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Skin Temperature Assessment During Lumbar Sympathetic Blocks by Infrared Thermography

Mar Cañada-Soriano, José Ignacio Priego-Quesada, Paula Rubio, Maite Bovaira, Carles García-Vitoria, Rosario Salvador Palmer, Rosa Cibrián Ortiz de Anda, and David Moratal, *Senior Member, IEEE*

***Abstract*— Complex Regional Pain Syndrome (CRPS) is a pain disorder that can be triggered by injuries or surgery affecting most often limbs. Its multifaceted pathophysiology makes its diagnosis and treatment a challenging work. To reduce pain, patients diagnosed with CRPS commonly undergo sympathetic blocks which involves the injection of a local anesthetic drug around the nerves. Currently, this procedure is guided by fluoroscopy which occasionally is considered as little accurate. For this reason, the use of infrared thermography as a technique of support has been considered.**

In this work, thermal images of feet soles in patients with lower limbs CRPS undergoing lumbar sympathetic blocks were recorded and evaluated. The images were analyzed by means of a computer-aided intuitive software tool developed using MATLAB. This tool provides the possibility of editing regions of interest, extracting the most important information of these regions and exporting the results data to an Excel file.

***Clinical Relevance*— The final purpose of this work is to value the potential of infrared thermography and the analysis of its images as an intraoperative technique of support in lumbar sympathetic blocks in patients with lower limbs CRPS.**

I. Introduction

Complex Regional Pain Syndrome (CRPS) is a chronic pain condition characterized by a “continuing (spontaneous and/or evoked) regional pain that is seemingly disproportionated in time or degree to the typical course of pain after similar trauma or another lesion” [1]. It is usually developed after injury or surgery, affecting generally limbs, and most patients suffer from sensory, motor, sudomotor, vasomotor, and/or trophic disturbances [1], [2]. CRPS patients can present symptoms and signs associated with automatic nervous system dysfunction in the affected limb including altered sweating, skin texture, or abnormal blood flow and temperature.

Sympathetic nerve blocks are a widely performed approach both in the diagnosis and treatment of CRPS as they may reduce some of the symptoms such as edema, decreased muscle strength, temperature anomalies, but especially pain. The injection of a local anesthetic drug (such as bupivacaine, lidocaine and ropivacaine) around the sympathetic trunks temporarily interrupts their function and may alleviate pain [3]. When upper extremities are affected, stellate ganglion blocks are performed whereas lumbar sympathetic blocks (LSBs) are carried out when lower limbs are afflicted [1]. Since the number of people diagnosed with CRPS is scarce, there is reasonably difficulty in recruiting patients to conduct studies and therefore there is no general agreement on defining whether a sympathetic block may be determined as successful or not.

LSBs are often considered correctly performed when there is radioscopically confirmed contrast dye spread i.e, forming a line conforming to the anterolateral margin of the vertebral bodies without any psoas spread laterally or intravascularly [4]. However, LSB under radioscopic guidance does not ensure an exact performance. Since the LSB changes the blood flow via its vasodilatory effect, monitoring changes in skin temperature are used to assess its effectiveness. Thus, a LSB has been considered successful when changes in the ipsilateral temperature (measured with thermocouple probes) between pre-block and post-block are ≥ 2 ºC [5].

Thermal imaging is a non-invasive technique that in the biomedical purpose it is used to detect alterations in skin temperature by capturing the emitted radiation from the skin [6]. Since it is performed at a distance from the body under study, it is harmless, and it allows rapid recording of radiation data. For this reason, IRT has been applied in medicine for monitoring diseases and it has broad application in several areas in biomedicine such as diabetic foot diagnosis, breast mass diagnosis, or CRPS [7], [8].

The main objective of this work is to analyze the infrared data of plantar foot acquired during the performance of LSBs in patients with CRPS affecting lower limbs to evaluate the potential of IRT as a support technique in the assessment of LSBs. To help in the analysis and processing of thermal data, a software tool based on MATLAB and with a Graphical User Interface (GUI) has been developed.

Corresponding author: David Moratal (e-mail: dmoratal@eln.upv.es).

M. Cañada is with the Applied Thermodynamics Department, Universitat Politècnica de València, Valencia, Spain.

J. I. Priego-Quesada is with the Research Group in Sport Biomechanics, Department of Physical Education and Sports, University of Valencia, Valencia, Spain, and with the Biophysics and Medical Physics Group, Department of Physiology, University of Valencia, Valencia, Spain.

