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THERMOGRAPHY AS A NON-INVASIVE, RELIABLE DIAGNOSTIC TOOL IN MEDICINE – EXAMPLES

Termografia jako nieinwazyjne i wiarygodne narzędzie diagnostyczne w medycynie – wybrane przykłady

EWA APLAS[1 A,B,D–F]
MAGDALENA GOLACHOWSKA[2 B,D,E]
DONATA KURPAS[3 B,E,F]

[1] MediTerm Klinika Termografii
[2] Instytut Kosmetologii, Państwowa Medyczna Wyższa Szkoła Zawodowa w Opolu
[3] Uniwersytet Medyczny we Wrocławiu

A – przygotowanie projektu badania | study design, **B –** zbieranie danych | data collection, **C –** analiza statystyczna | statistical analysis, **D –** interpretacja danych | data interpretation, **E –** przygotowanie maszynopisu | manuscript preparation, **F –** opracowanie piśmiennictwa | literature search, **G –** pozyskanie funduszy | funds collection

SUMMARY

Thermographic imaging is a measurement of a body surface temperature distribution. The symmetry of the skin temperature distribution is an important indicator of proper physiological body functions. Improper distribution brings information about the disorders which might be the first signals of a developing disease.

In recent years, the dynamic expansion of thermographic imaging Is observed in many medical areas such as rheumatology, neurology, rehabilitation, orthopaedics, oncology and sports medicine. Thermography allows to visualize initial patho-physiological changes which are still too small to be detected by any other anatomy imaging techniques which are widely used. It is a valuable addition to standard imaging methods and allows to monitor the therapeutic process (both pharmacological and physiotherapeutic) in a non-stress and, what is particularly important, non-invasive way.

Keywords: medical thermography, non-invasive imaging, early pathophysiology detection

STRESZCZENIE

Obrazowanie termograficzne to pomiar rozkładu temperatury na badanej powierzchni ciała. Symetria rozkładu temperatury skóry jest ważnym wskaźnikiem prawidłowej fizjologii ludzkiego organizmu. Nieprawidłowy rozkład temperatury informuje natomiast o zaburzeniach fizjologicznych, które mogą być początkiem stanu chorobowego.

Obecnie zauważany jest dynamiczny rozwój termografii w różnych dziadzinach medycyny, między innymi: reumatologii, neurologii, rehabilitacji, ortopedii, onkologii czy medycynie sportowej.

Termografia pozwala na obrazowanie zmian patofizjologicznych, zanim inne techniki obrazowania anatomicznego będą w stanie wykryć zaburzenie w organizmie. Stanowi cenne uzupełnienie dotychczas stosowanych metod obrazowania oraz pozwala na monitorowanie prowadzonego leczenia farmakologicznego lub fizjoterapeutycznego w sposób bezstresowy i – co najważniejsze – bezinwazyjny.

Słowa kluczowe: termografia medyczna, obrazowanie bezinwazyjne, wczesne wykrywanie zmian patofizjologicznych

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Introduction

Medical thermography (thermovision) is a diagnostic tool which serves as an additional visualization method of a patient's body. It allows to monitor physiological processes which are connected with temperature and detect and localize thermal anomalies associated with lower or higher skin surface temperature. The skin surface temperature is determined by the under skin blood circulation, which is regulated by the autonomic nervous system [1,2]. In order to visualize the temperature of the skin surface, thermography uses infrared wavelengths emitted by the body and converts them into electrical impulses [3]. Thermography is a non-invasive and non-contact diagnostic method which can be applied to various patients regardless of their age or clinical condition. It is widely used in children, women, pregnant women, men and seniors. Its effectiveness, safety, a non-stress way of measurement and relatively low costs allow this technique to be applied not only for the detection or diagnosis but also for continuous monitoring of a therapeutic process [4,5]. The relation between body temperature changes and various diseases is widely known and dates back to the origins of medicine.

