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INFRARED CAMERA APPLICATION IN CREATION OF THE DIAGNOSTIC METHOD FOR DEEP VEIN THROMBOSIS IN THE DISTAL PARTS OF THE BODY

OPRACOWANIE METODY DIAGNOSTYCZNEJ ZAKRZEPICY ŻYŁ GŁĘBOKICH W CZĘŚCIACH DYSTALNYCH CIAŁA Z WYKORZYSTANIEM KAMERY TERMOWIZYJNEJ

A b s t r a c t

The main purpose of this paper is to show major increases in the temperatures of the lower extremity limb in comparison to the latter. During the course of the study, it was found that a significant difference in the temperatures arises between the healthy left limb (subject to the conducted tests) and the sick right ('control') one, before and after performing an attempt to cool down. The examination consisted of a series of credible medical measurements with the application of professional thermal imagining equipment. The abovementioned study acknowledged the potential of thermal imagining diagnostics in terms of assessing the state of health of the examined subject. In terms of thermal imagining methods usage, it is possible not only to locate the inflamed spots effectively, but also to monitor the course of the treatment of the inflammatory conditions.

Keywords: diagnostics, thermal imagining, thrombosis

S t r e s z c z e n i e

W artykule przedstawiono wykorzystanie termowizji do wykrywania zmian w naczyniach obwodowych, w kończynach dolnych. Jest to możliwe, gdyż na obrazach termowizyjnych zaobserwować można różnice w rozkładzie temperatury, co jest związane z zaburzeniami przepływu krwi. W trakcie badań stwierdzono istotną różnicę w temperaturach między zdrową lewą kończyną (w zależności od przeprowadzonych badań) i chorą prawą („kontrolną"), przed rozpoczęciem i po wykonaniu próby na oziębienie. Badanie składało się z szeregu wiarygodnych pomiarów medycznych z zastosowaniem profesjonalnego sprzętu do diagnostycznego obrazowania zmian temperatury. Wyżej wymienione badania potwierdziły potencjał diagnostyki obrazowania termicznego w zakresie oceny stanu zdrowia badanego pacjenta. Wykorzystanie metody obrazowania termicznego umożliwia, nie tylko skuteczne zlokalizowanie stanu zapalnego, ale również monitoring przebiegu leczenia stanów zapalnych.

Słowa kluczowe: diagnostyka, kamera termowizyjna, zakrzepica

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1. Introduction

Thermography, also called the thermal imagining method, includes testing that relies on contactless and remote evaluation of the temperature distribution on the surface of the inspected body. This method is based on observing and recording the distribution of the radiation emitted by an infrared body temperature (higher than absolute zero) that is being converted into visible light [1].

Thermographic study enables visualization of the physiological changes in the human body. Through this visualization, it informs directly about the existence of irregularities in the body at an early stage of their occurrence, preventing permanent and irreversible changes from taking place.

Thermographic survey poses no threats to life and health of the test subject. It does not use a radius of X-rays (as in the case of a traditional X-ray imaging) and is to be considered as non-invasive and human-friendly method during the whole course of the examination [2]. The basis of the functioning of the infrared camera is the matrix that bears the possibility of detection (receiving) radiation in the infrared band. The received radiation signal is electronically processed and presented in the form of a graph of the temperature distribution. Temperature charts – being the result of the examination – of the specific areas of the entire body are presented as color images. Color spots displayed with intense shades of red determine the emission of higher temperatures and likewise – the greater the intensity of the blue tones, the more reduced the emission of the infrared radiation [3].

The application of thermography in medicine / medical sciences is based on the search mechanism and monitoring of the possible temperature changes caused by an inflammation of the tissues. The physiological basis for such exploitation is based on the fact that inflammation results in an increased blood supply in a part of the body. The above-mentioned inflammation also causes a localized increase in metabolism at the cellular level, connected to the activity in the body and regeneration process in the area of inflammation. [4, 5].

The more increased the cellular metabolism and the more blood that flows through the data spot, the more heat is produced (referred to as a ‘radiation infrared’). This allows to conclude that such a place – clearly distinguished with the infrared image – can be a viable subject to the observations conducted with the infrared camera (rather than parts of the body not affected by an inflammation).

Nowadays, the research thermal imagining is applied while diagnosing Reynaud’s phenomenon (accompanying disease for SLE – lupus erythematosus), monitoring and detecting inflammatory spots in the body (i.e. rheumatoid arthritis), detecting breast cancer, other breast diseases and venous circulation in the lower limbs or monitoring specific parts of the body [3, 6].

