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TEMPERATURE ELEVATION OF THE ROOT SURFACE IN VITRO DURING ROOT CANAL OBTURATION BY THE CONTINUOUS WAVE OF CONDENSATION TECHNIQUE

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The temperature changes on the outer root surface of 8 extracted human teeth with a single canal during the continuous wave of condensation technique (System B, Analytic, USA) were determined using an infrared thermal imaging camera (ThermaCam SC500, Flir, Sweden). The temperature changes during root canal obturation were recorded at three points (apical, central and coronal) on the outer root surface.

The results showed that the technique of continuous wave of condensation produced a relatively high increase of temperature on the outer root surface. Higher temperatures were recorded in the coronal part of the root (12,4°C; min.- 10,9 °C; max.- 14,5 °C), than in the middle (10,1 °C; min.- 7,7 °C; max.- 11,3 °C) or apical (6,15 °C; min.- 3,0 °C; max.- 12,2 °C) parts.

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TEMPERATURE CHANGES ON THE OUTER ROOT SURFACE DURING ROOT CANAL PREPARATION USING ULTRASONIC UNIT

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The aim of this in vitro study was to measure root surface temperature changes during root canal preparation using the Piezon Master 400 ultrasonic device.

Eight extracted human teeth with a single canal were fixed in the slate and ultrasonic preparation was performed using the Piezon Master 400 ultrasonic device (EMS, Switzerland). The device , which was fitted with 15, 20, 25 and 30 ultrasonic files and set for a minimal continuous flow of irrigation, was operated at full power. The temperature rise during root canal preparations were recorded at three points (apical, central and coronal) on the outer root surface using an infrared thermal imaging camera (ThermaCam SC500, Flir, Sweden).

The results of this in vitro study showed that temperature rise produced during the ultrasonic preparation were below the critical level and therefore should not cause damage to the supporting structures of teeth. Higher temperatures were recorded in the central part of the root (4,7 °C) than in apical and coronal parts (2,6 °C and 3,7 °C, respectively).

ROOT SURFACE TEMPERATURE RISE PRODUCED BY INJECTED THERMO-PLASTICIZED GUTTA-PERCHA

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This in vitro study compared root surface temperature changes during canal filling by Ultrafil and Obtura techniques.

Fourteen extracted teeth with a single canal were used .The teeth were divided into two groups, mounted in a slate and obturated with thermo-plasticized gutta-percha by Ultrafil (Hygenic, USA) (70 °C) and Obtura (Spartan, USA) (160 °C) techniques. Temperature changes were recorded using the ThermaCam SC500 infrared thermal imaging camera (Flir, Sweden).

The results of this in vitro study showed that during the injection of thermo-plasticized gutta-percha the temperature increase does not reach a level that is a danger to periodontal tissues. Higher temperature changes were generated by the Obtura technique (9,8 °C) than by the Ultrafil (2,1 °C) technique.

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KINETICS OF THE TEMPERATURE INCREASE OF PERIODONTAL TISSUES AFTER COOLING IN PATIENTS WITH INSULIN-DEPENDENT DIABETES MELLITUS-PRELIMINARY STUDIES

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It has been established that patients with long-term and decompensated type 1 diabetes develop inflammatory changes of the periodontium during their developmental stages more often than in healthy subects. Other changes frequently observed in diabetic patients are in the vascular system of the retina (microangipathy of the retina), in the kidney (nephropathies) and in nervous tissue (neuropathies). Similar pathological changes may also develop in other tissues, e.g. in periodontium.

It has not, however, been established which risk factors are the most important in the aethiopathogenesis of periodontal diseases accompanying diabetes. Recently, much attention has been paid to the role of the long-term metabolic decompensation which changes the response of the periodontium tissues to local irritating agents. The development of vascular complications can also be due to large variations in the blood glucose level. Results of the thermographic study of periodontal tissues in the vicinity of incisive teeth have shown higher temperatures in the group of insulin dependent diabetes melllitus (=IDDM) patients compared with healthy subjects (author's studies).

