Preliminary Assessment of the Health Status of Patients with Parkinson's Disease by means of InfraRed Thermography

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Abstract

In this work infrared thermography has been applied to investigate the health status of patients with Parkinson's Disease. 10 subjects have been monitored and IR images of their hands acquired. The first results highlight as thermography is able to identify trigger points and areas of hyper- and hypothermia distributed on the skin surface and muscle bundles. This could provide the extrapolation and classification of specific medical information for a continuous monitoring activity and an early diagnosis.

1. Introduction

InfraRed Thermography (IRT) is employed in the biomedical field to detect skin temperature differences in real-time conditions and to identify possible signs of health disorders in the human body. The first medical application of this technique dates back to 1956, when some patients with breast cancer were examined for asymmetric hot spots and vascularity [1]. Since then, its diffusion has progressively increased thanks to the development of technology over the years, which has become cheaper and easier to use. Additionally, improvements in resolution, image size and portability have made IRT as a valuable and non-invasive tool in clinical approaches. In fact, IRT is successfully employed in a variety of medical applications, including vascular, dermatological, neonatal and neurological disorders, rheumatic diseases, tissue viability, oncology, ophthalmology, surgery and fever screening. By following a specific protocol, the results can objectively support the diagnosis of certain diseases and monitor physiological responses to stimuli, such as thermal, chemical, or mechanical stress [2-4]. Parkinson's Disease (PD) is a progressive disorder that affects the nervous system and the parts of the body controlled by nerves. It causes tremors, stiffness, difficulty with balance and coordination. The symptoms start slowly and drastically worsen over time. Early diagnosis of PD plays a critical role in effective disease management and its delayed progression. Generally, it is based on motor symptomatology. However, PD is often accompanied or preceded by non-motor manifestations, including autonomic dysfunction. The last ones include symptoms such as orthostatic hypotension and excessive sweating, which could be suitably identified by means of IRT [5]. The scientific literature is rather lacking in studies that evaluate skin anomalies in terms of peripheral autonomic dysfunction by IRT. As an example, a study assessed the alteration in the regulation of blood flow variations in patients with PD at the peripheral limb level [6]. Instead, other investigations highlighted anomalies in the restoration of skin temperature in Parkinsonian patients after Cold Stress Tests (CSTs) [7, 8]. Recently, Anbalagan et al. [9] analysed the cutaneous vasomotor response to perform a differential diagnosis between Parkinsonian in early stage and patients with essential tremor. However, the most part of research studies in the literature have been limited on a relatively small sample of Parkinsonian patients, the thermal effects of the different stages of this disease have never been considered and, finally, no clear investigation protocol has been defined.

The presented study investigates the involvement of the peripheral autonomic nervous system in PD, which may manifest as an altered cutaneous thermoregulation of the patient's skin after CST. The aim is to assess through IRT whether the known alterations of peripheral nerve endings vary depending on the PD stages. The study has enrolled, according to inclusion and exclusion criteria, 5 adult patients with PD. Furthermore, other 5 healthy subjects have also been recruited as a control group. The patients' skin temperature has been measured using an IR camera, focusing on the hands in a frontal view. The first results show how standardized IR acquisitions help to identify trigger points and areas of hyper- and hypothermia distributed on the skin surface and muscle bundles. This could provide the extrapolation and classification of specific medical information about the patient's health status.

2. Materials and methods

The experimental setup consisted of an IR camera (mod. T650sc, FLIR Systems Inc., Wilsonville, OR, USA), a neoprene contrast panel and a computer for elaboration and storing of the data, as shown in figure 1. The IR camera, inclined of 30°, was mounted on a tripod stand, adjusted to approximately 120 cm above the floor and 70 cm away from the sample. The neoprene panel was employed as a support for the hands, and its opacity was exploited to prevent unwanted reflections. Finally, the acquired IR images were processed using a commercial software (ResearchIR MAX, FLIR Systems Inc). The clinical examination was conducted in a thermoregulated room dimensions not less than 10 m^2. After acclimatization of 15 min with a mean temperature of 23 ºC and a relative humidity of 60%, IR images were acquired. The skin emissivity value was considered as 0.987. The ambient temperature was recorded with a digital thermometer at the same time as IRT measurements were performed. Different Regions Of Interest (ROIs) were investigated, the distal phalanx of each finger of the hand. Before conducting the CST, a baseline temperature was stored. According to the guidelines reported in [10], the patient was instructed to immerse both hands, wrapped in latex gloves, in a bowl of cold water at 10°C. After 2 min of immersion, the glove was carefully removed from the hands without touching the skin. Immediately post-immersion, the decrease in skin temperature was continuously monitored from 0 to 10 min.