History

The first infrared detectors were built in the 1830s [6]. In clinical diagnostics, the infrared emission was applied for the first time by Lea Massoupurt. The first thermogram of the human body was measured by the US Army in 1954. While the first medical application of thermography was done by Ray Lawson during his studies on breast cancer in 1956 [7]. The term 'clinical thermography', which is used nowadays, was introduced in 1978 by George E. Chapman Ph D, a worldwide expert on thermography [8,9].

The initial low quality of the imaging systems and lack of methodology standards made thermography be left aside and not accepted as a reliable diagnostic tool. The present technology improvement and diligently constructed test protocols evoked high development of the method and its approval by medical and physiotherapeutic groups. In 1987 thermography scanning was officially approved as a medical tool by the American Medical Association.

Physical basics of thermography

Most of the visualization methods used in diagnostics are based on electromagnetic radiation spectrum [10]. Medical thermography uses non-ionizing radiation, which gives possibility for its harmless and unlimited application in a patient. About 80% of the infrared radiation that is emitted by human skin has the 8–15 μm range [11].

The infrared radiation, which serves as the basic mechanism for thermography, was discovered in 1800 by Hershel. With a prism splitting white light, he showed that there are wavelenghts undetected by a human eye, which he called infrared radiation (IR). Hershel noticed that, outside the visual spectrum that is below the red, the temperature rises. This area was described as dark radiation / heat. Every object with the temperature higher than the absolute zero (0 Kelvin or –273°C) emits heat radiation. The object with the temperature of merely few degrees Kelvin's emits electromagnetic radiation in the spectrum of far infrared. The objects with the room temperature emit mostly the waves with a wavelength of 10 microns. The items with a higher temperature emit more radiation with a shorter wavelength, which allows us to detect it. The physics of thermography is based on the Stefan-Boltzmann law, which states that "the total intensity radiated over all wavelengths increases as the temperature increases", that all energy emitted by an object of the temperature below 650°C is placed in the infrared part of the spectrum, unseen for a naked human eye. The law allows to determine the correlation of the total emissivity of a black body with its absolute temperature [11,12]. The conversion of the infrared rays emitted from the skin surface into electrical impulses allows for thermal images that depict the thermal composition of the surface tested. The images can be presented in a gray scale or in full colour [6,13].

The biological basics of thermography

Thermography utilizes the infrared emission spectrum of different areas of the body. The amount of infrared emission is related to the intensity of the tissue metabolism and blood circulation, which are dependent on the autonomic nervous system and local vasoconstrictors and vasodilators [14,15]. The distribution of the heat in the body is uneven, which is directly related to a different physiological activity of particular areas of the body or the inflammation occurring there. In healthy subjects, where there is no abnormal change, the temperature distribution on both sides of the body is symmetrical. This is the result of the central thermoregulation system (overriding thermoregulatory centres are located in the hypothalamus), which controls equally and simultaneously the temperature on the skin surface on both sides of the body. However, the correct pattern does not mean that the temperature level is equal on all the surfaces of the body. In fact, we observe places with a reduced or an elevated temperature, that are symmetrically placed on the left and right part of the body. During a disease, especially inflammation, the flow of the heat is altered, which results in a large temperature gradient between the area of the lesion and its immediate surroundings. Similarly, the cancer cells are characterized by an increased metabolism as a result of their continuous proliferation. Therefore, by the visualization of the temperature distribution on the thermogram of the body, these conditions can be successfully monitored as a measurable increase in the temperature and the lack of asymmetry relative to the other side of the body [1,2,5,12,16].

Thermography allows to record the body temperature and the rate of its changes with a resolution <0.1°C. The performance of the reliable measurement requires a patient's acclimatization to the room, conditions prior to scanning, the removal of all the objects emitting thermal radiation from the area and the use of standardized protocols [17].