The aim of this study was to assess the dynamics of the temperature increase in children and adolescents with diabetes type1. The subjects were 32 IDDM patients aged from 10 to 19yrs. with documented diabetic history of 4 to 14 years. High values of glycosylated haemoglobin HbA1>9,5% indicated metabolic decompensation. A control group included 18 healthy adolescents. Thermographic measurements were performed with an AGA Thermovision System 680.

The temperature changes (Tn) were measured at fixed time intervals after application of the cooling agent (1, 2, 3 and 4 minutes after cooling). The interpretation was based on the mean temperature values. The results confirmed the data obtained in a study of peripheral circulation in fingers, that the most significant temperature changes are observed in the first minutes after the application of the cooling agent.

SKIN BLOOD FLOW CHANGES UNDER SIMULATED ALTITUDE HYPOXIA CONDITIONS

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Performance of modern aircraft depends on the flight task being based on human psycho-physiological ability. One of the main hazards in aviation is hypoxia and low ambient temperature. It is well known that the circulation in man may be modified by ambient temperature. However, the blood volume redistributed under hypoxic conditions leads to an increase of perfusion in the central organs (heart, brain) and decrease of the peripheral tissues. However, there is lack of a clear explanation of the peripheral blood flow role in the mechanism of circulatory changes in literature.

The goal of this study was to estimate skin blood flow and temperature distribution on the skin surface simultaneously under simulated hypoxia conditions and considering subjects thermal status.

Healthy male, volunteers (n=9) aged 25 – 30, took part in this study. The experiment was conducted in a thermo-chamber, in thermal comfort and discomfort conditions (for the naked body) Ta 26 and 20°C. To simulate hypoxia conditions gaseous mixture (nitrogen-oxygen) with the oxygen content corresponding 7500 m o.s.l. altitude was used. Peripheral blood flow changes were estimated based on the continuous flow meter (SBF) (PeriFlux System 5000) at the tip of the index finger. Thermal images of the palm (Ts1) and forearm (Ts2) skin surface area were captured by the system THV 900 (Agema Infrared System). Thermograms were recorded at the 20th minute of adaptation period and then every minute during hypoxic mixture breathing and every 5th minute during the recovery period.

Under simulated hypoxic conditions a significant decrease of the Ts1 and Ts2 values was observed in comparison to the control conditions. The range and dynamics of these changes differed one from another reporting to the analyzed body area and ambient temperature. The lowest values were recorded under thermal discomfort conditions in the palm area, however in the same time an increase of the perfusion in fingertips was observed. Statistically significant increase of the SBF was noticed in +20°C ambient temperature only.

We can conclude that breathing hypoxic mixture simulating altitude 7500 m o.s.l. exposure causes decrease of the mean skin temperature in analyzed area reporting to the ambient temperature. As a consequence skin blood flow should be lowered which was not proven by perfusion measurements at tip of the index finger

STATISTICAL PARAMETERS OF THERMOGRAPHIC IMAGES FOR EARLY DIAGNOSIS OF BREAST DISEASES

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In this paper we present the results of analysis of thermal images of breasts for early detection of dis-

ease, with special application to breast cancers. The thermal image can be characterized by many parameters, such as statistical data of the first and second order. In this work, the mean value, standard deviation, histogram modality and steepness, as well as energy and entropy were considered. The thermograms from two groups of subjects were investigated, one with breast cancer changes, and healthy controls without changes. The first analysis confirmed that first order statistical parameters do not precisely discriminate healthy and non-healthy patients. This means that other parameters must be included in the investigation. We also present preliminary results using geometrical and structural parameters, together with second order analysis which is able to distinguish the two different classes of image. This study is the synthesis of application of the statistical parameters of thermal images used for patient classification. The results are obtained using Matlab software, and is an introduction for more advanced classification based on neural networks.

