THERMOGRAPHIC ANALYSIS IN TIBIAL AND FIBULAR CONSOLIDATED BONE LESIONS - CASE STUDY

Wally Auf Der Strasse[1], Celso Júnio Aguiar Mendonça[1], Jamil Faissal Soni[2], Mauren Abreu Souza[1,2], Percy Nohama[1,2]

[1] Federal Technological University of Paraná – UTFPR – Curitiba-Paraná/Brazil
[2] Pontifical Catholic University of Paraná – PUCPR – Curitiba-Paraná/Brazil

Abstract: Infrared thermography is a diagnostic method that can be used to follow up patients with bone fractures. The objective of the present study was to investigate alterations in the thermal pattern in consolidated fibular and tibia stress fracture in a 49 year old female athlete who had an intense manifestation of pain at the fracture site after the time period of 12 months after bone repair process. Two series of thermal images were taken in the proximal half of the metatarsals and in the distal portions of the tibia and fibula in the anterior (frontal), lateral and medial regions and in the medial and lateral malleoli, the knee and hip joints were kept centralized and aligned with anterior superior iliac crest. The thermal imaging was acquired by means of an FLIR®Systems Inc. Professional A325 camera with 0.08 ° thermal and 0.1 mm spatial resolution, with the actual integrated resolu-tion being 320 X 240 pixels, 16-bit at 60 Hz. There was a significant difference of 0.5ºC in the thermal values of tibia in the symptomatic point, as well as alteration of thermal value 0.7ºC in the medial malleolus symptomatic of the left leg investigated, comparing to the non-symptomatic points. There were differences in the evaluation of the thermal points of the left lateral malleolus with changes of thermal standard of 0.5ºC. The results indicate that medical thermography can be used as a good method of follow-up in consolidated fractures that present painful symptoms.

Keywords: Thermography; Stress Fractures; Consolidated Fractures

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Introduction

Infrared thermography (IT) is a diagnostic technique that captures and measures the radiation that is emitted by the body, providing an image of the thermal distribution of the skin surface[1,2].

Infrared radiation is invisible to the naked eye and indicates the degree of molecular agitation[2]. The thermal image is dependent on the emission of radiation from the surface of the skin and with the help of a special camera, an accurate thermal mapping of the human body can be achieved by converting the thermal energy emitted by the body into electrical signals that are scanned and presented in image form[3,4].

This diagnostic technique has been increasingly used to record thermal and physical body patterns, monitoring the distribution of skin temperature for evaluation of normal and pathological thermal physiological processes, characterized by increased or decreased skin temperature, as well as diagnostic method[5,6,7].

Thermography is a method of image evaluation that can also be used to monitor bone lesions and the regeneration process at early stages until the final consolidation stages[8,9,10,11].

The process of healing, formation and bone remodeling is directly related to metabolic and vascular changes at the fracture site. Observing the peak temperature in the period corresponding to the inflammatory phase of the bone regeneration process will support the physician in treatment decisions[12]. The authors[13,14] proposed the use of thermography for follow-up and evolution of the healing process of this traumatic lesion.

Thermography presents itself as a complementary analysis tool for different stages of healing and interpretation of these medical imaging results, as it is presented as a safe, non-harmful, non-invasive and painless technique, since no ionizing radiation is used to obtain the image[15,16,17].

The study[18] demonstrated that the application of thermal imaging may be useful in detecting distal radius and ulna fractures in children's pulses, presenting a sensitivity of only 96.8% when compared to X-rays. Compared to clinical examination, the results demonstrate sensitivity of up to 96.7%.

Stress fractures is a partial or complete fracture of a bone resulting from its inability to endure tension applied rhythmically and repeatedly[19]. It is a common pathology in amateur or professional athletes, dancers, soldiers in military marches with boots, but that can affect any individual involved in light to moderate physical activity or in daily or work life[20].

Thus, thermographic parameters may indicate alterations in bone healing delay, presenting as a diagnostic method to minimize the subjectivity of medical reports and provide additional information in diagnoses performed by conventional imaging methods.

The aim of the present study was to investigate alterations in the thermal pattern in consolidated fibular and tibial stress fracture in a female athlete, who had an intense manifestation of pain at the fracture site after a time period of 12 months after the bone repair.

Methodology

The sample consisted of a volunteer from the city of Curitiba, Brazil, aged 49 years, height 1.68 m and body mass of 57.0 kg.

Young female running for 15 years with diagnosis of consolidated stress fracture in the bones of tibia and fibula in the left leg with presence of bone callus, which occurred in August 2017.