P. Rubio, and D. Moratal are with the Center for Biomaterials and Tissue Engineering, Universitat Politècnica de València, Valencia, Spain.

M. Bovaira, and C. García are with the Anesthesia Department, Hospital Intermutual de Levante, Sant Antoni de Benaixeve, Valencia, Spain.

R. Salvador and R. Cibrián are with the Research Group in Medical Physics (GIFIME), Department of Physiology, University of Valencia, Valencia, Spain

II. MATERIALS AND METHODS

A. Experimental study

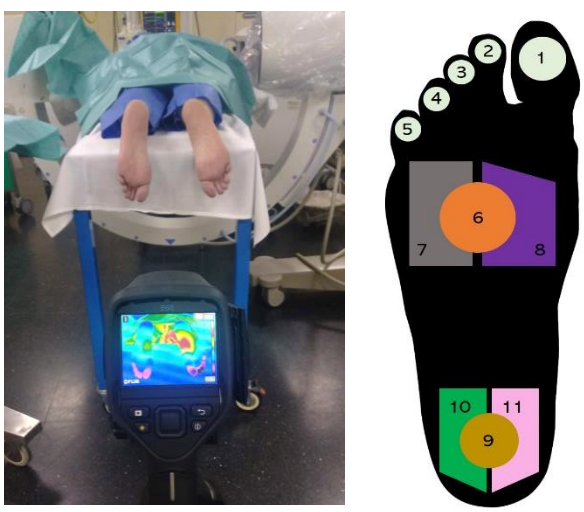
41 lumbar sympathetic blocks (LBS) for the treatment of lower limbs CRPS in 11 patients (7 men) with an age of 41 ± 7 years old (mean ± standard deviation) were performed. Patients were placed in the prone position with bare feet and their backs were sterilely prepared. The LSBs were guided by fluoroscopy and before administering the injection of the local anesthetic (2 ml lidocaine 2%), a contrast dye was injected to confirm needle placement. Immediately after that, thermal images were captured of both feet soles. Participants were instructed to keep their feet immobile while thermal images were taken. Data were obtained at Hospital Intermutual de Levante (Valencia, Spain). All procedures were performed by a team consisting of 1 or 2 pain medicine physicians.

The study was approved by the ethical committee of the Universitat de València (Reference: 1250779) and the participants signed the informed consent.

B. Thermal data acquisition

Infrared data were acquired using a thermal camera FLIR E60 (FLIR Systems, Inc., Wilsonville, OR) with a pixel infrared resolution of 320 × 240, a thermal resolution of < 50 mK at 30ºC and measurement uncertainty of ± 2ºC of the overall temperature reading. The camera was mounted on a tripod at distance of 1.5 m from the subjects' feet and perpendicular to them, as shown in Fig. 1a. The emissivity was fixed to 0.98 for skin measurements [9].

Measurements were made at the affected and contralateral extremities at baseline before the LSB and 10 min after the block. The thermal camera was connected via USB to a laptop with the software FLIR Tools+ (FLIR Systems, Inc., Wilsonville, OR). Infrared images were acquired automatically every 10 seconds for 10 minutes.



a) b)

Figure 1. a) Acquisition setup during a lumbar sympathetic block performance; b) 11 ROIs were selected in each foot.

C. Thermal analysis

A software tool to analyze the acquired thermal images has been developed using MATLAB (The MathWorks, Inc., Natick, MA), with a GUI to facilitate its use.

III. RESULTS

A. Graphical User Interface

The developed tool guides the user through the process (Fig. 2). Firstly, the user selects the infrared data to be analyzed. Then, the feet segmentation is done and, in the case the resulting mask does not adjust the foot properly, the tool asks the user whether modify or draw it again. When segmentation is finished, the user can view one frame at a time with the possibility of modifying, creating, eliminating and/or moving each ROI. Once every ROI is adjusted for every frame, the software offers the possibility of exporting the results data to an Excel file in order to process the information.

