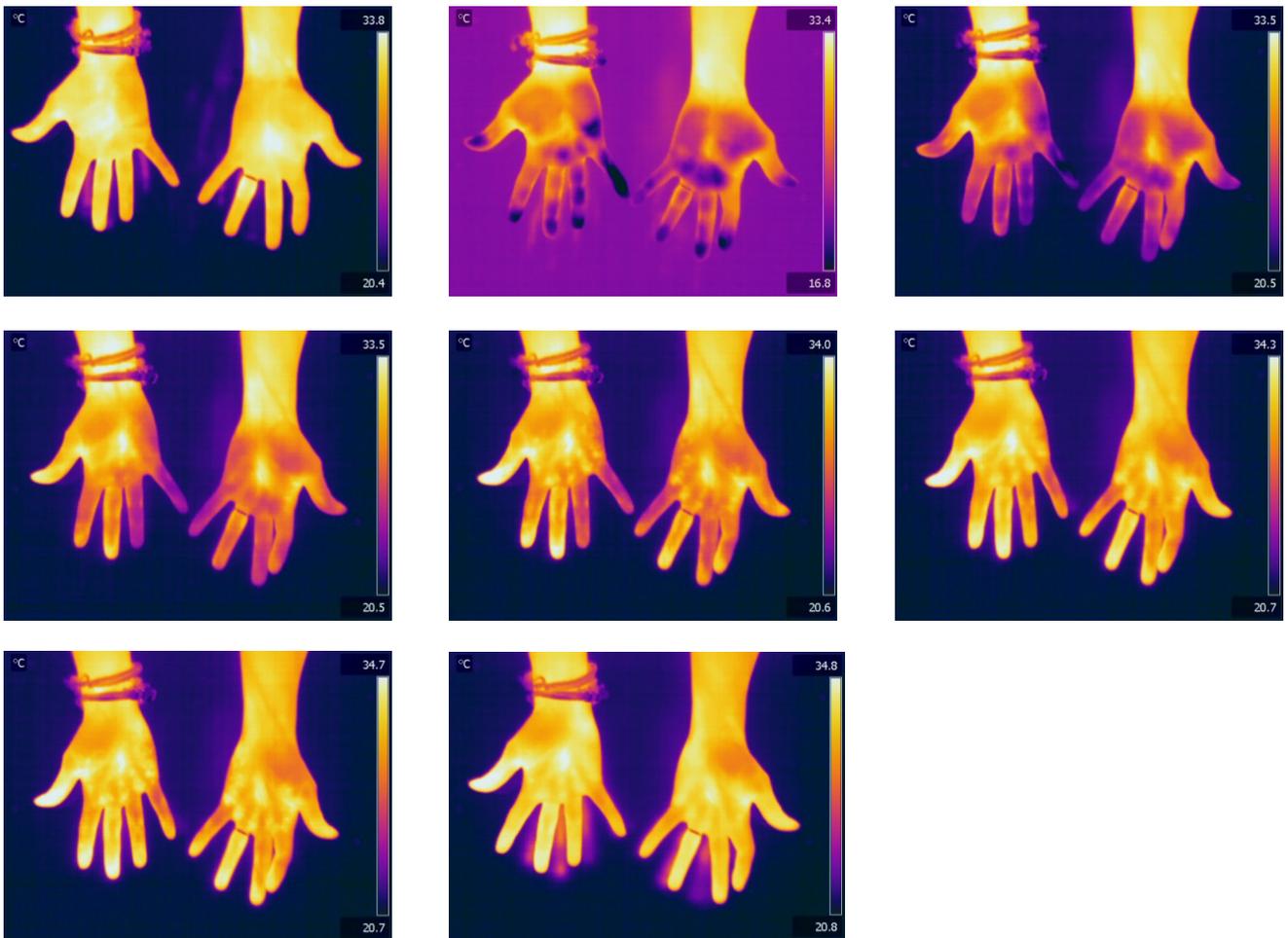


Fig. 8. Thermograms obtained with a patient suffering from a carpal tunnel syndrome in the right hand, after he washed his hands and put them on ice cubes then pictures were taken at 30 s, 60 s, 90 s, 120 s, 150 s, 180 s and 240 s.



Fig. 9. Thermogram obtained during the study of a subject diagnosed with carpal tunnel syndrome in three fingers of the right hand, at 90 s after contact with ice blocks.

4 Conclusion

In this work, we approached the possibilities of stimulated infrared thermography for carpal tunnel syndrome

detection. We first reported, following a literature review that can cause arteriolar vasomotion hand. Indeed, the sympathetic quota led by the median nerve has no myelin sheath, making them more susceptible to compression. It then modifies the threshold of excitability of nerve fibers based on these phenomena and therefore bloodstream. But a change in the circulation can cause a variation of the hand temperature, which is then detected by infrared thermography. Moreover, the sensory nerve fibers are surrounded by a myelin sheath; they will be affected later than the sympathetic fibers. Infrared thermography could allow early detection of the disease carpal tunnel. Moreover, the conventional method (EMG) is recognized 82% reliable only. As also it is invasive, it is worth trying to find a way of non-invasive diagnosis and why not more reliable. Thermography can in fact be a candidate. We then proposed an experimental protocol to be more rigorous and repeatable as possible. We explained the choice of a “long waves” infrared thermography camera. In the fourth step, we showed that the fingers with a carpal tunnel syndrome had a different thermal behavior, which enables the detection of the disease. At this stage, we showed also that the method allowed detection of anatomical variation on

Patient	ΔT Right hand	ΔT Left hand
healthy subject 1	0.9	-0.4
healthy subject 2	-0.8	-0.1
healthy subject 3	0.6	0.2
healthy subject 4	-0.1	0
healthy subject 5	0	-1.5
carpal tunnel syndrome 1 (Right)	16.2	0
carpal tunnel syndrome 2 (Right)	3.6	0.8
carpal tunnel syndrome 3 (Right)	13.3	0.1
carpal tunnel syndrome 4 (Right)	9.3	1.8
carpal tunnel syndrome 5 (Right and Left)	7.8	13.9
carpal tunnel syndrome 6 (Right and Left)	3.8	-12.6

Fig. 10. Difference in characteristic measured temperature in both hands healthy and diseased patients studied.

the distribution of the median nerve. In the fifth step, we proposed a quantification of the detection method. To do that, we defined a characteristic temperature variation and showed that it was close to zero for healthy subjects and higher for pathological subjects. This study of a cohort of restricted patient now needs to be generalized. Moreover, the robustness of the latter should be studied. It would be interesting to understand why the thermal signature of the carpal tunnel syndrome was generally positive but also negative in a particular case. It would also be interesting to investigate the cause of the kinetics of thermal reactions different from one patient to another. It would still be necessary to optimize the experimental protocol (duration excitement, excitement type, duration analysis, type of post-processing...). Finally, the influence and pertinence of selected exclusion criteria during this study should be considered as well. Studies in this direction are underway.

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