The volunteer had frequent complaints of painful symptomatology, at fracture points in physical activity, and at rest in the standing and sitting positions. The training frequency and volume were performed three times a week with a duration of 45 minutes and a course of 5,000m on each day of activity.

In August 2018, in the Laboratory of Medical Thermography of the Federal Technological University of Paraná (LABTHERM / UTFPR), the volunteer underwent thermal adaptation in the same room where the thermal images of the region of the tibia and fibula were collected , thus being climatized at least a minimum of 15 minutes before the thermographic collections, in a sitting position with the hands relaxed and supported on the thigh.

In order to adapt to the climate the volunteer was dressed in T-shirt and comfortable shorts, with controlled ambient temperature at 21°C.

The temperature of the Laboratory of Medical Thermography of the Federal Technological University of Paraná (LABTHERM/UTFPR) was maintained at approximately 21ºC a with closed doors and windows, following the recommendation of the International Academy of Clinical Thermology (IACT) and the Brazilian Association of Thermology (ABRATERM) for infrared image detection.

The air velocity was lower than 0.2 m / s, controlled by a digital anemometer, avoiding evaporation and consequent cutaneous thermal loss due to forced convection, by means of care of closed doors and windows and reduced movement around the researched volunteer. Black curtains between the evaluated subject and the windows, so that the external light did not influence the capture of the images.

Fluorescent lights were standardized in the environment of the thermogram collections. The volunteer was evaluated in the afternoon, so that there were no thermal changes due to variations in the circadian cycle[21].

In conjunction with the thermographic evaluation, the mean temperature and mean tympanic temperatures of the volunteer surveyed (central temperature) were measured. The ambient temperature was measured by an INSTRUBRAS benchmark digital thermohygrometer, visible and easy to read. Voluntary body temperatures were measured with a Braun Thermoscan Instant Thermometer digital infrared thermometer in the ear canal (equivalent to central temperature)[2].

The tympanic temperature reading (TT) was obtained according to the procedure recommended by Hungary (1995): the volunteer of the study accommodated sitting with lateral rotation of the head at 20ºC to check the temperature; the ear was gently rotated upwards and backwards and the infrared digital thermometer inserted into the gently, coupled ear canal and measuring duration of two seconds.

Both auditory channels were measured and the mean temperature was used for record. This thermometer captures the temperature of the tympanum and neighboring tissues, the main site for measuring body temperature due to its proximity to the hypothalamus and perfusion by the labyrinthine artery[2].

Regarding the capture of the thermal images of the fracture region of the tibia and fibula, which consists only of acquiring photographs with a thermal camera that records images in color gradient (according to the temperature of the surface of the skin), the volunteer was dressed in a t-shirt and comfortable shorts that did not compress the skin, in the sequence was positioned comfortably lying on his back (supine position) on a clinical table (stretcher), with arms extended along the body.

Cushions with cotton cloth pillowcases were used to protect the head in order to provide greater comfort during the collection of thermal images. The legs were extended and hypoallergenic disposable markers were used for individual use and fixed to the anterior and lateral tibia to delimit the study area and respective points of interest (ROI) for recording the skin surface temperatures (TP).

From each of the ROI, the software estimates the minimum, average and maximum temperatures (TP). The thermal imaging was based on the cutaneous margins and the inclusion of the proximal half of the metatarsals and the distal portions of the tibia and fibula and the anterior (frontal), lateral and medial regions, allowing a global view of the regions to be analyzed. The knee and hip joints were centralized and aligned with the anterior superior iliac crest.

Two sets of thermal images were taken at a fixed distance between the camera and the one surveyed. The duration of the collections with an average time of 40 min between adaptation to the required temperature and adequate positioning of the volunteer on the clinical table and capture of the thermal images.

The thermal imaging was taken by means of an FLIR®Systems Inc. Professional A325 camera with 0.08° thermal and 0.1 mm spatial resolution, with the actual integrated resolution being 320 X 240 pixels, 16-bit at 60 Hz.

This camera has sensitivity to detect temperature differences of less than 0,08ºC and has an accuracy of ± 2ºC of the absolute temperature, according to the manufacturer's specifications. Considered a thermal sensitivity of 0.1°C per tone of color, using a colorimetric scale (rainbow palette), according to Flir Tools program of the Thermographic Camera FLIR®Systems Inc. Professional.

The following parameters were adjusted: skin emissivity of 97.8% for human body[2], reflected temperature, air relative humidity below 60%.

