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Abstracts

THERMAL IMAGING AS AN OUTCOME MEASURE

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Outcome measure are defined as the systematic collection (usually prior to and following an intervention) and analysis of information that is used to evaluate the efficacy of an intervention. Various types of outcome measures exist such as patient-completed self-report questionnaires, clinician- completed observation scales, task-specific activities -tests e.g. sit to stand, tests to assess body structure and tests to assess body function. Thermal imaging must be understood as a technique that images function, but not body structure e.g. anatomy.

Common requirements of outcome measures are must been published in a peer-reviewed journal, requires a standardised procedure and written scoring procedure. The outcome measure must be appropriate, reliable, valid, responsive (i. e. sensitive to change), interpretable, acceptable and feasible. For each requirement examples related to thermal imaging will be discussed.

Thermal imaging was already used as outcome measure in trials of acupuncture for facial paralysis, physical therapy and drug treatment of Complex Regional Pain Syndrome, physical therapy of tennis elbow, exercise treatment of Thoracic Outlet Syndrome, lymphatic drainage of lymphedema, surgery for osteo. arthritis of the knee, exercise treatment of low blood pressure in children and drug treatment of occlusive arterial disease.

Thermal imaging meets all requirements for an outcome measure and may be used in clinical trials to assess the efficacy of interventions.

USEFULNESS OF EXPONENTIAL MODELS IN ESTIMATION OF THERMAL PROPERTIES OF BIOLOGICAL MATERIALS IN ACTIVE DYNAMIC THERMOGRAPHY

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In active dynamic thermography (ADT) the simplest one-exponential model described by thermal time constant is being used for evaluation of biological tissues thermal properties. Thermal conductivity, specific heat and thermal diffusivity are basic thermal properties while the thermal time constant is indirectly characterizing such properties. Solving heat transfer equations, assuming the simplest geometry and boundary conditions, the proportionality relation between the thermal time constant and the thermal diffusivity is valid.

For active dynamic thermography measurements and respective MATLAB numerical simulations the relations between the thermal time constant and basic thermal properties are determined. Usefulness of a multi-exponential model (a modified version of the oneexponential model) in estimation of the thermal diffusivity is shown. The nature of a nonlinear distortion of the relation between the thermal time constant and the thermal diffusivity is discussed. Such analysis may be of some importance in evaluation of practical validity of ADT experiments.

HYPERTHERMIC AREAS IN THERMAL IMAGES

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Hyperthermic areas within medical thermal images may be caused by inflammation, increased blood flow, growing tumor, heat generation due to muscle contraction or artefacts due to the environment. Examples will include inflammatory joint disease such as rheumatoid and osteoarthritis, inflammation of tendon insertions and tendon sheets and bursitis. In Paget´s disease of bone hyperthermic areas have been related to increased blood flow within the affected bone.

Skin inflammation caused by herpes infection, skin rash due to virus infection, irradiation induced dermatitis will be presented. Varicose veins and deep venous thrombosis are related to hyperthermic changes. A diffuse hyperthermia on the diabetic feet may be caused by neuropathia, an intensive local hyperthermia was related to underlying osteomyelitis.

Malignant tumours of the female breast or of the skin such as melanomas can be visualised in thermal images as hyperthermic areas. These "hot spots" might be caused by an increased angiogenesis.

Recently conducted muscle work, muscle spasms and tender points in fibromyalgia patients are all characterized by increased skin temperature. Artefacts due the environment such as heating by infrared radiation, conductive heat therapy or skin contact with other hot surfaces can result in hyperthermic areas on the body surface

ENHANCED LASER-TISSUE INTERACTION USING INFRARED THERMOGRAPHY

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The application of infrared thermographie methods in laser-tissue interaction continues to grow in signifieanee. The development of portable lasers has increased the application of laser therapy and in some cases the number of laser operators. The efficacy of manually operated lasers and treatment protocol is largely dependent on the skill of the operator including optimizing laser parameters. Therefore infrared thermography is able to enhance efficacy and reduce the incidence of unwanted side effects by:

. optimising laser parameters prior to therapy,

. monitor laser -tissue interaction during laser therapy and

. during computerised laser scanning of tissue.

Thermographic intervention will reduce the occurrence of excessive heating, missed treatment areas and reduce pain.

Alongside developments in laser technology is miniaturization and reliability of thermal detectors and improvements in display technology. It is envisaged that in the future smart laser devices will evolve with integrated thermographic capability. This paper begins this process by comparing thermographic results taken fom the skin surface during manual and computer laser scanning. These results are compared to a Monte Carlo model.

SKIN TEMPERATURE AND LASER DOPPLER FLUX IN HEALTHY ADULTS: REFERENCE MEASUREMENTS AND DEGREE OF CONTRALATERAL ASYMMETRY AT SIX BODY SITES.