Thermography in medicine

Thermography is a tool that provides valuable information about the physiological condition of a human in

an objecttive way. It is a good supplement to the imaging methods used so far. It allows to overlay the image of the anatomical picture with the physiological condition of the patient [18,19]. For this reason, an increased interest in the use of thermography is observed in certain areas of medicine such as: neurology, oncology, orthopaedics, dentistry and dermatology [20,21]. In recent years, thermography has also been used in surgery. It allows to monitor the restart of the blood flow through the coronary arteries during the open-heart surgery [24]. Medical thermography helps to visualize disorders in vascularisation and blood flow in particular areas, the occurrence of an inflammation in the body and its precise localization, the conduction disorders in the nervous system, some metabolic disorders, as well as the location of the exact place of pain and its intensity [20,22]. The use of thermography in medicine is presented in Figure 1, while Figure 2 shows its imaging capabilities.

The examples of thermography applications

Breast cancer

Empirical studies have confirmed that tumor cells' clusters have a higher temperature than the surrounding tissues (Figure 3). The higher temperature is a consequence of an accelerated metabolism of tumor cells (cell division), and their ability to produce chemicals that stimulate the rapid growth of pathological capillaries (cancer angiogenesis). Thus, from the beginning, a growing tumor is characterized by an increase in the temperature of the tissues, at least by 0.7°C. The temperature rises with the growth of the tumor. In contrast, benign tumors and cysts have a temperature lower than the surrounding tissues, which is depicted in Figure 4 [23].

Studies show that an early detection of cancer gives an 85% chance for the recovery of diagnosed breast cancer patients compared to a 10% survival after the detection of cancer in the later stages of its development. Therefore, the early detection of changes in breasts is so crucial. The research done by Spitalier, who monitored 61 thousand women for 10 years, showed that medical thermography allows the earliest detection of breast cancer in 60% of cases. It was confirmed that the pathological patterns obtained from the thermal infrared scanning provide a very clear indicator of the risk of developing breast cancer later [24]. Moreover, Gamagami during his research on angiogenesis monitored by thermography, showed that in 15% of the cases, thermography was more effective than mammography in detecting breast cancer [25]. In addition, thermography is an excellent tool for a complementary, non-invasive monitoring between two successive mammography tests, which are usually conducted every 2 years, creating a time gap in which tumors might grow and expand undetected.

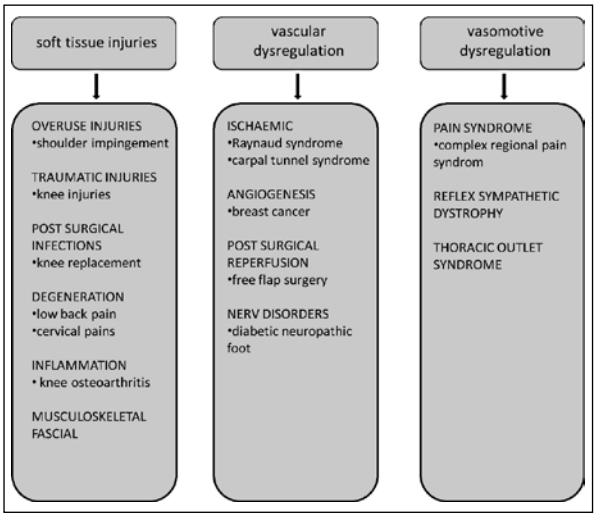

Figure 1. Thermography in medicine [26]

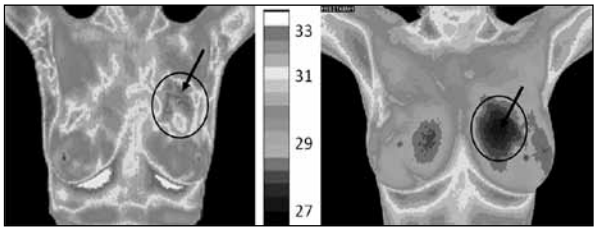

Figure 3. Thermogram shows ductal carcinoma, area with increased temperature compared to locations adjacent. The red represents high temperature, while blue is cold. Images taken with a thermal imaging camera Meditherm Iris 7.5 Thermal Imaging System. Image source – courtesy of Klinika Termografii, [first author's own material].