Fig. 1. *An image in lateral view of the experimental setup for the assessment of PD health status.*

3. Results and Discussions

As preliminary results, the measurements of 10 different cases are reported, 5 Control Subjects (CSs), considered as reference of good health status and 5 subjects with PD diagnosis between 50 and 70 years of age. Furthermore, for simplicity only the data related to the right hands are presented.

The first problem in a thermographic measurement is to find a uniform surface, where to place the investigating sample, that can reduce undesirable reflections. For this purpose, after various tests with different materials, such as paper or wood, a neoprene panel was taken into consideration. It was tilted 16° to promote blood circulation for temperature recovery after CST.

After the measurement, a thermal imprint remains on the surface for a few minutes, it is necessary to wait about 20 min for its disappearance before proceeding with the next measurement.

The protocol provides for the video capture of 20 s to record the baseline temperature in the considered ROIs, i.e. the distal phalanx of index, middle, ring and little finger of each hand.

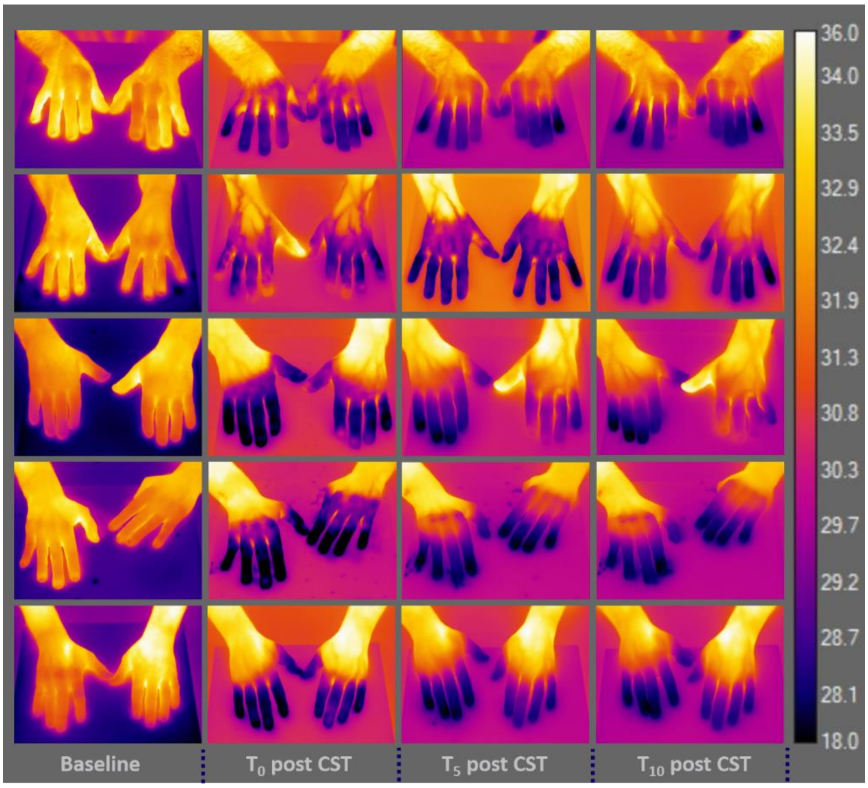

Fig. 2. *Thermal distribution of the PD hands before CST (Baseline), immediately afterwards the test (T_0 post CST), after 5 min (T_5 post CST) and 10 min of CST (T_{10} post CST).*