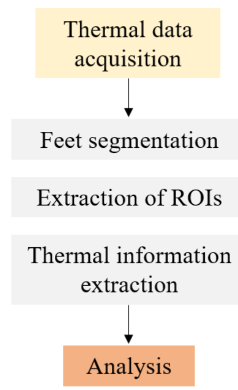


Figure 2. Flow diagram showing the methodology.

B. Regions of Interest

Each plantar foot has been divided into 11 regions [10], [11] shown in Fig. 1b: toes corresponding to ROIs 1 to 5, ROIs 6 to 8 are the areas placed on the ball of the foot and finally the ROIs 9 to 11 are the ones situated on the heel of the foot. For each of these regions, the maximum, the minimum, the mean temperature, and the standard deviation are extracted for each frame.

C. Lumbar sympathetic blocks performance outcomes

The majority (80%) of temperature changes in the affected foot occurred within 4 minutes after the lidocaine test, as can be observed in Fig. 3a and 3b. In those cases, the spread of the contrast agent was radioscopically confirmed. Thus, when the warming thermal pattern was observed on the infrared camera (considered as a "successful" test), the drug was injected. As shown in Fig. 3a, there is a demonstrable remarkable difference in temperature between the ipsilateral and contralateral foot. Besides, observing the infrared image in minute 4 after the lidocaine test, the warming thermal pattern in the affected foot stands out. In this case, a LSB was considered correctly performed ("successful") since temperature changes in the affected limb were observed within the first 4 minutes after the lidocaine test.