It should be clearly stated that thermography cannot be used as an independent diagnostic method, monitoring or treatment of any disease. It should rather be used as an optional one, back-up for traditional methods, until the quantitative and qualitative data to support the full value and the reliability of its results is obtained [7, 8].

Depending on the type of the thermal imaging camera, the measurement may be:– exact to indicate the temperature of a particular place – through the use of sensors measuring – or the measurement can rely on observation of changes in the distribution of infrared radiation on the whole surface – detector of observation.

2. Conducted research

The person tested/test subject (treated as a patient):

- Female; aged 26,
- Diagnosed with deep vein thrombosis in the distal-proximal section of the right lower limb. Hormonal drugs used in the treatment of other diseases were determined as a trigger factor for the deep vein thrombosis.
- Confirmation of the disease on the basis of:
  - A preliminary study conducted with the usage of Scale Wells clinical probability of deep vein thrombosis – 'The Scale of Wells' clinical probability of deep vein thrombosis – is used to qualify the patient to a group of small, medium or high probability of the presence of deep vein thrombosis. This scale is extremely useful in clinical practice. The probability of deep vein thrombosis: 0 points – small; 1–2 points – moderate; ≥ 3 – big. Here: 5 points,
  - Determination of D – Dimer – a score of 5 722.8–3958.8 ng/mL,
  - Research – capillaroscopy,
  - Ultrasound examination of venous leg (Doppler). Ultrasound of the right lower limb veins extremity visible: thrombus in the field of extended bays of the soleus muscle, veins posterior tibial and peroneal, heterogeneous thrombus completely fill the extended light popliteal veins, femoral veins, popliteal, femoral vein common initial section of the external iliac vein.

Radiation is divided into 3 ranges: near infrared (0.7–5 microns), medium infrared (5–30 microns), far infrared (30–1000 microns).

Keep in mind that the higher the temperature of a body, the greater the radiation emitted by it. For each body, temperature is a characteristic wavelength at which the radiated power is at its maximum. As temperature increases, the maximum radiation shifts towards shorter wavelengths. For example, for the Sun (reaches a surface temperature equal to 6,000 K), the maximum radiated power is in the wavelength range of 0.5 μm. For the human body (temperature 300 K), the maximum radiated power is in the wavelength range of 10 μm.

The infrared radiation can be presented as a blackbody absorbing all radiation that shines on it, regardless of the angle of incidence, wavelength or power radiation source. We can assume that emittance (the energy flux density emitted by a surface area of the body) of the source of emission is proportional to its temperature. This means that radiation from the infrared range emitted by a body with a temperature is greater than absolute zero. It is proportional to its temperature. From the point of view of the infrared mapping, emissivity of the measured object is really important. The emissivity value is introduced to the reference of blackbody radiation as an effective pattern [2].

Preparation of a subject and the test room

The patient must be present in the testing room for 30 minutes to stabilize the skin surface, as the condition for a stable measurement is to obtain a skin surface temperature – so that the test results could be considered reliable.

There are special requirements for the room where the test is to be carried out.

The guidelines [6, 9]

I. The room in which they are held, infrared measurements should:
- allow convenient placement of measuring devices,
- allow visualization of the entire study area,
- provide comfort for both the researcher and patient,
- the size of the room cannot be less than 6 m^2 (2 × 3 m) – as optimal 12 m^3 (3 × 4 m) or greater, to be considered,
- In practice, it happens that the minimum dimension of the test facility depends on the parameters of optical cameras, such as:
  - The minimum focal length, FOV (Field of View),
  - Spatial resolution IMFOV (Instantaneous Measurement Field of View),
  - Dimensions of the examined object.

The key element of the thermographic measurements is to maintain a constant temperature in the testing room – preferably in the range of 20–24°C. Studies show that the human body cools very quickly, and the next two to three quarters of an hour correspond to the temperature stabilization [1]. It is important that the ambient temperature should be comprised within the optimum range of 18–25°C (below 18°C too rapid cooling occurs, and above 25°C the patient begins to sweat). Proper temperature is extremely important, due to the fact that the measurement of active temperature fluctuations makes it difficult for the later analysis of the results and may contribute to the loss of important data.

Another important measurement parameter is the relative humidity of the air – it determines the heat exchange process. For studies of thermal imagining, it is recommended to maintain a humidity level of 45–55%. In addition, it is recommended to limit the flow of air, because air circulation can cause non-uniform temperature distribution. In the research room, no central heating devices should be placed – such as stoves or radiators. An extremely important issue is also to limit the amount and intensity of the light sources – the most reliable measurement results are those obtained in rooms that are poorly lit.

Before the thermal imaging test, each patient must be acclimatized to the ambient conditions. Acclimatization should take approx. 15–20 minutes.