Figure 4. Thermogram shows a cyst, an area with reduced temperature relative to the adjacent places. The red represents high temperature, while blue is cold. Images taken with a thermal imaging camera Meditherm Iris 7.5 Thermal Imaging System. Image source – courtesy of Klinika Termografii, [first author's own material].

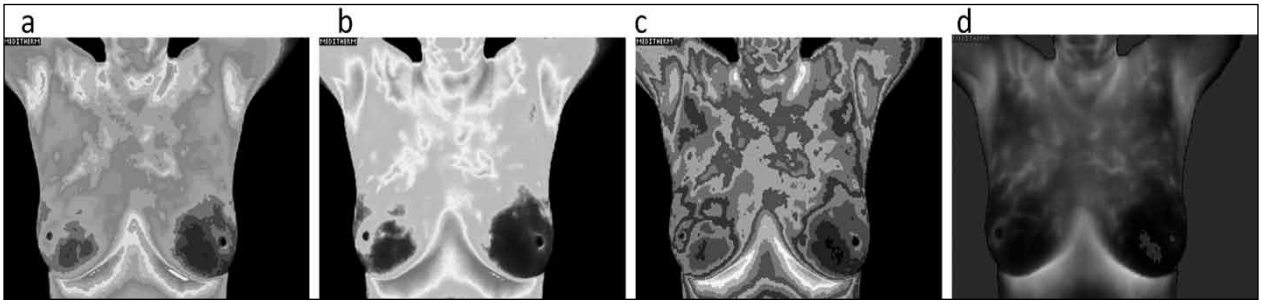

Figure 2. Imaging capabilities of thermographic camera Meditherm Iris 7.5 Thermal Imaging System. Breast thermogram a) a base image sent for evaluation by a physician; b) image with higher resolution; c) image contrast; d) grayscale image [first author's own material]

For the first time thermography was used for the diagnosis of a heart disease by Borodulin [27], Markiewicz and Bednarzewski [28]. They studied the temperature of the skin of the chest in the patients with acute myocardial infarction [27,28]. They found that in 27 patients suffering from acute myocardial infarction, the skin temperature of the chest decreased by 0.5 to 3°C. Currently, thermography is successfully used for the early diagnosis of coronary heart disease.

Sports injuries, orthopaedics

Athletes are constantly exposed to physical stress. During practice and competitions it is not uncommon to cross the physiological limits of the body. Proper diagnosis and location of the over-trained areas as early as possible is an important step in determining an appropriate route of treatment. Moreover, the possibility of monitoring conducted physiotherapy and the assessment of its effects is an invaluable medical information (Figure 5). [29,30]. Apart from athletes, injuries and physical pain affect nearly everyone. Sometimes, however, despite standard tests (ultrasound, CT, MRI) doctors are not able to determine the real causes of pain (Figure 6, 7).

Thermography also helps in this regard. What is more, it allows to specify whether the disorder is an inflammation (local raise in temperature) or damage to the autonomic nervous system, which is manifested by local cooling of the area. Medical thermography can also identify myofascial pain and tendonitis [31].