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Background A protocol for the assessment of inflammation in childhood localised scleroderma plaques* was adapted to obtain reference readings for skin temperature and laser Doppler flux at six body sites from 7 adults (4F, 3M). All subjects gave informed consent to participate in the study, which was approved by the Ethics Committees of the Great Ormond Street and Royal Free Hospitals.

Method: For each subject triangular aluminium foil markers were applied to the skin at 6 body sites (arm, leg, abdomen, back, cheek and forehead) and at a further 6 precisely contralateral sites. The subject then acclimatised at a room temperature of 23 ± 1°C for ten minutes. Standard thermographic views of all marked body sites were then captured with a Flir SC500 Thermacam thermal imager. Ten seconds of laser Doppler flux data were recorded sequentially adjacent to the tip of each triangular marker (Moor Instruments MBF3D blood flow monitor, 810nm). The sequential laser Doppler readings were then repeated twice more for each body site, and the mean laser Doppler flux over the 3 measurements at each site was calculated. The skin temperature at each body site was determined by defining a square region of interest of dimension 2cm x 2cm positioned at the tip of each triangular marker in the thermograms (Flir Thermacam Researcher 2002 image analysis software).

Results The hottest body site was the forehead, which also showed the least inter-subject variability (mean T = 34.2°C, SD = 0.3°C). The coldest site was the leg (mean T = 31°C, SD = 0.9°C). The cheek had the greatest inter-subject variability (mean T= 32.6°C, SD = 1.5°C), and this was also the site with the greatest mean asymmetry between contralateral measurements (0.5°C, SD = 0.3°C). The leg was also the body site with the lowest laser Doppler flux (mean = 9.3 AU, SD = 1.7 AU). The cheek exhibited the highest flux, and the greatest inter-subject variability (mean = 57.6 AU, SD = 38.2 AU). We defined a laser Doppler "asymmetry index" by taking the absolute value of the difference in flux between contralateral sites, and dividing it by their mean value. This index was found to be greatest at the cheek with a mean value of 0.34 (SD = 0.34).

Conclusion Our data confirm the variation of skin temperature between body sites. The findings also support the previously published assumptions that contralateral differences of more than around 0.5°C should be considered abnormal.

Laser Doppler readings were low in the periphery and lower limbs, and high in the head, as would be expected due to orthostatic factors. The data also suggest that variation in flux readings between contralateral body sites of less than about 50% is entirely normal. Findings in the cheek support our impression from clinical cases that temperature and flux can be quite asymmetrically distributed in some areas of the face, and there is also large inter-subject variability in the readings. Our flux and temperature readings from the forehead, however, showed acceptable inter-subject variability and symmetry.

Further work is required to validate reference ranges for the thermography and laser Doppler techniques. In particular, "normal" skin temperature and laser Doppler flux readings may be dependent on age, sex and body weight.

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Visentin M, Howell KJ, Lavorato A, Jones CD, Martini G, Smith RE, Denton CP, Zulian F, Black CM, Harper JI and Woo P. Is thermography a sufficient tool to detect active disease in juvenile localised scleroderma? (Poster). 8 International Workshop on Sclerodrma Research, 1st-4th August 2004, Trinity College, Cambridge, UK.

ADVANCED THERMAL IMAGE PROCESSING – IMAGE FEATURES AND CLASSIFICATION

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In this paper we present classification of the thermal images in order to discriminate healthy and pathological cases. As an example breast cancer thermal images were used for verifying the proposed method. Different image features and approaches for data reduction and classification have been used. The most promised method was based on wavelet transformation and nonlinear neural network classifier.

Thermal image classification is a powerful tool during breast cancer screening. At the Technical University of Lodz, in Institute of Electronics, the software for calculation image features, their selection and processing, as well as classification algorithm has been developed. Among the variety of different image features, statistical thermal signatures (1st and 2nd order) have been already effectively used for classification of images represented by raw data. In the research presented here some new features based on wavelet transformation was introduced.

It is possible to define hundreds of features for an image, and obviously, the selection and reduction are needed. Two approaches were applied in this work, based on Fischer coefficient and by using minimization of classification error probability (POE) and average correlation coefficients (ACC) between chosen features. It can reduce the number of features to a few ones, maximum to 10. The next step is the features preprocessing which generates new parameters after linear or nonlinear transformations. It allows to get data which less correlated and of the lower order. Two approaches were used in the research, i.e.: PCA (Principal Component Analysis) and LDA (Linear Discriminant Analysis).