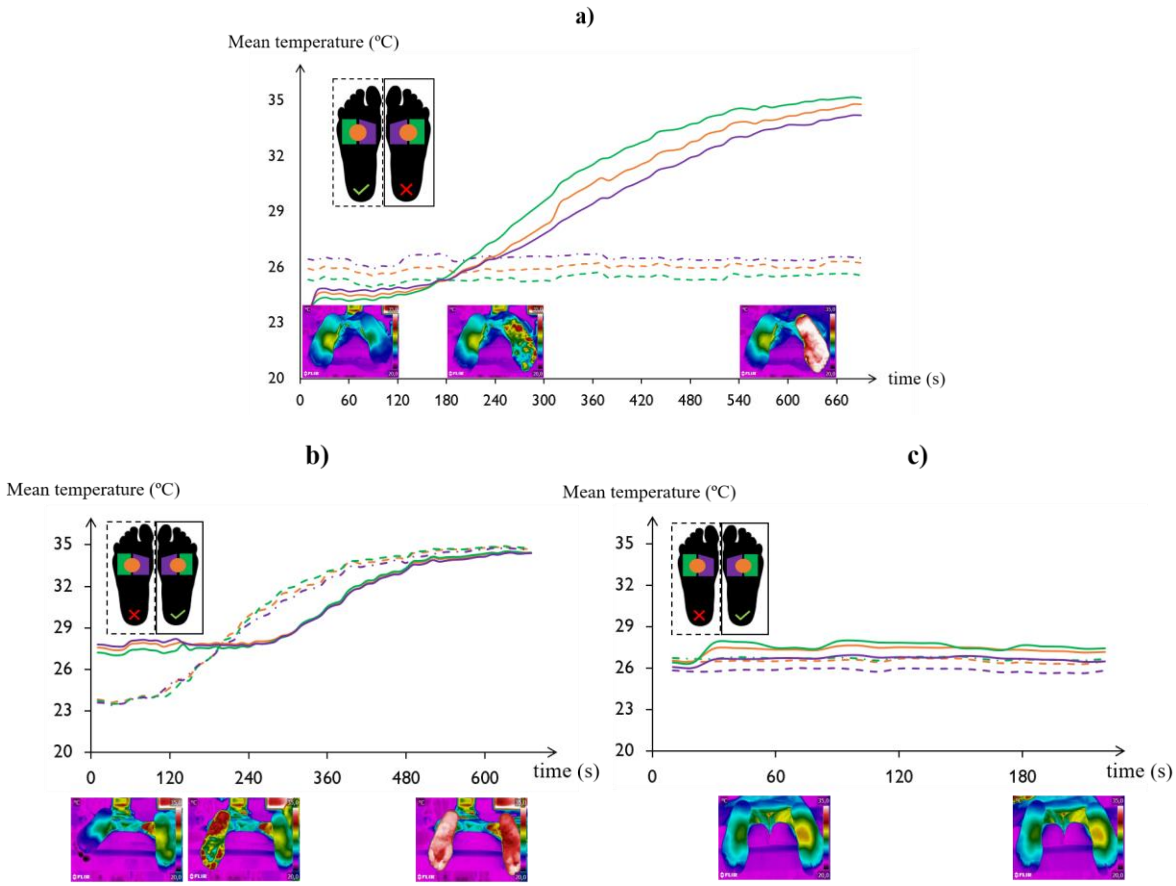


Figure 3. Ipsilateral (solid lines) and contralateral (dashed lines) mean temperature after the lidocaine extracted from ROIS on the ball of the foot (6, 7, 8) at 1-min intervals in 3 cases of LSBs: a) "successful"; b) temperature rise in the contralateral; c) "failed".

On the other hand, in 20% of the LSBs analyzed, temperature changes in the contralateral were also observed (Fig. 3b). In such cases, the onset time for the temperature rise was generally slower than the one in the ipsilateral. However, in 13 out of 41 LSBs, there were no thermal pattern alterations after the test within the first 4 minutes (Fig. 3c). Under these circumstances, LSBs were considered unsuccessful ("failed"). For this reason, a repositioning manoeuvre of the needle and the procedure repetition (lidocaine test along with the temperature evaluation) were required. Following this, 7 out of 13 BSLs were reassessed as correctly performed, observing temperature changes in the affected limb by means of the infrared images, and thus confirming the correct needle placement.

IV. Discussion

The lack of clinic efficacy attributed in many cases to the LSBs might be due to a lack of accuracy in the technique. In all cases in which a first negative test after optimal radiographic vision were found, the procedure would have probably ended with an ineffective drug injection.

Several studies [5], [12], [13] have focused on monitoring changes in skin temperature of the limbs to evaluate sympathetic blocks. To do so, temperature measurements were acquired using skin probes (DM 852 Medical Precision Thermometer, Ellab A/S, Hilleroad, Denmark) attached to the middle of the plantar surface of the ipsilateral foot [13] or attaching adhesive thermocouple probes (accuracy of ± 0.1 ºC) (Solar 8000M, General Electric Healthcare, Milwaukee, WI) to the plantar surface of the feet [5]. However, measurement of skin temperature using probes not only implies a much more laborious analysis, but it also can be insufficient if the temperature of several points on the foot must be measured. In this sense, infrared thermography, provides much more information in a very short time, specifically, the IR camera used in this study gives 76800 temperature values (320 × 240 pixel infrared sensors). Furthermore, given that thermal data are obtained without physical contact, IRT is non-invasive so the skin temperature is not altered. Finally, since the set of these sensors are depicted on an image, it enables the physicians check in real time the thermal patterns taking place on the feet soles. In accordance with that, the thermographic intraprocedural control might be an instrument of great help in the achievement of better outcomes.

However, some limitations are found: shifts in feet's position due to discomfort or pain result in greater readjustments of the ROIs during the analysis and, consequently, the time required rises. Variations in performing the procedures, such as a different pain physician performing the LSB, changes in room temperature or inherent features in patients, such as the diverse morphology of feet and fingers also made the analysis difficult. Finally, in order to determine the degree and/or duration of pain relief after LSBs for the treatment of CRPS, an in-depth analysis of the thermal patterns should be performed. These further studies would establish the underlying cause of the temperature increase in the contralateral foot and whether it would have influence on the clinical improvement of the patient. The warming process and the temperature patterns across the fingers and toes should also be correlated with the clinical outcomes.

V. Conclusion

This paper presents a potentially useful tool for the evaluation of thermal data of plantar feet in patients with lower limbs Complex Regional Pain Syndrome (CRPS) who underwent lumbar sympathetic blocks (LSBs). Since infrared images provide a complete vision of thermal patterns taking place, they can be used for assessing temperature responses in real time in both the ipsilateral and contralateral. Furthermore, the developed tool enables the user to analyze the thermal data obtained by extracting characteristic parameters such as mean, maximum or minimum temperatures for both foot and at every frame from the selected ROIs.

To conclude, this preliminary study suggests that IRT is shown to be reliable and a powerful method to evaluate the performance of LSBs. As a non-invasive technique with considerably feasible clinical applicability, it has shown a great potential to improve procedural accuracy in the performance of LSBs and therefore in the achievement of better outcomes.

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