QUANTUM WELL AND THERMAL DETECTORS – NEW TRENDS IN INFRARED TECHNOLOGY

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In this paper, the comparison of uncooled thermal and extensively cooled QWIP (Quantum Well Infrared Photodetector) detectors are briefly presented. Different types of QWIP detectors have been described. The limits of detectivity both for thermal and photon detectors are discussed. Today, significant progress is observed in infrared technology. This is due to increasing interest of infrared sensitive equipment, especially in the domain of uncooled devices, which are much cheaper yet with satisfactory parameters. Such detectors are widely used for e.g.: thermal inspection, observation, and maintenance. On the other hand very precise quantum detectors are still under development. The most efficient quantum detection based on MCT (HgCdTe) has now a competitor which uses traditional wide band-gap semiconductor (AlxGa1-xAs/GaAs), where the carrier excitation takes place in a quantum well. Both responsivity and detectivity of quantum infrared detectors are a function of wavelength, and do not depend on spectral range.

THERMAL WAVE METHOD - LIMITS AND POTENTIALITIES OF ACTIVE THERMOGRAPHY IN BIOLOGY AND MEDICINE

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In this paper we present the basis and preliminary application of lock-in and pulse thermography for Non Destructive Testing (NDT). 3D modelling is presented to confirm usefulness of simple analytical solutions, and to setup the experiments. As an example, the thickness of thin film coatings is briefly described. Active thermography is the method where a sample is heated by an external energy and the thermal response is measured. While the process is dynamic, the sequence of temperature distributions can be used for material parameter estimation. In many publications this method was successfully applied for solid materials and thin film measurements. In biology and medicine active thermographic methods can be for measuring skin thickness, inflammatory regions, density of tissues, blood flow, etc

A COMPARISON OF THE FACES OF MONOZYGOTIC TWINS AND THERMAL PHENOTYPES

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There have been numerous studies on twins that have focused on morphological differences and delineation of the factors predefining emergence of the particular changes. A literature analysis of twin related research has shown that the question of differences in thermal phenotypes of monozygotic twins has not yet been considered.

The first attempt to describe the differentiation of the monozygotic twins' thermal phenotypes was undertaken in August of 2001, on the IV European Twins Festival in Szczecin. This study was an attempt to describe a differentiation of thermal phenotypes of monozygotic twins (MZ) faces, and an attempt to compare the thermograms of MZ and dizygotic twins (DZ). The study was based on thermographic measurements of 30 monozygotic twin pairs and 10 dizygotic twin pairs. Zygosity of the twins was determined through the PCR method and the research was simultaneously carried out in the Hemogenetic Lab. of The Forensic Medicine Department at Szczecin. The thermographic recordings were made with an infrared (IR) camera ThermaCAM ^{TM} SC500. Facial thermograms were recorded for each pair. In order to provide better conditions for more accurate comparative analysis the twins were imaged together on one thermogram.

The morphologic differentiation of temperatures' distribution the MZ twins pairs shows a very high level of intra-pair similarity. In the studies of MZ twins the thermograms of the face showed individual thermal symmetry, and each face was divided into the left and the right half. Similar asymmetry was found within pairs of twins.

With the use of a"Threshold temperature" function the proportional participation of particular temperatures was evaluated. A 0,5°C temperature span was established. The largest proportional participation for the MZ twins was at 34-34,5 °C and 33,5-34 °C for the DZ twins.

Mutual, intra-pair-similarity was computed using Ward's minimum variance method to evaluate the level of Euclidean distances between the objects. They were found to be very small and they did not exceed 25 units for a 100 units scale.

Thermal areas of the face containing "threshold" temperatures were also analyzed by means of Zeiss Imaging Processing Software (KS300) installed on PC (PII 350, Matrox Milenium graphics card). Thermograms were imported directly from the image files into Adobe graphics software. A selection of the particular elemental area was made with the tolerance of 5 pixels. In order to carry out the proper morphometric measurements the elements were pasted into KS300. The artifacts were eliminated with the use of a built-in software module which separates the objects with extreme characteristics. The procedure allowed for direct comparison of the MZ and DZ thermal areas and established the level of selected thermal elements' morphological similarity. A very high level of intra-pair similarity was found among MZ pairs in comparison to DZ pairs.

THERMAL EMISSION FROM THE SHOULDER GIRDLE REGION IN MASTECTOMIZED WOMEN

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Measurement of thermal radiation is increasingly accepted as a method for assessment of local circulation, particularly in neoplastic and inflammatory conditions.