II. During the acclimatization, the tested area (which will be recorded):
- must be bare – for the process of heat exchange with the environment to stabilize,
- tested area must not be touched, rubbed or leaned on.

III. Preparation of a patient:
- physical activity should be reduced to a minimum,
- it is recommended not to drink hot fluids or eat hot meals a few hours before taking measurements,
- vigorous exercises, drinking alcohol and smoking cigarettes are prohibited,
- usage of any drugs that could cause a change in body temperature,
- application of any cosmetics on the test surface,
- contraindications to the research are also to be indicated on the same day of the physiotherapy treatment, except when we want to assess their impact on changes in temperature.

Compliance with the rules for dealing with the test surface and the preparation of the subject is particularly important in medical research. It has been proven that all factors mentioned above have an effect on the cardiovascular system, and hence, also the surface temperature distribution. Their effects can be seen on the thermal image, but can also persist on the screen for a period from a few dozen to a several minutes [6, 10, 11].

IV. Preparation of the test

During registration of the thermal images:

- patient should be in a fixed position and in the right distance from the camera,
- distance between the camera and the patient must not be less than 1–1.2 m,
- recorded area of the body must be in the perpendicular position to the lens of the infrared camera,
- during the registration sequence, the researcher should pay attention to the correct focus of the camera.

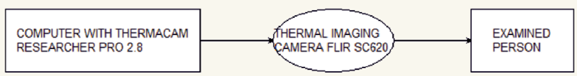


Fig. 1. Diagram of the research position

Fig. 2. Research position

After setting the position, the next stage is the calibration of measuring and control instruments.

The parameters of the thermal imaging camera: [12]

I. Emissivity = 0.98

The most important parameter of the thermal images (which must be correctly entered) is the emissivity. Object materials and their surfaces are characterized in terms of emissivity from 0.1 to 0.95. A highly polished (mirror) surfaces have an emissivity of less than 0.1, oil paint (whatever its color in visible light is) has an emissivity in the infrared region of more than 0.9, human skin exhibits an emissivity close to 1.

II. Ambient temperature

Temperature is a parameter that is used to compensate for the radiation reflected from the object and the radiation emitted by the atmosphere located between the camera and the subject. If the emissivity is low, the distance is large and the temperature of the object is nearly ambient, it is important to adequately compensate for this temperature.

In order to make an accurate temperature measurement, it is necessary to compensate for the effect of other sources of radiation. This is done automatically by the camera, after the introduction of the object parameters:

- emissivity of the object,
- ambient temperature,
- distance between the object and the camera,
- relative humidity.
- Measurements were performed in a separate room:

– constant temperature of 24°C.

III. Humidity 37%

Measuring position (Fig. 2)

- FLIR SC620 thermal imaging camera,
- PC with installed software – ThermaCAM Researcher Pro 2.9,
- thermometer for measuring the temperature in the room,
- hygrometer to measure the humidity in the room,
- camera to capture digital images [additional element].

Due to the need of ensuring proper working conditions for the infrared camera, it is vital for its first launch to take place about 30 minutes before the beginning of the study. During testing, the camera is faced at a fixed distance of 150 cm from the tested patient.

Research

Enter all values: temperature, humidity, distance. There are also other variables necessary to take into account during the research – set the focus of the lens, the position of the LCD display and an overview of the subject. All the factors indicated above allow an assessment of whether: the points of elevated temperature are visible, the measurement is conducted with a suitable distance, the image is proper and the object is in the camera view, whether the elementary angle of view (spatial resolution) is ensured.

By registering thermograms, it is important to make sure that the maximum temperatures do not exceed the upper limit of the measuring range, this would result in a loss of information of the actual value of the maximum temperature of the object. Depending on needs, the appropriate range should be chosen (in this case it is 30–38°C) [3, 7].

Registering a static image of the lower limbs

Thermal image of the temperature ranges from 25 to 40°C, which cannot directly determine the pathologically changed areas.

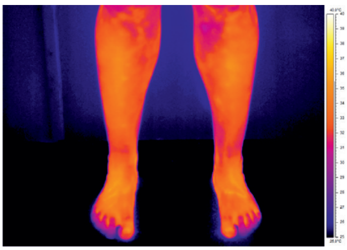
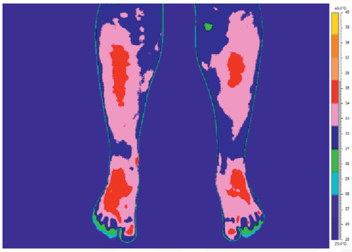


Fig. 3. Thermal image (temperature from 25 to 40°C)

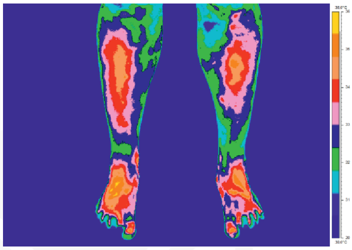
ThermaCAM Researcher allows you to apply one of a number of infrared pallets, which find their application depending on the recorded image type, or effect you want to achieve.