Finally, classification was performed using different Artificial Neural Network (ANN), with or without additional hidden layers, and with different number of neurons. Additionally, we have compared ANN classification with widely used Nearest Neighbour Classification (NNC)

THERMOGRAPHY AS AN OUTCOME MEASURE IN RHEUMATOLOGY

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The term rheumatology embraces as wide range of musculoskeletal and articular joint diseases. In many of these clinical conditions, inflammation is present. Unlike acute inflammation, which may be localised and may be naturally resolved, chronic inflammation leads to systemic complications and tissue destruction.

Early research in Bath UK in the 1960-1980's focussed on the fundamental issues of objective assessment of chronic inflam-

matory diseases. These studies showed that when the skin temperature over an inflamed joint was raised, this was often a sign of deeper inflammation, which could be detected in a number of ways. Arthroscopy of joints, biochemical markers especially those measured from synovial fluid, and clinical signs of joint swelling pain and stiffness are all used to investigate arthritis. We were able to show that the measurement of skin temperature over a joint was an effective and non-invasive means of monitoring the level of inflammatory activity in each selected site on the body. The technique, using a thermal index for quantification, was used to monitor differing doses and differing analogues of prednisolone. The technique was also useful for the quantification of response to oral non-steroid drugs, and the more powerful anti rheumatic drugs. In Paget's disease of Bone, intermittent dosage with bisphosphonates could be monitored by thermography to determine optimum dose and frequency of intermittent treatment required for each patient.

These studies provided valuable understanding of the manner in which some of the anti-inflammatory agents worked. At low dose, frequently showing complete absence of side effects, the oral non-steroid drugs were purely analgesic in their action. As the dose increased, anti-inflammatory action and decrease of joint temperature was observed, more rapidly in the small affected joints such as fingers, and more slowly with large joints such as knees and ankles. I was possible to carry out dose response curves in both experimental animals (stage 1) and on patients (stage 3) of a new drug development.

This procedure, as with al, quantitative studies, requires a rigorous clinical routine, and stable and controlled room temperature, and large numbers of subjects Thermography is still one of the very few techniques which can be used for clinical trials as well as on animal models of inflammation for new drug development. Detecting a non-responder to a non-steroid drug as early as possible in clinical treatment has clear advantages for both patient and physician.

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THERMOGRAPHIC ASSESSMENT OF THERMAL EFFECTS OF ER:YAG LASER IN PERIODONTAL SURGERY

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Introduction: Lasers in dentistry have been applied to many procedures, i.e. soft tissue cutting applications, removal of carious lesions, laser-assisted scaling or disinfection of root canals. One of the most effective instruments for dental soft tissue surgery is the CO laser. Despite its unquestionable advantages, the numbers of studies are undertaken to developed a new devices based on lasers of erbium-type, with ability to cut the dental soft tissue. Due to the advantages of CO laser i.e. precise of incisions or healing without scaring, the Er:YAG laser has been proposed for various types of oral soft tissue surgery. The superiority of the Er:YAG laser to CO laser is the elimi- nation of damaging thermal effect during dental hard tissues procedures.

The uses of dental devices with erbium laser for various procedures like the removal of carious lesions have been explored for several years. With the development of fiberoptic contact delivery system for Er:YAG laser it can be used for many others treatment procedures. To confirm usefulness and effectiveness of Er:YAG laser for intraoral soft tissue surgery a number of clinical research are still carried out.

Methodology: The investigations were carried out on Wistar rats. After administration a general anaesthesia animal was stabilized on the lab table. The Er:YAG laser system (model 1243 KaVo KEY) was used. Intraoral soft tissue surgery of frenectomy, frenulectomy and excision of lingual mucosa was performed.

Thermographic measurements were carried out under carefully controlled external operating environment. The room temperature was maintained at 20C and was controlled automatically by air-conditioning. In view of high dynamic of temperature changes at the time of laser irradiation, thermal imaging camera ThermaCAM SC3000 (FLIR Systems) was used. Thermal images were taken at a very high rate of 750 frame/sec.

Results: Heating of fiberoptic tip at the time of laser-assisted frenectomy and frenulectomy was analyzed because of high temperature rises observed. The mean temperature of the end-point of optical fiber at laser energy of 100mJ and repetition rate of 25Hz over a period of 0,7sec reached 350°C, and then the temperature ranged from 270°C to 360°C. The maximal temperature observed was 500°C.

Furthermore dynamism of thermal changes on the surface of oral mucosa at the time of laser application was analyzed. The rise in temperature higher than 50°C pegged at about 0,4sec. The maximal temperature recorded on the surface of operation area was 238°C, but the time of influence of temperature higher than 100°C was at about 100 milliseconds. Continual rise of minimal temperature was observed. This phenomenon occurred because of indispensable time for relaxation of thermal stimuli. Another step of analysing was distribution of temperature of the surgical area along selected line at maximal rise of temperature. The rise in temperature above 50°C at energy of 100mJ was recorded on the length of 2mm and at en energy of 300mJ – 3mm respectively. The increasing of laser energy resulted in temperature rises of about 25% (from 230°C to 290°C) on the surgical field.