All images were taken with the camera fixed on a tripod, positioned horizontally and facing the volunteer surveyed at a distance of one meter and height of 80 cm corresponding to the height of the clinical table, aligned with the median line of the tibial fracture region and (region of interest) with a 90º angle, and perpendicular to the camera lens[22].

A straight line was delimited on the floor with adhesive tape, from the position of the thermographic camera to the researched volunteer, to assist in positioning for the correct acquisition of the thermal images, as well as a smaller line perpendicular to it, for delimitation of the positioning of legs and perfect location of tibial and fibular stress fracture.

The volunteer evaluated was oriented so that on the day of the test should not ingest alcoholic beverages or coffee; as well as not using talcs, lotions, creams or body oils and / or blockers; do not wear tight clothing; avoid touching the area to be analyzed and do not cross the legs during the thermal adaptation, before the examination.

The thermal mapping and image interpretation were performed using the Flir Tools software, with the values of absolute, maximum, average and minimum temperature of the investigated region.

Results

There was a significant difference of 0.5ºC in the thermal values of tibia in the symptomatic point, as well as alteration of thermal value 0.7ºC in the medial mal-

Table 1 - Maximum, mean and minimum absolute temperature values of the tibia and asymptomatic and symptomatic medial malleolus

	Maximum	Minimum	Average
E1 Tibia asymptomatic portion	29.0ºC	28.8ºC	28.9ºC
E2 Tibia symptomatic portion	29.5ºC	29.4ºC	29.5ºC
E3 Asymptomatic medial malleolus	30.4ºC	30.3ºC	30.4ºC
E4 Symptomatic medial malleolus	31.1ºC	30.7ºC	30.9ºC

Table 2 - Maximum, average and minimum absolute temperature values of the fibula and lateral malleolus

	Maximum	Minimum	Average
E1 asymptomatic fibula	28.9ºC	28.8ºC	28.9ºC
E2 symptomatic fibula	29.4ºC	29.2ºC	29.3ºC
E3 Asymptomatic medial malleolus	29.6ºC	29.4ºC	29.54ºC
E4 Symptomatic medial malleolus	30.1ºC	30.1ºC	30.1ºC

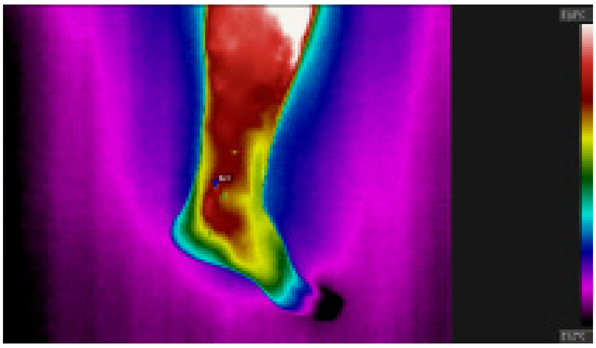

Figure 1: Thermal image of the tibia and medial malleolus of the left leg

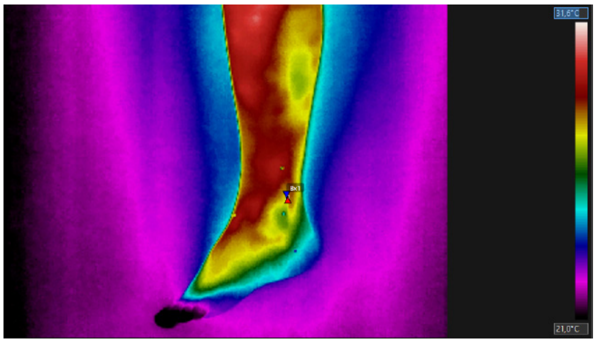

Figure 1: Thermal image of the fibula and lateral malleolus of the left leg.

leolus symptomatic of the left leg investigated, comparing to the Asymptomatic points, according to the values presented in Table 1 and Figure 1.

There were also differences in the evaluation of the thermal points of the left lateral malleolus with thermal pattern changes of 0.5ºC relative to the symptomatic point and the fibula, despite presen-ting painful symptomatology there was no signifi-cant thermal difference, according to data shown in Table 2 and Figure 2.

Discussion

Thermograms analysis showed changes in the thermal pattern at the local points of tibial and fibular fracture as well as in the medial and lateral malleoli of the left leg, coinciding with the report of the volunteer investigated regarding the manifesta-tion of pain in the lower limb affected by the stress fracture occurred in the year of 2017.

Bone consolidation is a simple biological phe-nomenon that occurs in phases: formation of he-matoma, inflammation, angiogenesis, formation of cartilage and, finally, bone remodeling (23,24).

