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Research Article

Standard Protocol of Preparation of the Subject with Risk Foot for Taking Images by Infrared Thermography

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Abstract

Infrared medical thermography is a current, accurate, quantifiable, objectivable and non-contact patient diagnostic technique that is used to visualize and quantify surface temperature changes using high-performance thermal imaging cameras. With this work we develop the update of the standard protocol of preparation of the subject with risk foot for the taking of the images by means of infrared thermography.

Keywords: Diabetes; Diabetic Foot; Infrared Thermography; Medical Thermography; Risk Foot

Abbreviations

IR: Infrared thermography; PubMed-NCBI: National Center for Biotechnology Information; EAT: European Association of Thermology; ISO: International Organization for Standardization.

Introduction

Infrared Thermography (IR) is a technique that allows to measure the temperature or the radiated heat at a distance of a body and without needing physical contact with the object to be studied, by means of the capture of the infrared radiation of the electromagnetic spectrum [1,2]. Ring published the characteristics of infrared thermographic technology and improvements in standardization protocols [3].

The measurement of the temperature of the skin of the feet using a thermal camera is feasible and reproducible, demonstrated in temperature patterns of fingers and toes with similar temperatures in the contralateral limbs in healthy subjects, providing the basis of the investigation of the thermography in the diagnosis of vascular insufficiency [4]. The current scientific literature shows studies that relate the increase and decrease of the plantar temperature of the foot and the appearance of diabetic foot complications [5,6].

Materials and Methods

We used databases and bibliographic search engines Medline, PubMed-NCBI (National Center for Biotechnology Information), ISI Web of Knowledge, Ingenuity, Science Direct, EBSCO, IEEE Xplore Digital Library, Spanish Medical Index and SCIELO, to identify related scientific works with infrared thermography and its relationship with Diabetes Mellitus and diabetic foot. Due to the huge list of keywords, there was not a single "search phrase", but a combination between the keyword "infrared thermography or infrared or infrared temperature thermometry or thermometry or infrared or thermal images" correlated with "diabetic foot", "Diabetes", "Diabetes Mellitus" and / or "injuries", "ulcers".

The search was conducted between the months of February 2016 to February 2017. Analyzed and identified the studies were preferably considered original works published in the last 20 years. The inclusion criteria for the selection of the work were the literature written in English, the users were human beings and the temperature of the skin measured by infrared thermography was made without contact.

The study sample consists of subjects framed in two groups, group cases (people with diabetes) and control group (people without diabetes). The sample consisted of a total of 277 people, with an average age of 63.41, of which 138 are men and 139 are women. In the same way for the control group, the number consisted of 202 users, with an average age of 61.92, of which 99 are men and 103 are women.

The inclusion criteria that define and characterize the study population were established, and the exclusion criteria for those users who, even meeting the inclusion criteria, had to be excluded for some objective reason [7].

Results of the protocol update

Forty-eight hours before the data collection, the user was notified by telephone about the need to control possible interference in the tests (do not apply any type of foot cream or alcohol-based products, physical activity or physical treatment). Recent, ingestion of food, smoking or alcohol, exposure to UVA) because these could change the emission of heat on the surface of the skin [2,8-11].

The testing room was comfortable and acclimated so that the user felt in a cozy and relaxing environment, where he could be calm before entering the tests, in order not to cause physiological changes (sweat or tachycardia, dizziness, etc). It was guaranteed that the subject was at rest with the aim of reaching a thermal equilibrium, since if he was sweating, his skin would show a temperature that could generate errors in the samples. Also, it was important not to take inappropriate postures like crossed legs. All the above was taken into account so that the surface temperature of the skin of the feet was not altered in the subject [12].

The data and images were taken in days of tomorrow to reduce the influence of the circadian cycle on the variation of temperature in patients [13-15].

In order to obtain precise and useful results for clinical practice, the thermograms of the participants in the study were carried out in compliance with the protocols and guidelines set by the International Academy of Clinical Thermology Standards and Protocols [16].

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Figure 1: FLIR MR77 device.
Source: Available on the FLIR website [25].

Adequacy of the room where the tests will be carried out

The testing room complied with a series of norms for the correct acquisition of the images. The ideal temperature to take thermographic images should be between 23°C and 25°C [12,13,17]; as well as a relative humidity close to 50% [3,13,18-24].

The device used for the control of the ambient temperature and the humidity of the habituation was the FLIR MR77 device (Figure 1).

In our study, the average temperature of the test room was between 22.63 ± 2.28ºC, with a relative humidity of 33.50 ± 8.10%; in this way, the assessment and data collection was carried out in a cabinet with standardized conditions of temperature, humidity and atmospheric pressure = 942.69 ± 3.03 mb/hPa) following an adaptation of the guidelines of the European Association of Thermology (EAT) [26,27].

In addition, we ensure that air currents from air conditioning are not circulated directly on the foot, as they could have a decisive influence on the thermal situation of the same [28].

Likewise, we control direct sunlight on the camera lens as well as reflective objects in the camera's visual field [12].

The thermographic tests were performed in a podiatric chair that allowed to place the subject in a sitting position, in a comfortable and adequate position for making the thermographic image [29] (Figure 2).

Infrared thermographic camera equipment

All images constituting this research were carried out with the FLIR E60bx® camera (FLIR® Company, Boston, USA), complying with the basic safety and essential performance requirements of the human temperature screening thermographs established by the International Organization for Standardization (ISO). The thermographic camera has advanced technical characteristics, complying with the recommendation of 320 x 240 pixels of resolution, which allow that the capture of images is optimal to extract useful data for research [11,30-33] (Figure 3).