The maximal temperature registered on the surface of tongue during procedure of lingual mucosa excision was 200°C at laser energy of 80mJ, moreover the rise in temperature above 40°C was observed on the length of 1,6mm of the operation area. For laser irradiation et energy of 160mJ the maximal temperature reached 230°C and the rise above 40°C was observed on the length of 2,5mm. The rate of cooling for both cases was lower than 0,5sec.

Conclusions: Side effects of heating (up to 80°C) the end point of optical fiber as well as the surface of oral mucosa observed in experiment did not cause persistent histological changes in course of healing.

To prevent undesirable thermal side effects and overheating of operation area optical fiber should be moved very fluently, without contact with tissue.

Results obtained in this study suggest, that thermal imaging system can be a useful tool for monitoring thermal effects of Er:YAG laser/tissue interaction during periodontal procedures.

Acknowledgments. We would like to thank FLIR Systems Company for facilities of thermal imaging camera ThermaCAM SC3000 for our investigation.

DYNAMIC THERMOGRAPHY AS A DIAGNOSTIC TOOL FOR MEDICINE

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In this paper the basis of lock-in and pulse thermography are presented, showing both potentialities and limits of this method,

especially for medical applications. Active thermography is the method where a sample is heated by an external energy and 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 thermography methods can be applied for measuring skin thickness, inflammation regions, density of tissues, blood flow, etc.

Lock-in thermography assumes the periodic excitation on the front side of the investigated body and synchronous thermal image acquisition. Such a case can be theoretically described as a fluctuating heat flux transferred to/from the front face of the sample. The flux can be generated in different ways, typically using radiation power obtained from high-power lamp. Pulse thermography is using single shot excitation, and the temperature rise and decay are measured. By using pulse or lock-in thermography, one can measure e.g. the thickness of the thin film coating or rusted areas, mainly in invisible places. The typical thickness measurement by active thermography assumes that it is of the order 30-150?m, depending on the substrate and coating thermal properties.

MEDICAL INFRARED THERMOGRAPHY AND THE MEDICAL DEVICES DIRECTIVE: WHAT CAN BE LEARNT FROM PUPILLOMETRY.

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Under the European Union medical devices directive (MDD) (93/42/EEC), a medical device is defined to include "any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for the proper application, intended by the manufacturer to be used for human beings for the purpose of diagnosis, prevention, monitoring, treatment or alleviation of a disease, an injury or a handicap".

Under this directive any device put on the market with the intention for it to perform a measurement on a patient must now comply with the requirements of the directive: it must be CE marked to the MDD

We will take as an example the infrared pupillometer. This is a device for measuring the size of the pupil of the human eye in any ambient light levels. The eyes are bathed in near infrared radiation and by means of suitable optics and a CCD camera, an image of the eye is created. Software extracts parameters from the image such as pupil diameter. Stimuli, for example light pulses, can be applied to interrogate neural pathways and a dynamic sequence obtained. Asymmetry between left and right eyes also provides valuable information. Primary applications are the measurement of resting pupil diameter prior to refractive laser surgery and investigations into autonomic function. The Procyon P3000 binocular infrared static and dynamic pupillometers are CE marked to the MDD

Excepting that Infrared thermography utilises endogenous radiation there are many parallels with pupillometry. Both are non-contact (except for patient supports), produce an image of the body, from which software derives an absolute measurement (length, temperature) which is used to make diagnostic and therapeutic decisions. Both techniques employ stimuli to obtain dynamic responses, and contralateral asymmetry is of interest.

However, the thermographic cameras used by the medical community are not sold as medical devices. In particular they do not meet IEC601-1, the standard for electrical safety of medical devices.

We will argue that a thermographic camera used for patient measurement should be considered to be a medical device. We will discuss the commercial issues around CE marking to the MDD. Finally, we will outline the need for adequate and sufficient risk assessments to be in place in medical thermographic laboratories to ensure patient safety with currently available thermographic cameras. Central to the assessment is that there is an traceable record of temperature accuracy and image quality. We will also recommend the use of standard operating procedures coupled with a library of standard views.

THE EFFECT OF WATER FILTERED INFRARED-A IRRADIATION (WIRA) OF THE ABDOMINAL WALL ON SKIN TEMPERATURE AND SKIN BLOOD FLOW MONITORED RESPECTIVELY BY INFRARED THERMOGRAPHY AND SCANNING LASER DOPPLER IMAGING.