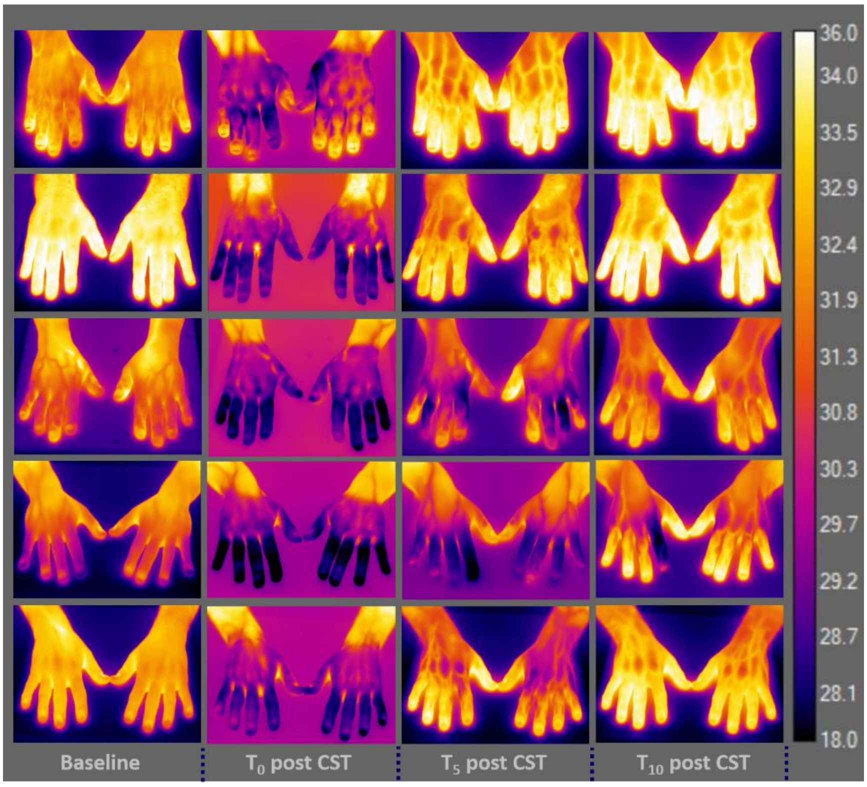

Fig. 3. *Thermal distribution of the CS subject hands before CST (Baseline), immediately afterwards the test (T_0 post CST), after 5 min (T_5 post CST) and 10 min of CST (T_{10} post CST).*

Figure 2 and figure 3 show respectively the thermographic images of the PD and CS with a graduated scale of temperature between 18 and 36°C. More in detail, the basal thermal distribution of the hands before the CST (Baseline, reported in the left), immediately afterwards the test (T_0 post CST), after 5 min (T_5 post CST) and 10 min of CST (T_{10} post CST).

In the PD case, it is possible to appreciate by the thermographic view, how the hands show difficulties in thermoregulation, that is, an autonomic dysfunction in the thermal recovery, in fact they maintain a rather cold temperature.

As regards the case of CS, it is clear that there is no thermoregulatory problem, the subject has a normal trend of thermal recovery. His hands are completely heated after 10 min of CST.

In order to establish a preliminary parameter as prognostic marker of PD, the Thermal Recovery Ratio (TRR) for each ROI after 10 min was computed as a diagnostic measurement for vasoconstriction in the subjects. The calculation of TRR is depicted in Equation (1) as ratio of the difference between the temperature 10 min after CST and the temperature immediately afterwards the test (T_0 post CST) and between the average of the baseline acquired 10 s before CST and T_0 post CST. Its values are reported as a function of the acquisition time in figure 4 and figure 5.

$$TRR = \frac{T_{10_{post\ CST}} - T_{0_{post\ CST}}}{T_{baseline} - T_{0_{post\ CST}}} \quad (1)$$