Mastectomy combined with axillary lymphadenectomy frequently leads to abnormal lymphatic drainage in this region, resulting in lymph retention and chronic edema around the shoulder girdle.

In an effort to reveal disorders of peripheral circulation, we have measured thermal radiation from the shoulder girdle and breasts of 30 women after total or partial mastectomy combined with lymph node dissection. The time from surgery varied case by case, from a few months to some years.

All measurements were performed at standard temperature and humidity. Temperature distribution along lines from the base of the neck to the middle of the palms on the front side and similarly on the rear side was recorded. The armpits were studied separately.

In some patients there was a left-right asymmetry in temperature distribution without evidence of lymph retention. Temperature distribution was almost perfectly symmetric in some women. The greatest differences were noted for armpits, with temperatures higher on the operated side.

TRIAL OF INVESTIGATION THE THERMOGRAPHY FOR THE DIAGNOSIS OF PIGMENTED SKIN NEVI.

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Malignant melanoma is the leading cause of death from disorders of the skin. A high number of pigmented skin nevi is regarded as a predisposing factor for malignant melanoma development. Prognosis and survival in melanoma patients is depended on the early diagnosis of this cancer. The non-invasive method of the pigmented skin nevi examination is still not completely solved problem. According to the literature, opinions differ on the usage of thermography in the diagnosis of pigmented skin lesions.

In our investigation we tried to apply practically the thermal imaging (using Therma CAM TM SC 500 camera) in the diagnosis of the pigmented skin nevi. The range of temperature (TR) was measured during the examination of every pigmented lesion. TR was defined as the difference between the maximal and minimal temperature within each nevus. The fourth - grade scale was stated as follows: I. TR value up to 1 °C; II. TR from 1.1°C –to 1.5°C; III. TR from 1.6 °C to 2.1°C; IV TR value over 2.2°C. TR values for the pigmented lesions were mostly in the grade I. Early diagnosis of melanocytic nevi was based on ABCDE rules (American Cancer Society) and dermatoscopy. Molles stated atypical findings according to ABCDE rules and these were excised and the diagnosis was based on histo-pa thology. A correlation was found between TR grade and the nevi examination due to ABCDE rules, dermatoscopy and histopathological examination results. There were no atypical findings in cases of pigmented nevi in grade I. Some of pigmented skin nevae in grade II and most of lesions in grade III were found to be atypical.

Thermography may be useful in differential diagnosis of pigmented lesion. Further work is to be undertaken to confirm these findings.

THERMOGRAPHIC ASSESSMENT OF RAYNAUD'S SYNDROME IN CHRONIC HEMODIALYSIS PATIENTS

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Vascular damage occurring in hemodialysis patients, superimposed on the arteriovenous shunt cir-

culation can lead to the development of Raynaud's syndrome (RS). Non-invasive thermography is routinely used for cold stress assessment in the diagnosis of RS. The aim of the study was to evaluate the frequency of RS in chronic hemodialysis patients by thermographic investigation. The study group comprised 21 chronic hemodialysis patients (15 female, 6 male, mean age 32.6±15.0 years). Ten healthy age-matched individuals (6 female, 4 male) served as controls. The Cold Stress Test (CTS) was performed in all subjects. Thermographic evaluation of both hands with the use of Inframetrics 760 camera was conducted at baseline and every 10 seconds for the 10-minute period following the cooling of both hands with water immersion. The measurements were performed on a day between the dialysis sessions. RS was diagnosed provided that CTS was deemed to be positive i.e. when CTS thermographic measurements revealed increased negative temperature gradient towards the fingers. *Results*: RS was found in these dialysis patients significantly more often than in the study group (11/21 vs 1/10, respectively; $p<0.05$). Interestingly, the dialysis patients with RS were treated with dialysis for a significantly shorter time than patients without RS (52.2±42.5 vs 89.8±54.2 months on dialysis, $p<0.05$). Moreover, the time of the restoration of normal temperature in cooled hands was significantly longer in the hands with arteriovenous shunts than in the shunt-free hands. Based on our results, it might be concluded that RS is a frequent finding in hemodi alysis patients. However, it might be suggested that some autoregulatory mechanisms may play a role in the attenuation of RS symptoms in long-term dialysis patients.