The use of pallets of medical imaging allows for the distinction of pathologically altered areas.

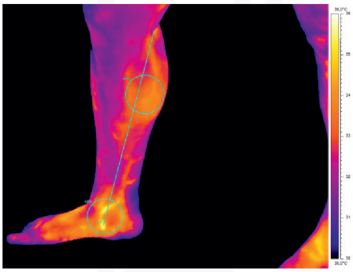
For the temperature range from 25 to 40°C – clearly increased temperature for the right leg (diagnosed with deep vein thrombosis):



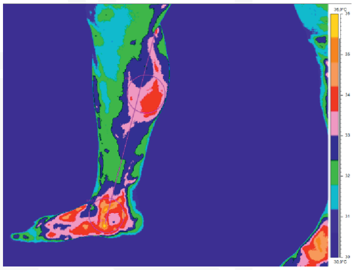
Temperature range from 30 to 36°C – allows better determination of the points (or area) for which the temperature is considerably higher (shown with red ellipses):



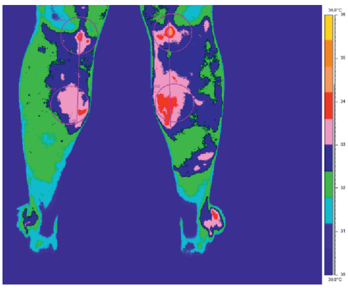
Iron pallet, including a scale in the range from 30 to 36°C and the indication of the area with red ellipse disorder of disease:



Medical pallet, including a scale in the range of 30 to 36°C:



Medical pallet, including a scale in the range of 30 to 36°C



Rain pallet 900, including a scale in the range of 28 to 36°C – used in order to illustrate the lesions and the area rate of the disease more clearly.

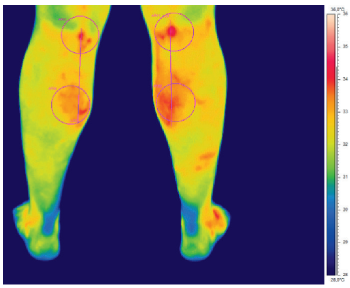


Fig. 4–9. Thermal images

The cooling attempt – applied due to the downward trend in exploration and temperature rise comparing both legs.

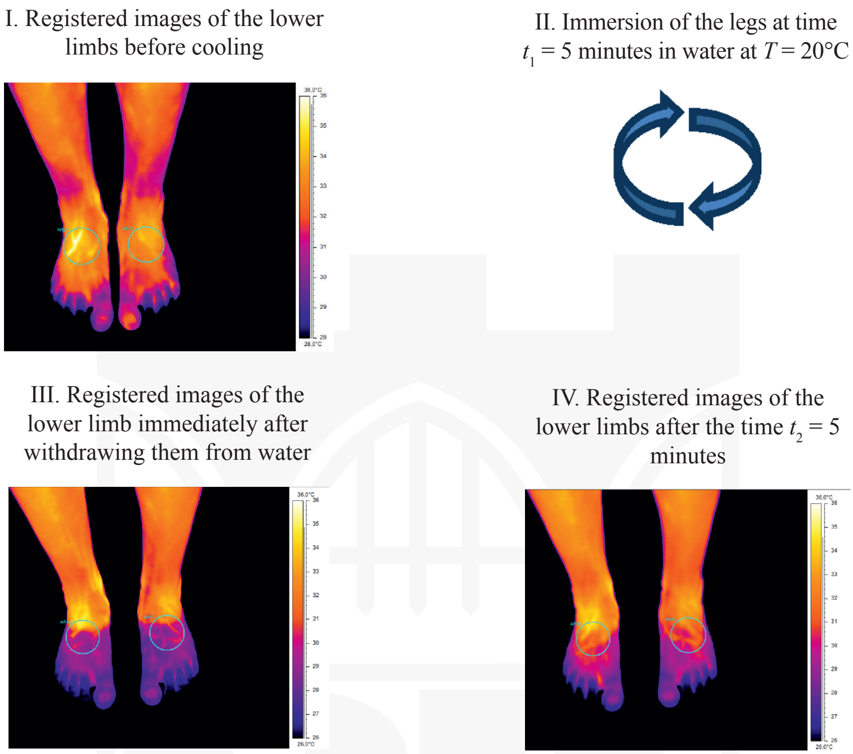


Fig. 10–12 Thermal images – cooling attempt

Findings

Findings obtained during the testing series of thermal images allow to determine the minimum, maximum and average temperature in the analyzed areas of the limbs.