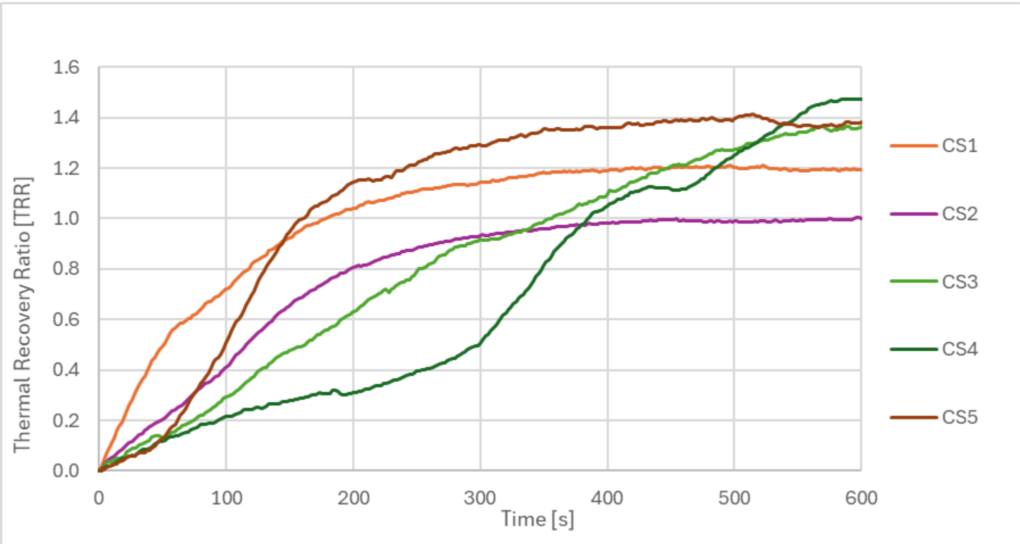

Fig. 4. *TRR trend as function of acquisition time in HC.*

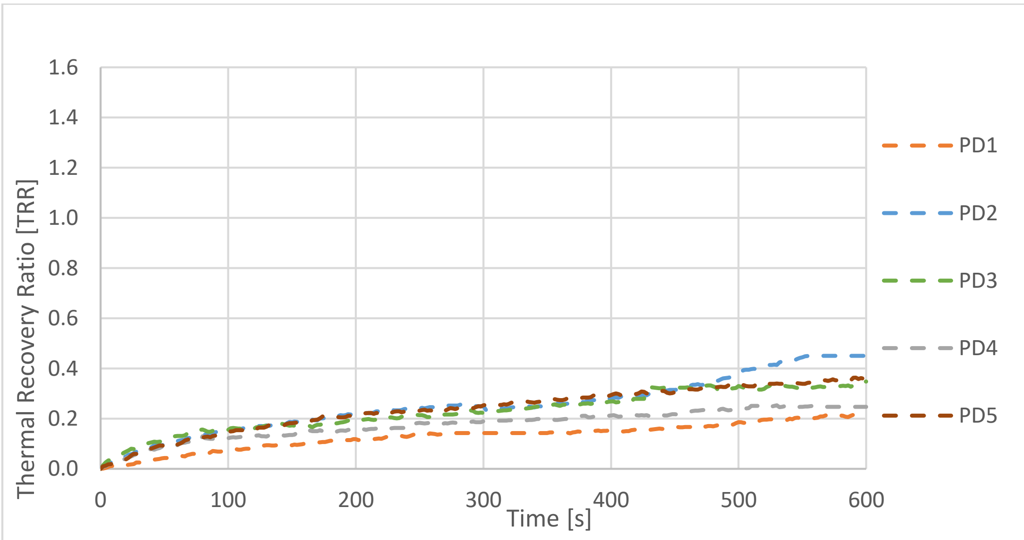

Fig. 5. *TRR trend as function of acquisition time in PD.*

TRR is a parameter that in these preliminary measurements showed values lower of 0.5 for an illness subject and upper to 1.0 for a healthy subject. PD maintain fairly constant temperature values and show a low TRR. The mean value of the TRR between the four fingers, i.e. index, middle, ring and little finger has been calculated and reported in the histogram of figure 6.

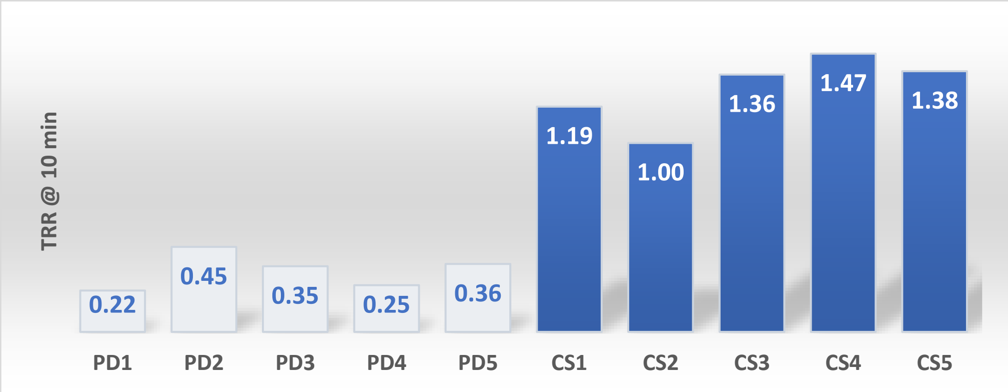

Fig. 6. *Average of TRR for each investigated subject.*

The TRR for a PD subject shows values between 0.22 and 0.36 according to the severity of the disease. Compared to measurements obtained in the case of CS, it is expected that from cutaneous thermographic analysis in Parkinson's patients there will be an altered autonomic innervation and an anomalous vasomotor reflex in the skin, as described in the PD literature [8]. Indeed, PD patients reveal abnormal cutaneous thermal responses, suggesting cutaneous autonomic dysfunction.
In addition, in PD analyses, it is expected that the thermographic curves will exhibit a shallower slope, as the thermal RR will be reduced. Other parameters will be calculated to obtain a marker of the disease. Furthermore, it will be important to investigate the relationship between thermoregulation and motor asymmetry.

The obtained data will then be correlated with the scores from neuropsychological tests and clinical examinations. Finally, after a large number of measurements, it will be possible to find a mathematical model that better approximates the calculated temperature distribution function, as well as done previously in other areas [12].

Conclusion

In conclusion, traces of α-synuclein in PD subjects induce vasoconstriction, resulting in skin vasomotor dysfunction and this vasoconstriction leads to diminished blood flow in the blood vessels, which causes the limbs to cool. The occurrence of vasoconstriction is attributable to autonomic dysfunction, a phenomenon commonly observed in individuals with neurodegenerative diseases such as PD, Alzheimer's Disease, and Multiple Sclerosis.

IRT holds promise as a valuable tool in the assessment of the health status of patients with Parkinson's disease. Its ability to non-invasively detect and monitor autonomic dysfunction, motor symptoms, pain, and complications provides a complementary method to traditional clinical evaluations. Continued research and development of standardized protocols is necessary to fully harness its potential in clinical practice.

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