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Introduction A major advance in reconstructive surgery has been the success of free-tissue transfer. Although success rates greater than 90% are normal with microvascular free flaps, surgeons continue to be confronted by occasional flap loss. The most common denominator of flap loss is prolonged ischemia, which causes irreversible tissue damage and complicates reconstructive surgical procedures. Heat shock priming has shown to increase the tolerance of tissue for ischemia and is defined by the temporary exposure of cells to supra-physiological levels of heat. After recovery cells become, in response to this heat shock, more resistant against a second stress, including surgical trauma and ischemia. Heat shock priming is known to protect flap tissue also after tissue transfer and can therefore be used to precondition the flap. This study investigates the effect of water filtered infrared irradiation (wIRA) from a Hydrosun® wIRA irradiator (Hydrosun® Medizintechnik GmbH,Germany)of the abdominal wall on skin temperature and skin blood flow. The lower abdominal wall is a frequent used donor area for free flaps. If supra-physiological levels of heat are obtained by wIRA irradiation then it could be used to precondition flaps.

Methods: Ten healthy female volunteers (age 37.1 ± 7.9 years; BMI 22.8±1.8) participated in the study. The lightly clothed subject lay in a supine position on a conventional treatment bench at a room temperature of ca 23°C. The treatment con- sisted of a 20-minute period of wIRA irradiation of the abdominal skin on the right side with the left side covered during treatment. Abdominal skin temperature and skin blood flow (SBF) were measured respectively using infrared thermography (Nikon Laird 270 infrared camera, Nikon ltd., Japan) and a scanning laser Doppler (MoorLDI-2 laser Doppler imager, Moor Instruments ltd; England). Measurements were made before, and at 0, 5, 10, and 15 minutes after the period of wIRA treatment. During measurements (before and after irradiation), the coverage on the left side was removed to allow bi-lateral measurements of SBF and temperature.

Results: Before irradiation, SBF was on average 70 PU (perfusion units) and average skin temperature was 32.5°C. At the end of the irradiation period, SBF on the irradiated side of the abdomen had increased over 10 fold to ca. 710 PU while skin temperature increased by 4.5°C to 37°C. SBF on the non-irradiated side of the abdomen did not change during the wIRA period, while skin temperature increased by about 0.5°C. Both SBF and skin temperature on the irradiated side decreased in parallel during the post-irradiation period although both were still greater than their respective pre-irradiation values at 15 min post-irradiation (ca. 200 PU and 34.2°C respectively).

Discussion: The results clearly show that wIRA provides a rapid and powerful means of increasing skin temperature as well as increasing skin blood flow. The significant rapid increase in perfusion will most likely be beneficial in a model where the flap is pre-conditioned with alternate cooling and warming, as has been previously demonstrated.

Conclusion: wIRA irradiation of the skin with a Hydrosun® wIRA irradiator causes a significant increase in skin temperature and skin perfusion.

DYNAMIC THERMOGRAPHY AS A RELIABLE, NON-INVASIVE AND EASY METHOD FOR MONITORING PERFUSION IN FREE FLAP SURGERY, PRELIMINARY RESULTS.

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Introduction: The use of free flaps in reconstructive surgery has become common practice. A good example is the use of the Deep Inferior Epigastric Perforator (DIEP) flap for breast reconstruction after surgical treatment for breast cancer. The DIEP flap consists of skin and subcutaneous tissue from the lower abdomen and relies for its blood supply on the deep inferior epigastric artery and vein. During free-flap transfer, both the artery and vein are separated from the parent vessel which results in cessation of blood flow to the flap. After transfer of the flap to the thoracic wall, the surgeon connects the flap's artery and vein to respectively the internal mammary artery and vein. The connection, called the microvascular anastomosis, is the most critical procedure during the operation. Reperfusion of the DIEP flap is dependent on the viability of the anastomosis. Monitoring flap perfusion intra- and postoperatively has proven to reduce partial and complete flap loss, which can be a devastating experience for a patient. In this pilot study, dynamic infrared thermography was used intra- and postoperatively to monitor the blood flow status of the DIEP flap used in breast reconstruction.

Methods: Eight patients undergoing breast reconstruction with a DIEP flap were included in this study. Intraoperative infra-red thermal images of the DIEP flap were taken before and after the microvascular anastomosis was completed to monitor active re-warming of the flap. Afterwards, dynamic thermography was used to monitor re-warming after an intraoperative thermal challenge with surface cooling. In the days, weeks and months after the operation dynamic thermography monitored re-warming after a short period of fan cooling. All IR-images were taken using a Nikon Laird S270 (Tokyo, Japan) IR-camera. For processing the electronically stored IR digital images we used image analysis software PicWin-IRIS (EBS system technik GmbH, München, Germany).