– The maximum and minimum temperature for the sick limbs is 36.1°C and 31.6°C.
– The maximum and minimum temperature for the healthy limb is 34.8°C and 31.1°C.

1.3 ° C is the difference between the maximum temperature values of both legs.

The measured points show abnormalities in blood flow in the vascular system, increased difficulties in the flow and pressure. Studies show that there are significant differences in the average temperature between the healthy and the sick limb.

The differences were shown both before and after an attempt to cool down. Before attempting to cool down, the registered average temperature of the healthy limb was higher than the temperature of the "sick" one by 1.6°C. After cooling the limbs in water at 20°C, average temperature for the patient's limb was higher by 1.2°C. This indicates a faster rise in temperature for the diseased limb, rather than the healthy one.

During the study, significant differences in the occurrence of the higher temperature values were also observed. This is due to the degree of blood circulation in the assessed limbs, both before and after the load of the patient's attempt to cool down (Fig. 10–12).

Infrared thermography as a non-invasive, painless and safe method that helps to specify the physiological state of the examined tissue due to the emission of thermal radiation can reflect the rate of occurrence for these metabolic changes associated with local blood supply. The difference in temperatures is associated with impaired blood supply in comparison to the observed areas of the body, indicating impaired blood flow in the studied area [1, 2].

The thermal images of the lower limbs received during the tests unequivocally illustrate the differences in the temperature distribution within the studied area. Comparing the average value of the temperature before and after cooling down, the sample in the area of the healthy limb and the limb with the deep venous thrombosis has been demonstrated with a higher temperature of the diseased limb [2, 13].

The effectiveness of the ongoing process of the deep vein thrombosis could assist with the thermal imaging diagnostics, directly visualizing the progress of the treatment and rehabilitation. The results of research obtained this way could therefore form the basis for determining the intensity and level of effectiveness of treatment and rehabilitation in the rehabilitation of the patients with a history of disease states of deep vein thrombosis. This is a prerequisite for any further research focused on the application of thermal imaging diagnostics imaging of cardiovascular diseases.

3. Conclusions

In the course of the study, significant increases in the temperature of the right lower limb (in comparison to the left) were found. The study showed the presence of the substantial temperature difference between the left and right lower limb, before and after the performance of the cooling test.

Presumably, research done on a larger group of patients could increase the statistical possibility of testing thermal imaging as a credible medical research.

The above-described thermal imaging studies point to the possibility of using thermal imaging diagnostics in assessing the state of health of the examined person. Finding and monitoring the treatment of the areas affected by the inflammation are possible thanks to the application of thermal imaging methods. Comparing thermal images of the same area, at certain intervals, could help to observe diversification of the production and heat loss to the environment.

The use of thermal imaging makes it possible to detect changes in peripheral vessels in the legs and arms. It is possible due to the fact that, in the images of thermal imaging, the differences in the temperature distribution can be observed, which is associated with impaired blood flow.

An additional benefit of using a thermography test as a method of diagnosis in medicine is the economic problem. Full-size studies can directly show anomalies in the human body due to the detection of inflammations, being indicative of poor health. This would not save only time, both patient's and physician's, but it also can reduce the cost of medical diagnostics, the whole or a specific area of the body.

Based on the writer's own research, the convergence of methods of thermal imaging by Doppler ultrasound, and others described in the theoretical part of the MSc work [14], was demonstrated. Results of the Doppler ultrasound examination indicate the existence in the right limb of a disease state – deep vein thrombosis. Registration of temperature with the application of infrared camera confirms the presence of areas of elevated temperature – which is indicated by the blood flow disturbances. Thermal imaging method could thus be complementary to conventional methods of diagnosing cardiovascular diseases.

Infrared thermography as a diagnostic method has a high potential in research or diagnostics. It already has a considerable interest in both the scientific and medical communities. Its development potential also provides the ability to determine – at the first contact with the patient – the existence of irregularities in the body, which are visible in the paintings of thermal inflammations characterized by increased temperature values.

Thermal imaging is not yet considered a fully reliable method. While using thermal imaging on humans or animals in particular, only reliable and accurate results must be presented. Please be sure to remember that incorrect measurements lead to erroneous conclusions.

But certainly, summing up the above conclusions, it should be clearly stated that the establishment of a uniform methodology for research thermal imaging as a method of diagnosis has a development potential and needs further study.

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