THERMOGRAPHIC EVALUATION OF CONSERVATIVE TREATMENT WITH GLYCOSAMINOGLYCANS AND PROSTAGLANDINS FOR CHRONIC LOWER EXTREMITIES ISCHEMIA

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In this study the use of thermographic monitoring for the assessment of peripheral circulation after treatment with glycosaminoglycans and prostaglandins was evaluated. 40 patients with chronic lower extremities ischemia were randomly allocated into two groups of 20. All patients had thermographic assessment and ankle-brachial blood pressure index. All measurements were performed during the morning hours, under constant physical conditions of the environment in accordance to standardization requirements.

The thermographic evaluation was performed prior and post treatment using an Agema Thermovision 900 equipment The tests were performed within a special compartment with constant ambient temperature of 20°C (±1°C) and humidity of 60%. The distance between camera and patient was fixed at 3,7 m.

The mean temperature of the investigated area of extremities in the group treated with glycosaminoglycans was 28,65°C (±1,49) at the right side and 28,90°C at the left. After treatment the thermographic evaluation showed an increase of the mean temperature of 0,63°C at the right side and 0,76°C at the left.

The mean temperature of the investigated area of extremities in the group treated with prostaglandins was 28,83°C (±1,39) at the right side and 29,09°C at the left. After treatment there was increase of average temperature of 0,65 and 0,71°C respectively.

In conclusion thermographic assessment as a non-i nvasive method can be:

·An auxiliary diagnostic method for lower extremities circulation disturbances;

·used for the evaluation of effectiveness in conservative treatment

STATIC THERMOGRAPHY (TG) IN STUDIES OF VASCULAR ACCESS IN HEMODIALYZED SUBJECTS

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Complications of vascular access are among the most frequent causes of morbidity in chronically dialyzed patients and may significantly decrease dialysis adequacy. Thrombi within the fistula, strictures or aneurysms, abnormal blood flow, non-physiological blood pressure values in the course of hemodialysis (HD) treatment may lead to re-circulation and a decreased effective clearance (Kdeff). The diagnosis of the type of fistula malfunction is predominantly based on invasive methods (fistulography, angiography) or non-invasive procedures (color Doppler ultra sound). From the urea kinetic modeling it is possible to calculate the dialysis index Kt/V, Kdeff and the percentage re-circulation (%R). The evaluation of vascular access using thermography has only been described in a small number of publications. Static thermography, is a non-invasive, simple and rapid method which can be used at the bedside. It was employed in the evaluation of Cimino-Brescia fistula in 15 chronically hemodialyzed subjects aged 14-70 years. The average HD treatment was 5.8 years (SD=3.9). Having cooled the forearm by immersion in water at 10° C for 5 minutes and having dried the skin, a thermographic camera (V-20ER005-25, Vigo System, Warsaw, Poland) equipped with a HgCdTe detector with thermoelectric cooling. The temperature resolution

of the camera was 0.05° C, and the 1% measurement accuracy was regarded sufficient. The acquisition time for one scan was approximately 25 seconds. Twenty-five scans were performed on each patient and were subsequently further processed and analyzed. In each patient, the value of Kt/V, Kdeff and %R were calculated. The analysis of thermographic scans was based on a semi-quantitative scale, where scores were used to describe the degree of pathology of the fistula and the forearm vascular system. In the majority of patients, the TG scans were verified by colour Doppler ultra sound.

Results: The analysis of 90 thermograms (6 from each subect, taken after 25, 50, 100, 150 and 300 seconds, with and without cooling) yielded results that were comparable to results achieved in X-ray fistulography. Doppler ultra sound provided a precise calculation of blood flow and fistula diameters at sites recognized as abnormal, thus confirming the strictures or dilatations of the fistulas. No correlation was obtained between the score assigned in fistula evaluation on the semi-quantitative scale and %R (r=0.06, p=0.8), or the value of %R calculated in the basis of Kdeff (r=-0.11, p=0.7) (Spearman's rank correlation test).