The procedure to configure the FLIR E60bx camera were the following: We turned on the thermal imager and waited 30 minutes before taking any action. The laptop starts with the FLIR IR Monitor software. In the camera the emissivity is adjusted to 0.98, data corresponding to the emissivity value of the skin of the human body [34-36].

The value we use for the detection of complications is 2.2°C. This criterion is the only one that has been validated clinically to determine the complications of diabetic foot with temperature measurements [37,38].

The calibration of the camera is carried out, prior to the study, by focusing the lens on a black body. We activated the audible alarm (beep) and clicked "Apply". The camera was configured according to the conditions of the moment. Regarding the reliability of the FLIR® software, all the images were made and evaluated in two different laptops with the same software, in parallel, to avoid inter-scanner bias.

Modern image reproduction software controls and monitors graphics in an unlimited way, showing the patient's sensations, such as pain [39].

Position of the subject in the acquisition of images

The comfort of the patient was very important at the time of taking the images, since it can be longer in the correct position, which influences the measurements and helps to reduce the registration error.

The patient remained with the leg and foot uncovered, in a sitting position for 15-20 minutes before performing the test, to eliminate the influence of external factors on the temperature conditions of the foot [40,41]. Similarly, other authors considered that an interval between 10 -15 minutes was sufficient [42].

A position was adopted in which the patient met the following conditions

The adequate position of the user was essential to avoid variations in terms of muscle contraction and blood perfusion. This in order to reduce the chances of registering false temperatures, reducing the error in the measurements of infrared images [43].

We facilitate an adequate blood flow in the foot that was going to be captured since this directly influenced the body temperature, that is, the higher the flow, the higher the temperature [43].

The user must be relaxed and free of muscle tension in the member to be examined (left or right foot), since the stresses generate body heat, which introduces errors in the measurement [43].

External arterial obstructions (pressure on some area of the limb that prevents the correct blood flow) were avoided, since when there is pressure on some area of the limb, the blood flow decreases. Therefore, the temperature of the foot will decrease, generating errors in the measurements [44,45].

Distance between the subject's foot and the infrared camera

Once the thermographic camera is configured, the thermal parameters are calibrated. We point the camera at the foot that has a presumably normal temperature. Liu et al placed the IR camera at a distance of 860 mm from the plane of the object [46].

In our study we consider that the distance from the camera lens

Figure 2: Podiatry chair.

to the feet of the person should be such that the image of the feet on the screen covers at least 75% of the image width, occupying 2/3 of the image, and perfectly focus the foot area with a suitable infrared sensor resolution, that is, there must be a minimum amount of 25 pixels per unit area [26,32]. We adjust the rectangular measurement box to cover the area around the fingers and the person's plant, achieving a crisp camera focus to increase the quality and quantity of the number of pixels.

The position and placement of the camera was through the use of a large format camera support, whose pillar was resistant, maintaining the image to 90º towards the objective, and allowing a vertical adjustment of the camera parallel to the ground.

Realization and asymmetric analysis of the thermal image

At the moment of capturing the infrared images, the camera was configured with an objective thermal scale, defining a range of 1 or 2 degrees below the ambient temperature to adequately capture the temperature of people who are correctly conditioned and as an upper limit of said range, 36°C or 37°C, since it is the core temperature of the human body. In this way, it can be clearly visualized how the feet are acclimatized over time.

First, we measure the reflected temperature, which is the temperature emitted by the objects that are around the area of interest, in order to avoid external sources of infrared radiation and that can be measured by the thermal imager [47].

Subsequently, we take a temperature sample, as a test, to 10 people with presumably normal temperatures to establish the reference temperature. The camera software maintains a moving average of the last 10 temperature readings in its First In- First Out memory (FIFO).

Once we do the above, we start obtaining the thermographic image. We positioned the camera on the foot of the person whose temperature we wanted to obtain. If the maximum temperature of the person (within the area of the box) is higher than 2.2°C above the reference temperature, as well as if it is lower than this parameter, the alarm will be triggered [37,38].

Four thermograms were recorded, two for each sole of the foot; two separated by 5 intermediate seconds, and the next two in the same conditions and time 15 minutes later, and the areas of interest are marked. All images are evaluated by observers who will perform the analysis independently [48].

Figure 3: Cámara FLIR E60bx.

Regarding the color scale of the thermographic image, the temperature range of the human body is limited (typically 10°C), so we have a range of 'rainbow' colors, with red as hot and blue / black as cold. The color temperature scale used at the time of image capture is displayed next to the final image [32].

Infrared thermographic image evaluation

The interpretation and analysis of neuropathy and vasculopathy screening together with the thermographic image was made by thermoplantar comparison with the other similar or contralateral body region [5,37,38,49-51].

In the evaluation of the thermograms we differentiate between the qualitative variations, where we observe alterations in the thermal symmetry that characterize the physiological thermal pattern, and the quantitative variations with the quantification of the temperature of the foot under study as well as the existence of a temperature difference greater than 0.2-0.3ºC with respect to the thermal area surrounding the studied area or with respect to the same area in the contralateral member [52].

Thermograms with zones of elevated temperatures will appear when there are inflammatory reactions with increased blood flow by cellular activation, however, areas with decreased temperatures will exist compression or degenerative processes [53]. The evolution of this alteration depends on the severity of the biological phenomenon as well as the level of tissue involvement in the area, the extent and depth of the tissue involved [19].

Conclusion

With this work we demonstrate the correct handling, measurement and monitoring of all parameters to be taken into account in the use of infrared thermography as a technique in the early identification of diabetic foot manifestations, as a safe, non-invasive and low cost technique that allows the quick and non-contact record with the patient of the radiated energy of the body.

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