PERIODICUM BIOLOGORUM
VOL. 112, No 4, 475–478, 2010

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Extremities Perfusion Stimulation and Dynamic Evaluation by Thermography Analyses

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Key words: Infra red medical imaging, dynamic thermography, blood circulation, thermo web

Received September 29, 2010.

Abstract

Dynamic thermographs are potentially a very valuable method for medical application, especially for vascular diseases. We realized a Dynamic Thermography (infra red imaging) Analyses (DTA) research and development of blood circulation stimulation in patients with peripheral vascular diseases. Abnormal blood flow is common in older adults, especially those with elevated blood lipids, diabetes, hypertension, history of smoking, etc. Vascular circulation problems have a high prevalence in our population, often with more than one condition in the same individual. The differences in blood flow are revealed by temperature differences in areas of the extremities as well as other regions of the body. At the state of the art in diagnostic techniques we needed an imaging technique for dynamic evaluation of circulation and revilement of the blood flow in real time. For that purpose we used the IR real time dynamic thermography imaging technology which can show detail venous system and small temperature changes associated with blood flow. Pilot test patients with vascular diseases were tested in a clinic set up pilot project. Their legs and feet were stimulated and imaged. We observed significant temperature differences at the foot, especially toes. More valuable information was obtained from the temperature distribution maps.

INTRODUCTION

Thermography studies are non-invasive imaging techniques that are intended to measure the skin surface temperature distribution of various organs and tissues. Thermography measures the infrared radiation energy (heat generation) which is constantly being emitted from the surface of the human body thought the skin. Skin is an organ which cools us as well as keeps us warm by letting heat out or keeping it in by controlling/regulating the amount of circulation, or blood flow, in the skin. This automatic regulation is done without conscious thought and is controlled by the autonomic nervous system via the sympathetic nerves. The whole biochemical process is called the body thermoregulation *(1)*.

Today many people have cold hands, cold feet, sharp pain in the legs, peripheral arterial disease. These symptoms may be early warning signs of more serious blood circulation problems. To prevent progression of these symptoms we developed a sophisticated early detection possibility methods based on dynamic thermography technology. Measurement of the skin surface temperature is a crucial component of energy transfer. Thermography is a non-invasive diagnostic technique based on digital imaging which is able to detect pathologies that are difficult to detect using other methods and at a much earlier stage of their evolution. The physiological and pathophysiological basis of thermography is the dissipation of body heat through the skin which is detected as infrared radiation and which depends on the flow and volume of the subcutaneous blood circulation dynamics. In cases where diseases are associated with neurogenic inflammation, the liberation of nitric oxide produces intense vasodilatation and consequently a significant increase in the emission of infrared radiation energy. These inflammatory diseases may be the result of trauma, rheumatism or infection or even cancer. Thermal imaging through the thermal map distribution is able to pinpoint the location of this inflammation. The temperature gradient is often less than 1 °C, which means that leaf temperature should be measured to within 0.07 °C (at 30 °C) temperature resolution and high spatial resolution (min. detectable size is 0,64 mm^2). The infrared radiation from the tissues reveals temperature variations by producing brightly coloured patterns on a liquid crystal display. Extremities perfusion dynamic evaluation is possible with advanced high sensitive and sophisticated dynamic thermography methods.

Scope of the existing methodologies

Well known standard angiography's methods as DSA, UZV CT and MSCT gives the diagnoses of magisterial vessels. Disadvantage of these methods is impossible to recognize the microcirculation, primarily at the main arteries occlusion on thigh.

Images obtained with currently commercially available devices have often haloes which are difficult to read and interpret due to impossibility to discriminate whether the thermal situation detected by skin contact is consequence of the superficial blood flow or the deep vessel flow.

Moreover, the deep circulation heat signal diverges as it moves away from the vessel and toward the surface of the body: for example at the large deep vessels of the breasts, currently obtained thermo graphic images have large haloes with blurred contours and dimensions which are significantly larger than the actual dimensions of the deep vessels.

It has been found experimentally that the less a thermo graphic examination is disturbed by the thermal situation due to surface blood flow, the more it improves in significance, reliability and unequivocally of interpretation *(2)*.

In practice, it has been found that if the surface of the organ to be examined, for example the breasts, is cooled appropriately before resting the thermo graphic plate, the images that form on the plate are first of all less disturbed by the heat due to surface blood flow and secondly, over time, are affected by the heat that gradually arrives from the deep regions: essentially, it is possible to choose, among the images that appear sequentially, those that are most significant and indicative of the thermal and circulatory situation at the various depths of the organ *(4)*.

The aim of the presented method is to obviate the above cited drawbacks of conventional devices. Objectives of the research is to provide a dynamic thermo graphic analytical method which allows to produce images which are affected to a limited extent by surface blood circulation and allows to obtain a series of images from which it is possible to clearly detect the situation of functional blood circulation in various area.