Results: The thermal images showed that the flap cooled down after cessation of the blood flow. Rapid, active re-warming of the flap started from one "hot spot" in the flap after the anastomosis was completed and patent. This was followed by appearance of other hot spots. A clear arterial Doppler signal could be heard over these hot spots. Re-warming of the flaps could be well distributed and in these cases no perfusion problems were seen postoperatively. Re-warming of the flap was improved by anastomosing an extra vein for drainage of the flap. No hot spots appeared when the anastomosis did not function or with external compression on the vessels. A new anastomosis or repositioning of the vessels was followed with active re-warming of the flap. The postoperative phase showed an initially rapid re-warming during dynamic IR-thermography that became less profound in the weeks and months that followed. Visualization of the indirect blood flow with IR-thermography was highly appreciated by patients and experienced as an assurance of the success of the operation.

Conclusions: Rapid active re-warming in free flap surgery is only possible by perfusion. The use of dynamic IR-thermography provides the surgeon a new, reliable and non-invasive method for monitoring perfusion during and after a free-flap transfer.

INTERMITTENT ISOMETRIC CONTRACTIONS OF THE RECTUS ABDOMINIS MUSCLE BY APPLICATION OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) AND ITS EFFECT ON SKIN TEMPERATURE AND BLOOD FLOW IN THE OVERLYING SKIN.

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Introduction: Breast reconstruction has become an integrated part in the overall treatment for patients diagnosed with cancer of the breast. Patients with autologous breast reconstructions with a free transverse rectus abdominis musculocutaneous (TRAM) or deep inferior epigastric perforator (DIEP) flap are specifically pleased with the natural shape, soft consistency and permanency of the superior results. However, there is a recognised incidence of partial flap necrosis in both the TRAM and DIEP flaps. The main blood supply of both flaps is the deep inferior epigastric artery. It is the dominant artery of the rectus abdominis muscle and only musculo-cutaneous perforators arising from this artery provide blood to the free TRAM and DIEP flap. Muscular blood flow can increase up to 25-fold during extreme physical activity. The increase in blood flow elicited by voluntary and electrically induced muscle contractions by transcutaneous electrical nerve stimulation (TENS) appear to be similar in magnitude. An increased blood flow in the contracting muscle could result in an augmented flow through the myocutaneous perforators to the skin. This could be a non-invasive method of preconditioning the TRAM or DIEP flap for autologous breast reconstruction and could augment the volume that can be used in breast reconstruction. However, there are contradictory reports on the effect of TENS on skin temperature and cutaneous blood flow ranging from no effect to an increased microcirculation in skin areas overlying stimulated muscle. In this study, the effect of burst-mode TENS of the rectus abdominis muscle on the microcirculation in the skin was investigated. This pattern of external stimulation more closely mimics the intermittent muscle contractions during, for example, sit-ups.

Methods: In ten healthy female volunteers, average age 37.1 ± 7.9 years and average BMI 22.8 ± 1.8, two pairs of oval shaped stimulating surface electrodes (50mm x 100mm), each with a surface area of 39.3cm, were placed on the abdomen. One pair was situated on the right side and the other on the left. Skin temperature and skin blood flow were measured with respectively, infra-red thermography using a Nikon Laird S270 (Tokyo, Japan) IR-camera.and laser-Doppler imaging (Moor LDI-2 laser Doppler imager; Moor Instruments ltd; England) before, during and after intermittent isometric contractions of the rectus abdominis muscle. During the experiments, only the left electrode pair was stimulated. By increasing the intensity (0-40 mA), visible intermittent muscle contractions were evoked. Each patient was subjected to a 20-minute period of stimulation. To examine the possible effect of TENS on skin surface temperature, either directly through increased skin blood flow or indirectly via heat conducted to the skin surface from the stimulated muscles, the average skin surface temperature of two identically oval shaped areas (ca. 26 cm) was calculated. The scanning laser Doppler (SLD) was adjusted to cover an area of approximately 360 cm,

which included all 4 TENS electrodes. In each experiment scans lasting ca.90seconds were made prior to the start of TENS stimulation, immediately after the end of TENS, and at respectively 5, 10 and 15 min of the recovery period following TENS. For each SLD image two 20 cm rectangular areas of skin lying between each lateral pair of electrodes were used for calculating average skin blood flow in perfusion units (PU).

Results: No significant changes in skin temperature were found while minor changes in skin blood flow (SBF) (a decrease in SBF on the stimulated side) were registered.

Conclusion: It is concluded that burst-mode TENS does not increase blood flow in the skin overlying the stimulated muscle and is unlikely to precondition the DIEP flap.

THE METHOD OF ANATOMICAL POINTS SELECTION IN THE FACE THERMOGRAM."

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Objectives. The aim of paper is a presentation of the method suggested for anatomical points selection in the face's thermogram.