Conclusions: Static thermography may be regarded as an equivalent of fistulography, without the negative effects of contrast medium. The patients did not report any negative effects of upper extremity cooling prior to the study. The analysis of thermograms and discussing the results with nursing staff responsible for fistula needling allowed for the improvement of dialysis adequacy in 4 patients by lowering the re-circulation. The congruence of TG scans and color Doppler ultrasonograms enables the recognition with static TG as the first and in some circumstances essential diagnostic tool in fistula assessment in each case of suspected fistula dysfunction.

MECHANICAL PROVOCATION TESTS IN THERMAL IMAGING

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Positioning and exercise are used as a form of mechanical stress in a variety of diseases for the enhancement of thermal changes on the surface of the human body. Exposure to vibration may also induce changes of perfusion, which can be identified by thermal imaging.

Typewriting can be regarded as a challenge that combines exercise and exposition to some kind of vibration, which may result in increased heat of working muscles and/or low temperature readings over the finger-tips due to disturbed perfusion.

The risk of developing disorders caused by hand-transmitted vibration are currently predicted in ISO 5348 (1986), British Standard (1987) and similar standards. However, a standardised vibration exposure test is not yet available.

Indications for mechanical stress testing are suspected motor deficit (neurogenic or disuse induced), thoracic outlet syndrome (TOS), repetitive strain injury (RSI) and vibration induced white fingers.

This paper reviews some protocols and study results obtained from studies dealing with mechanical stress testing. In repetitive strain injury, the influence of the duration of typewriting for the occurrence of cold fingers was shown. In thoracic outlet syndrome, the protocol for positioning and temperature evaluation is described. A high inter- and intra-rater reliability of the temperature evaluation was found. The influence of the fist manoever on finger temperature and the beneficial effects of exercise- induced posture correction on the temperature difference between index and little finger was reported. In patients with peroneal palsy of either radicular or peripheral origin, the enhancement of temperature changes by exercise was clearly shown.

Mechanical stress can be used successfully for the enhancement of thermal changes on the surface of the human body that can be detected and recorded by thermal imaging.

PROCESSING OF SEQUENTIAL THERMOGRAPHIC (TG) SCANS IN VASCULAR ACCESS EVALUATION

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In the described studies the authors attempted to evaluate the vascular system in hemodialyzed patients with sugically created A-V fistulas in the forearm. TG scans were obtained using a thermographic camera with a single detector. The TG pictures resulted from scanning the scene in two dimensions. Having cooled the forearm by immer-s ion in water at 10ºC for 5 minutes and having dried the skin, 15-18 scans were acquired at 25-seconds intervals. A TG scan was registered before cooling to assess dynamic changes. In order to determine dynamic parameters of temperature changes, it is necessary to precisely match the subsequent thermograms. To avoid the necessity of introducing restrictive laboratory conditions, the authors proposed a set of techniques for image sequence processing that would compensate for not keeping the object during the measurement in fixed position. The algorithm was as follows: 1. Median filtering. 2. Subpixel horizontal line displacement correction. 3. Identification of the whole object (forearm) shift

in front of the camera through searching for corresponding pixels in the consecutive images (for a preselected set of 15 points) – the block-matching technique was applied. 4. Subpixel correction of detected shifts. 5. Correction of local shifts within the object based on the assumption of temperature monotonic growth. The prepared sequence of TG scans may then be used to plot a map of time constants for the temperature changes approximated by exponential law at each point of the image (Fig.1b). These computations, with exponential regression applied for averaging, indicated that in the vicinity of the large vessels time constants amounted to about 50 seconds, while in other regions their values were often above 200 seconds. A model with a single time constant yielded temperature curves that were only slightly different than the actual values. When the temperature increased within intervals of 5-14ºC, the average model error equaled approximately 0.5ºC with the same SD value. Comparing the temperature changes obtained from model and measurement, the authors found that in the vicinity of blood vessels initially the temperature rose faster than the modeling curve, while falling below that line in the second phase. In regions devoid of large vessels, the relative changes of actual and modeled curves were opposite (Fig.1c). Fig.1d presents the map of weighted sums of deviations from the model. The weight values were +1 for the scans numbered 2-8, and –1 for the later scans. The results obtained confirmed the value of the image processing techniques for the evaluation of dynamic features of temperature changes on the forearm surface. These are used to indicate the blood vessel structure without the necessity for precise immobilization of the forearm in front of the camera.