Dynamic thermography method and device description

The DTA method using ThermoWEB instrument for the contactless measurement of temperature, which is based on an expansion of the measuring and operable usage possibilities of the thermo vision camera NEC Thermo tracer TH7102WL *(5)*.

This camera's standard area for reading off temperatures is limited to one central point of the obtained thermal picture of the object. By using the additional programming support and hardware expansions, which is developed by Ruđer Bošković Institute, it is possible to choose any point inside the obtained thermo graphic picture of the object and get a quantitative and time-dependent value of temperature distribution. To the thermo vision camera has been added a camera that registers the visible spectrum (CCD color camera), thus making it possible to accept pictures from the measured object in IR and in the visible spectrum. The camera system for measuring is controlled by a computer, which has a wireless or physical connection to the Internet.

The result of these improvements is the realization of a high quality network system for remote and contactless measuring of temperature over the WEB (ThermoWEB).

The hardware component of the ThermoWEB measuring system (Figure1.) includes the thermo vision camera NEC Thermo tracer TH7102WL (1), a video CCD color camera (640x480 pixels) (2), set in an appropriately shaped housing (IP54), with a mechanical adapter for

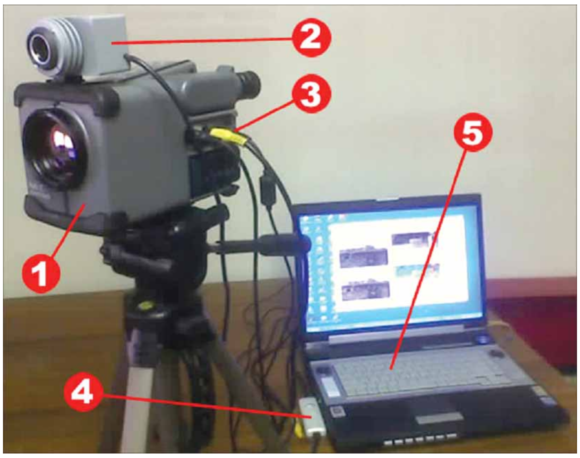


Figure 1. *Components of the ThermoWEB system.*

assembly onto the housing of the IR camera, and a circuit for choosing and accepting video signals (4) from the camera to the computer (USB2) (5).

Operation of the functions of the IR camera is done by using a computer with RS232 interface (3).

The software support for the measuring system comprises of:

- main menu of the ThermoWEB system,
- ThermoCAM control, software support for control of the IR camera (TH7102WL),
- ThermoWORK, software support for measuring of temperature and ThermoMED, specially adapted program pack for medical infrared analysis of dynamically thermographic images, which prepare data necessary for DTA method.
- Software support for remote control and data viewing over the WEB.

The portable ThermoWEB, specialized equipment offers the advantage as useful diagnostic methods for peripheral circulation diseases.

The Microstim KLM 500 physiotherapical device has been used in order to treat capillary vessels circulatory problems. It generates special waves introduced into the human body through ultrasound gel and that way improves circulation and delivers oxygen and nutritives to blocked areas. We used this vascular circulation stimulator to induce the dynamic thermal effect for DTA method evaluation Treatment time was 15 minutes. Transducer head (surface 33 cm^2) was fixed to the foot by elastic band (Figure 2). The applied power was 5 W in a wide band therapy mode.

Evaluation of experimental results

The DTA method included temperature measurement procedure, which can be performed on one picture only (single frame-mode freeze) or it can continually monitor the time dependence of changes in temperature intensity of a point or surface by taking pictures with a max. frequency of 60 Hz. The continued time-tracking of temperature intensity makes it possible to determine

Figure 2. *The left leg capillary vessels stimulation.*

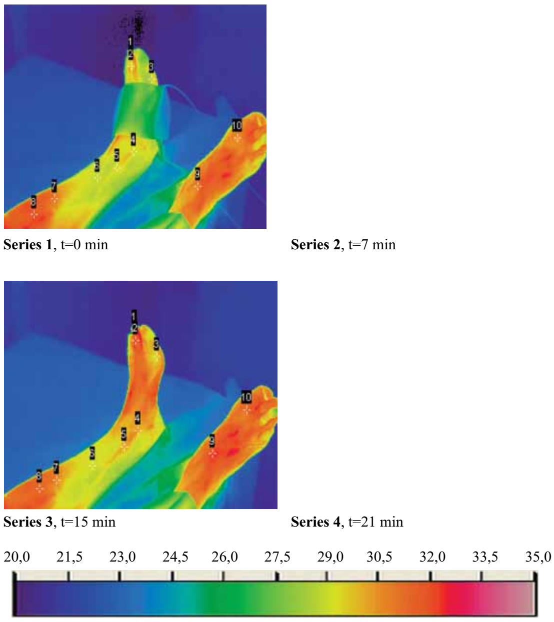


Figure 3. Thermal *imaging of patient's legs at various times with distribution of measurement points*