Although bone callus was present in the bone remodeling phase according to the magnetic reso-nance imaging (MRI) images presented in the year 2017, the volunteer manifested painful symptoms after 12 months of the bone lesion.

The volunteer's return to sports activities with inadequate training volume suggests that these are the possible factors of the clinical manifestation of pain.

The return to sports training activities should be gradual and with continuous follow-up of clini-cal evolution by orthopedists through diagnostic imaging so that stress relapse does not occur, further damage to soft tissues, because these bone lesions are frequent in the practice of street racing.

We highlight the inconvenience in the follow-up of stress fractures the adverse effects of the ioni-zing radiation that the patient is exposed with the accomplishment of numerous radiological exami-nations for follow-up and clinical monitoring evolu-tion of the bone lesion.

The frequency of occurrence of fractures as well as the complexity of bone and muscle damage are very important aspects for traumatologists. Incor-rect medical judgment and treatment and ac-com-paniment failures may lead to poor results regar-ding bone healing response (25).

The results showed that the thermography examination showed to be an important correlation factor of the thermal images with the painful symp-tom presented by the volunteer, evidencing the metabolic alterations still present in the sites of formation of the bone callus offering additional data in the support direction treatment decisions and clinical evolution of traumatic lesions minimi-zing continued exposure to ionizing radiation.

According to the study conducted in Croatia (26), which evaluated temperature differences in pediatric trauma in patients aged 4 to 14 years, the authors' research demonstrated the use of thermo-graphy in the evolutionary follow-up of bone fractu-re consolidation after 7, 14 and 21 days after the appearance of the bone lesion.

In continuity to the studies on the applicability of thermography in bone consolidation, the study carried out in Russia (27) stands out with 18 pati-ents who underwent repair surgery. The sample consisted of (9 women and 9 men) between 12 and 74 years, the bone lengthening performed by the Ilizarow method. The extended segments were: the lower part of the leg - in 13 patients, the thigh of 4 patients and the forearm - in 1 patient. The asses-sment of healing status was done as part of periodic x-ray outpatient checks comparing them with thermograms.

Based on the radiographic exams, thermal indi-ces were determined - temperature difference of the extended end in place of its extension and symme-trical end in the same level and the temperature difference of the extended end in the location of its extension and in selected near points. This study demonstrated that the thermographic examination is a valuable complement to traditional imaging methods and can be successfully used in orthope-dics and traumatology. Another important study that contributes to the findings is the research (28) that analyzed extraction algorithms to determine the characteristics for detection of abnormality based on Euclidean distance. These authors propo-sed an Euclidean distance of color image segmen-tation algorithm based on abnormality of arthritis thermography, stress fractures, long bone fractures and ankle lesions, this research demonstrated that the Euclidean distance can be a parameter for the detection of abnormalities in the lesions studied.

Thus, another study, which also corroborates the applicability of thermography in bone lesions, (13) carried out an investigation of the thermal changes during bone healing with 25 patients aged between 50 and 80 years who presented with distal fractures in the radial bone with thermal imaging on the day of fracture, after three days, after five days, after 11 days and after 23 weeks of follow-up.

The results of the research demonstrated signi-ficant temperature changes during the healing process of the radial bone fractures and supported the initial hypothesis of the investigators that the thermography examination is feasible in the clinical practice of orthopedics as an excellent method for monitoring the evolution of the bone healing pro-cess.

According to a pilot study (29) that analyzed 476 thermal images of bone stress in Australian Army soldiers during three months of research into the detection of pathology of stress fractures in the legs of Australian Army basic trainees, results focal changes in the tibial and fibular bones and allowed control in the development of biomechanical stress fractures in lower limbs during military training.

In this way, thermography presents itself as a complementary diagnostic tool in the evolutionary follow-up of the different stages of cicatrization, presenting as a safe, non-harmful, non-invasive and painless technique, since no ionizing radiation is used to obtain the image (15,16,17).

The findings of the present study corroborate with the previous studies presented and denote the possibility of medical thermography as an alterna-tive for immediate diagnosis and in the evolutio-nary follow-up of stress fractures, allowing the re-duction of differences in medical decisions and treatment options.

Conclusion

The results indicate that medical thermography can be used as a good follow-up method in trau-matology and orthopedics, but new investigations are required with larger samples of patients with the diagnosis of stress fracture in the different stages of bone consolidation, allowing accurate information of the profile during the healing pro-cess and also in consolidated fractures.

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