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REFERENCE DATABASE OF NORMAL THERMAL IMAGES OF HEALTHY SUBJECTS

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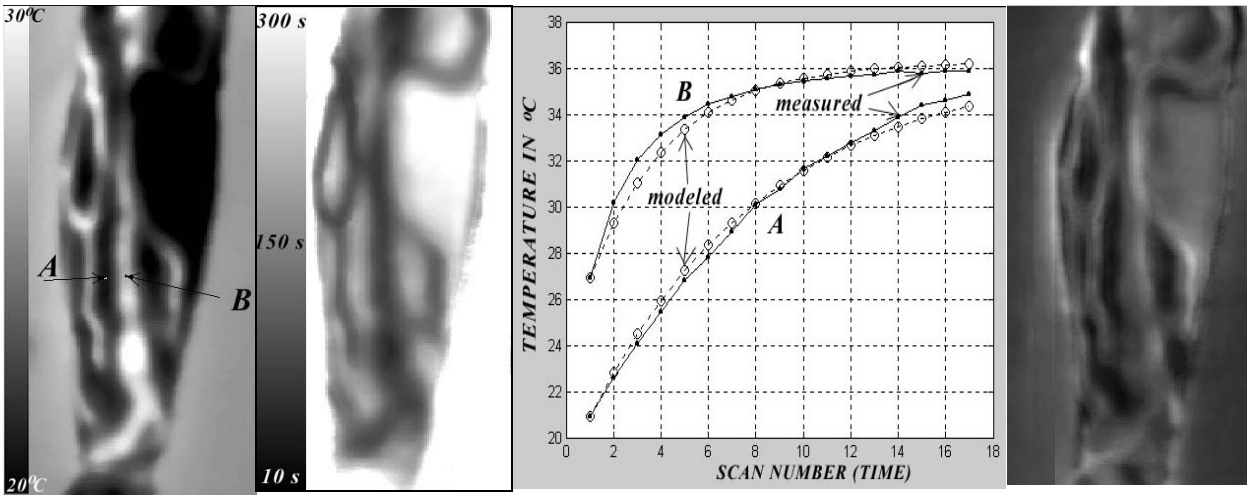
Temperature maps in so called normals with respect to the symmetry of temperature distribution on the body's surface were published in the eighties by Uematsu, Goodman, and restricted to temperature readings over joints by Ring and Engel. However, these papers did not describe the definition of health in their selection criteria nor did they meet the requirements for a representative sample for the population in a defined geographical area. Anthropometrical features such as weight, height, body mass index and gender had not been considered.

Standardized positions of the body for image capturing and definition of reproducible placement of



A) b) c) d)

Fig.1.a. A forearm of a hemodialyzed patient: the first TG scan in the sequence. b. The map of plotted time constants. c. The comparison of the modeled and measured temperature changes for points A and B. d. The map of weighted deviations from the applied model (see details in text).

regions of interest (ROI) for temperature measurements can reduce systematic errors. Images captured and analyzed in a clearly defined protocol will show mainly the individual variations of temperature distribution, and deviations from these standard images would be suggestive for a physical dysfunction.

We have established a protocol for capturing a series of images that covers the whole body of a healthy subect. The protocol defines a healthy subject as someone who had no problems with mobility, no difficulty in caring for himself, no restrictions in performing normal activities, experienced no pain or discomfort and was not suffering from anxiety or depression. A total of 24 views of the body were specified and within these views, a total of 87 regions of interest (ROI) were defined. The repeatability of some standard views by different investigators and the inter- and intra-rater reliability of temperature readings from selected regions of interest was investigated.

The consistency of the standard views "Face", "Anterior Left Arm" and "Dorsal Hands" was evaluated. The distance, measured in pixels, from the upper or the lower edge of the image to anatomical landmarks was used for evaluation. The cross section tool of Ctherm was used for the determination of distances.