Image analysis has been a main point of interest of many scientists for many years. They usually have worked on the graphic file like bitmap, where natural scene described as R, G, B values have been used as a source for analysis. A different situation exists in the analysis of thermograms , where we usually work with pseudo images – the graphical representation on the temperature distribution on the surface. This means that the thermograms of the same object can be presented differently dependant on colour function and may generate different R, G, B values.

The proposed method is independent of colour function and can be useful in a automatic face's thermogram analysis software.

Methods. The base for this method is an analysis of the temperature matrix as a result of the single man observation. It means, it is possible to select in the scene the man and some others object in the background. Analysis can be divided in to 4 steps named: Filtration, Head searching, Head area analysis and Anatomical point selection.

The aim of first step is to remove all data from the temperature matrix which represent with high probability objects outside of the face or have unknown temperature values. This value is typically reported by the thermographic camera as a "Not a Number" value. At the end of this step image area of interest is decreased.

The "Head searching" is based on isotherm processing. The isotherme matrix processing generates data which are the base for the best fitted ellipse.

"Head area analysis": this step removes all data from the matrix data which are outside of the outline of the head and generates the mask for the next processing step.

During the last one "Anatomical point selection" step we used basically one of the standard filter methods such as Sobel, Previtt, Roberts and Canny filters. 256 level black & white, thermograms were the source for filtering. In many cases these filters generate a set of points which cab be useful in the next step of analysis. But there also many thermograms where these filters work incorrectly.

Our suggestion is based on image processing of a filtered temperature gradient matrix. During this process, some isotherms are removed lines, if the enclosed area is smaller or greater than empirical values . After this, the second step of filtration is made. This step is based on the geometrical relation between position of the eyes and nose to the outline of the head.

At the end. a set of anatomical points is presented as a matrix of coordinates.

Results: We have tested the presented method in a pilot study with 32 thermograms from people of different age and gender with good results.

In a second study the proposed method was tested in series of thermograms from 12 different subjects.. For each subject a series of 27 thermograms was recorded consisting of 9 views from 3 distances [1, 2, 3m]. The method works correctly in most of the cases.

Problems has been observed when the distance was equal to 3m and when the object (head of the subject) was rotated or the the view of the recording camera was not perpendicular to the object.

Conclusions: The presented method may be useful for image processing of facial thermograms. It can be specially useful for the identification of the position of the eyes and the nose. This method may be helpful in the generation of automatic systems for the evaluation of facial thermograms for example in patients suffering from maxillary sinusitis.

LIQUID-CRYSTALLINE CONTACT THERMOGRAPHY IN MEDICINE

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The physical background of liquid-crystalline thermography (LCT) and some information regarding the technology will be presented. This will inc1ude the effect of selective light reflection and the influence of body temperature as weIl as the properties of thermographic foils on the colour of reflected light. The measuring technique, moreover advantages and disadvantages of the LCT will be discussed in details with the special attention paid to the effect of the environment. The review of studies on medical applications of LCT will be given. In the summary the comparison between LCT and thermovision systems will be given, moreover the perspective of LCT application in practice will be proposed.

RENAL FISTULA ASSESSMENT USING COMBINED THERMAL IMAGING AND COLOUR DUPLEX ULTRASOUND

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Vascular and clinical assessments of fistula function are important in patients undergoing or preparing to undergo renal dialysis. Objective assessments at Freeman Hospital now indude combined colour duplex ultrasound and medical thermography measurements. For example, these modalities can help study problems relating to either fistula failure or to excessive fistula fIow which can result in vascular steal (digital blood fIow impairment resulting in skin temperature reduction). The aims of this pilot study were a) to determine if fistula region skin temperature is related to fistula blood fIow and b) to determine if simple bilateral differences in hand temperature relate to clinical steal grading.

Renal patients were clinically assessed for vascular steal by the transplant surgeon (either steal or no steal). Patients also underwent objective vascular measurements which comprised thermal imaging of the hands and fistula region followed by fistula blood

flow estimation using colour duplex ultrasound at the brachial artery. Differences (fistula - non-fistula side) in the mean hand temperature and in the mean I maximum fistula region temperatures were determined using dedicated image processing software (FLIR SC 300 thermal imaging system with ThermaCam Researcher image processing software, skin emissivity 0.97). These temperatures were then compared with fistula flow and steal grading.

Fifteen patients were studied (mean age 60 years), with flVe dassed as having some degree of clinical steal. Ultrasound measurements also identified the presence of stenosis in 5 patients. Estimated fistula flows ranged from 30 - 1950 ml min-1 (mean [standard deviation] of 920 [680] ml min-1) and were significantly correlated with bilateral differences in maximum fistula region skin temperature ($R = +0.71$, $p<0.01$). Therrnography usually deany highlighted the warmer superficial blood vessels in the region of the fistula (mean 33.3 [1.1] °C, maximum 35.3 [1.0J °C). Hand temperature differences with threshold set to -1 °C were found to separate steal from non-steal patients with an accuracy of 93.3% (specificity 100%, sensitivity 80%). In this study the maximum difference between mean hand temperatures for a patient with steal was close to 5°C.