Summary

With the advent of modern thermal imaging cameras, improved software to handle data and carefully designed protocols, thermal imaging diagnostics has been greatly improved. As a consequence, a wider acceptance of this new tool, as an additional method of imaging, is seen in medical environment . Today, thermography is not only helpful in the accurate diagnosis of a disease entity but it can serve as a great tool for monitoring the effectiveness of both pharmacological and physioterapeutic treatments at various stages. The main advantage of thermography is its ability to detect lesions at the very early stages of the development where the variability in the blood flow already occurs but is often impossible to be detected by using other methods [5,11,12,32]. Moreover, the non-invasive and non-stress way of measurement with a thermographic camera makes this tool be exceptionally patient-friendly and does not cause exclusions (the elderly and pregnant women also can be examined). Medical thermography also allows to determine risk factors for the development of a diseases (i.e. breast cancer and the diseases of the cardiovascular system). It may serve as a clinical marker that allows a doctor to plan further evaluation and treatment carefully. Today, there are many scientific reports that medical thermography can be successfully used in the early detection of diseases and pathological conditions such as breast cancer, nerve damage, rheumatic diseases, in sports medicine and many others [3,20,23,25]. Thermography allows the visualization of pathophysiological changes before other anatomical imaging techniques are able to detect the pathological changes [16]. Note however that, like any other patient imaging technique, thermography is not a substitute for the other diagnostic tools, and is carried out as a valuable component to the diagnosis. Infrared thermography is a method that has both a high potential for further research and diagnostics. Thermography is used quite often in the research studies at Polish universities, however, it is still not popular in medical diagnostics, and only few doctors in Poland use it on a daily basis. Therefore, more clinical studies are needed to popularize this method. The empirical evidence of the correlation between pathology and infrared imaging is essential to validate thermography in the eyes of doctors. Building databases, gathering knowledge and experience for the interpretation of thermographic pictures are the next steps for introducing thermography as a popular, non-invasive and reliable diagnostic tool in the medical environment in Poland.

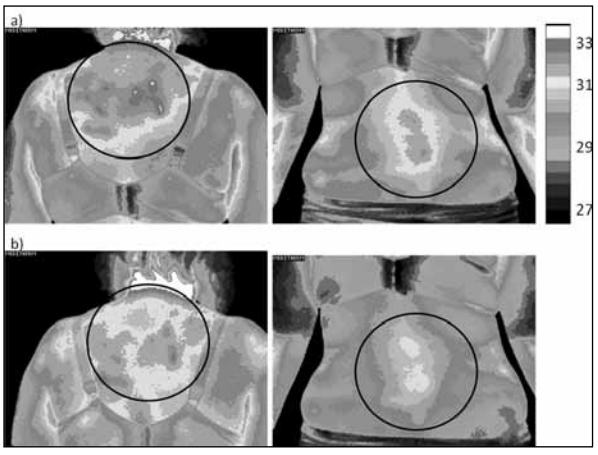

Figure 5. The patient with back pain in the lumbar region a) before physiotherapy - clearly visible tensions in the lumbar, thoracic and cervical regions (red areas); b) after physiotherapy - reduced tension in the lumbar, thoracic and cervical region (decrease in red surface). Images taken with a thermal imaging camera Meditherm Iris 7.5 Thermal Imaging System. Image source – courtesy of Klinika Termografii [first author's own material].

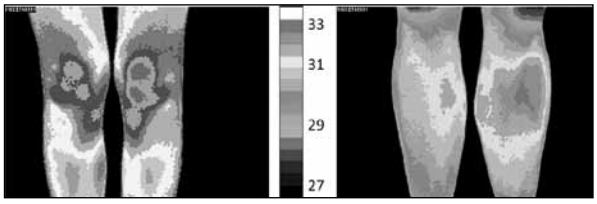

Figure 6. A patient suspected of having a tumor in his right knee. Thermogram indicates the cyst. Ultrasound examination inconclusive. Arthroscopy and histological examination confirms the thermographic examination. Images taken with a thermal imaging camera Meditherm Iris 7.5 Thermal Imaging System. Image source – courtesy of Klinika Termografii [first author's own material].

Figure 7. A patient with a clear temperature distribution asymmetry in the vicinity of the tibia, indicating inflammation from physical overload. Images taken with a thermal imaging camera Meditherm Iris 7.5 Thermal Imaging System. Image source – courtesy of Klinika Termografii [first author's own material].

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The conflict of interests

The authors do not report any conflicts of interests.

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Correspondence address:
Ewa Aplas
ul. Wieluńska 1
51-009 Wrocław
Tel. (+48) 604 456 137
E-mail: aplas.ewa@gmail.com

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