The inter-rater reliability of temperature measurements of 3 regions of interest on the view "Anterior Arm" was evaluated in five newly trained investigators. Another experiment evaluated which shape of the ROI over the knee showed the highest degree of repeatability. A circle, a square and an hourglass shaped area were applied to the same image in the standard view "Anterior Knee" by three newly trained investigators.

Positioning for the face varied in very narrow way and hand views varied in a wider range than the positioning of the face. Related to the difficulty of positioning the arm, where 3 landmarks must be placed within the image, repeatability of this view was slightly better than the positioning of hands. Using the hourglass shape revealed a better precision of temperature readings than the other shapes. The reason for that might be that the alignment of the region of interest is easiest to perform with the hourglass shape. This evaluation resulted in deviations from the mean temperature of the region of interest between 0.001 and 0.10 °K at the elbow, between 0.06 and 0.27 at the upper arm and between 0.02 and 0.1 at the upper arm. Mean difference between 1st and 2nd measurement of individual investigators was 0.024.

The repeatability of standard views vary by the body regions investigated. However, standards views can be reproduced within a narrow range. Inter-rater reliability coefficient alpha and ICC of the ROI "Lower Arm", and the hourglass shaped ROI at the anterior knee confirmed excellent repeatability of ROI placement. Reference values for the surface temperature of body regions based on images captured according to our protocol will reflect mainly the individual temperature variation.

ERRORS AND ARTEFACTS IN THERMAL IMAGING

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Infra red thermal imaging is a powerful tool for the study of human body temperature. Modern thermal imaging systems are highly developed, and produce a digital two-dimensional image of skin temperature. In clinical practice there are a number of essential steps to apply the technique to the examination of the human body. There are now a number of factors recommended for clinical practice, which are needed for reliable and reproducible thermal imaging. Ignoring any one of these steps leaves the investigation open to error, and thus reducing the clinical acceptance and understanding of thermal imaging for medical applications. A knowledge of normal thermal patterns and temperatures is required, and awareness of clinical causes for those patterns to be changed, with increased or decreased temperatures.

The critical factors in a thermal imaging protocol begin with the patient. Prior information to and from the patient is needed. To register any possible effects of drugs, physiotherapy or surgery on body temperature, the patient is always asked to rest in a cubicle, with the examination areas unclothed for a minimum of 10 minutes at a defined ambient temperature.

The equipment must be of proven stability and accuracy, with the IR camera mounted on a parallax free stand. The examination room must be at a controlled temperature, usually from 20°C (used for inflammatory studies) t0 24°C (used for vasomotor studies). Standard views of each required area of the body are essential, and the angle between camera and patient should be around 90° whenever possible. Standard distances are also advised, since resolution (thermal and spatial) are usually decreased as scanning distance increases.

Image analysis must also be standardized. Regions of interest are frequently chosen on subjective parameters, which have been shown to be irre producible even by the same investigator on the same image with repeated analysis. A protocol for defined regions of interest based on anatomical limits is the only sure way to minimize inter operator variation.

Finally, reporting the images requires al relevant data on the temperature range and level of the camera setting, the location of regions of interest and their data, and the conditions under which the ex-

amination was carried out. Failure in any of these parameters can lead to sizable errors, and misinterpretation of the findings.

Examples will be given of false results in thermal imaging from failure of the investigator to understand the essential factors for the patient examination. Inadequate camera settings, or unproven stability after starting the camera have been found to significantly alter the final image. Errors resulting from subjective sizing and placement of regions of interest also show significant variations, all of which can be avoided. The importance of standardized reporting is evident when comparisons over time are required. In medical-legal issues, each image must be clearly identified, and shown to be taken under comparable conditions. No less a standard is required for normal clinical work with this technique. Knowledge of the normal patterns, and causes of hyperthermia or hypothermia are also important to both the technician and the physician using this technique.

Under correct conditions good reproducible images are obtained from which reliable thermal data can be extracted. Poor technique results in avoidable errors and artifacts, which confuse and even invalidate the clinical findings. A good knowledge of thermal physiology is important, but is not enough, if protocols for image capture and analysis are not carefully followed. Modern hardware and software have transformed this technique in recent years, the limitations are more subjective than obective. User-friendly software can provide prompts to help the inexperienced user of thermal imaging.