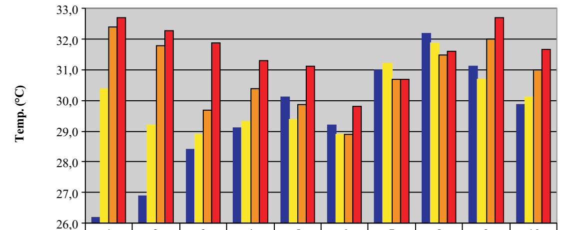
the frequency change of a single thermal surface inside the picture. The resulting thermal data can be rendered as a series of color images that can be used to differentiate normal and abnormal changes in temperature, which results in the possibility of recognizing snap action (influence) of the vascular circulation stimulator (Microstim KLM 500). Besides images (Figure 3), the ThermoMED application can also store video recordings.

Measuring temperature points can be added and removed to the image obtained from the IR camera. Size (from 1 to 961 pixels) and emissivity properties (from 0 to 1) can be modified for each measuring point. The max. number of measuring points is not predefined, so it can be set by the user.

For periodical temperature measuring the timer option is used. The time interval has to be set (1 to 600 seconds) and then the function is executed by pressing start. The application then periodically measures the temperature, and the measured values will then be shown in the table (Figure 4). The results can be stored in a text file or can be graphically shown on the screen.

In our case, we compared the temperature values of 10 measuring temperature points on lower extremities, 8 points on left foot and lower leg and 2 points on right foot. On Figure 3 we can see visual specter in four series, at the beginning of treatment (series 1), 7 minutes after beginning of circulation stimulation (series 2), after 15 minutes (series 3), and after 21 minutes (6 minutes after ending circulation stimulation-series 4).

In Figure 4. we can see changes of temperature on both legs during the treatment and 6 minutes after stopping the circulation stimulation. The greatest change of temperature is on second finger of left foot where we have a increase of 6,5°C. At the same time we observe de-



	1	2	3	4	5	6	7	8	9	10
Series1	26,2	26,9	28,4	29,1	30,1	29,2	31,0	32,2	31,1	29,9
Series2	30,4	29,2	28,9	29,3	29,4	28,9	31,2	31,9	30,7	30,1
Series3	32,4	31,8	29,7	30,4	29,9	28,9	30,7	31,5	32,0	31,0
Series4	32,7	32,3	31,9	31,3	31,1	29,8	30,7	31,6	32,7	31,7

Measurement points

Figure 4. *Surface skin temperature at various times of blood circulation in patient with peripheral vascular diseases.*

crease of temperature (0,7°C) in proximal part of lower limb.

We explain the change of redistribution of blood from vain pool of lower leg to dilated capillaries of the left foot.

Also we observe rise of temperature on right foot caused by the central autonomic nerves regulation.

Further Research

Further research and development will take place to develop the 4D IR camera that will allow three-dimensional view of the body with the temperature distribution. 4D thermographic system represent the creation of 3D thermal images, which contains information about the shape and energy state (temperature) or surface area of the heat distribution of the recorded body. Solution will mapping 2D thermographic images on a 3D model of the object obtained by advanced methods of 3D reconstruction. The new 4D thermographic system allows, besides the standard analysis of thermographic map, show the temperature distribution and characteristics of the recorded object on the reconstructed 3D model of the object incorporating the 3D scanning and thermography. Possible applications are in circulation dysfunction, the early diagnosis of breast tumors, skin tumors, arthritis and other inflammatory processes.

CONCLUSION

Thermo graphic research of blood circulation gives us closer look in the circulation itself. Thermo graphic probe that follows circulation stimulation with ultrasound gives us a better look in dynamic possibilities of peripheral circulation, what is important in vascular medicine and vascular surgery.

The method above is a new in a way it allows dynamic follow-up of blood circulation after treating foot with ultrasound and vibration.

Dynamic thermographs are important to determine potential capacity of capillary pool in patients with peripheral vascular insufficiency. In cases like that it is difficult to evaluate functional status of a limb, and thermographs are a method that gives us this possibility.

That fact can help surgeon with reversibility evaluation of ischemic tissue in differential cases, it can help in predicting of revascularization success, in making decision of amputation and the level of amputation. Also it gives us insight in functionality of reperfusion procedure after revascularization.

Acknowledgments: *The authors acknowledge financial support from the state budget by the Croatian Ministry of Science, Education and Sport, under grant 098 2562–2567, and would also like to thank University Clinic Hospital REBRO and Ruđer Bošković Institute for their support in setting-up our testing environment.*

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