We have demonstrated an association between fistula region skin temperature and estimated fistula blood flow. We have also shown that a bilateral hand temperature difference with threshold of -1 °c separates steal from non-steal patients with an accuracy of greater than 90%. Further work is now needed to explore the dinical utility of these findings, to identify which patients subsequently needed surgery, and also to examine the detailed characteristics of the fistula thermal profiles.

THERMOGRAPHIC EXAMINATION FOR DIAGNOSIS OF ABDOMINAL PAIN IN CHILDREN

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Abdominal pain of children, is despite medical progress, still a difficult and complicated diagnostic problem. The type of pain, its localization and associated symptoms do not always lead to easy diagnostic decisions and demand the use of additional laboratory tests and diagnostic imaging. The aim of this study was to investigate the usefulness of thermographic examination (THV) as a screening method for the identification of the underlying course of abdominal pain in children.

Material and Methods. A prospective study was conducted in 46 children, aged 2 – 18 years, who were hospitalized at the Departments of Pediatrics of Silesian Medical University in Katowice, between from 2002 to 2003. All patients suffered from abdominal pain, usually chronic and with various localizations. A control group of 20 healthy children in the same age was also studied. The Flir System THERMACAM PM595 was used for thermal imaging, which was performed under standard thermal conditions. Prior to the readings of the thermal images, the investigator was blinded for clinical symptoms and pain localization.

Results. Only 4 of 46 children had normal thermal images (8,7%). Abnormal thermal images were found in the 42 children. Thermal abnormalities did not always correspond with abdominal pain and/or the localization of the affected organ. Hot spots were observed on the left hand side of the lower abdomen and/or a "patchy" image of the entire abdomen in children with functional disturbances of the alimentary tract or colitis. Warm areas corresponding with the anatomical localization were seen in children with liver and pancreas diseases. Hot spots on thermal images outside the abdominal region in 3 children, lead to the correct diagnosis (neoplasm in two patients, sinusitis in one).

Conclusions. The thermographic examination can be a useful screening method for the detection of the underlying cause in children suffering from of abdominal pain.

A COMPARISON OF SKIN TEMPERATURE AND OBJECTIVE SKIN COLOUR MEASUREMENTS IN NORMAL SUBJECTS AND PATIENTS WITH RAYNAUD'S PHENOMENON SECONDARY TO CONNECTIVE TISSUE DISEASE

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Raynaud's phenomenon is a condition in which the blood supply to the extremities, usually the fingers and toes, is intermittently interrupted. An attack can be triggered by exposure to cold, or even just a slight change in temperature. The affected parts become 'white', and may turn 'blue' and finally 'burning red', before returning to their normal colour. There may also be pain, numbness, or loss of hand function during an attack. Raynauds occurs in approximately 10% of the UK population. It is often severe when related to other conditions, such as connective tissue disease.

Traditionally, Raynaud's phenomenon is assessed clinically by careful examination and the reported episodic skin color changes. Some specialist centres also employ objective temperature measurements to aid diagnosis. However, these tests are not fully reliable since some healthy people can have generally cold hands and feet, without the characteristic episodic skin colour changes ascribed to Raynauds. It is hypothesized that objective skin colour determined using the optical technique of spectrophotometry may aid the diagnostic process. The aims of this pilot study were a) to compare objective skin colour measurements from normal subjects with patients having Raynaud's phenomenon secondary to connective tissue disease, and b) to explore possible relationships between skin temperature and colour.

A total of 24 normal healthy adult subjects and 24 connective tissue patients with clearly described Raynaud's phenomenon were studied. All were Caucasian. A single operator (JA) collected spot skin temperature and colour measurements from the palm and the pulps of the corresponding middle/ring fingers under normothermic conditions using an electronic thermometer (Comark 1601) and a portable reflection spectrophotometer (Minolta CM-508i, giving the percentage reflection between the visible wavelengths of 400 to 700 nm with 10 nm resolution), respectively. Normative ranges of skin temperature and colour data were calculated for the finger, palm, and differences between the finger and palm sites. The patient group was then compared with these data and differences tested using the Student's t-test ($p<0.05$ for statistical significance). Skin temperature and colour data were also compared to determine if these were related.

When patient skin colour data were compared against normative ranges (for patient - normal differences) 3 distinct points were observed for the finger site, with positive peaks at 480 nm and 580 nm, switching to a trough at 660 nm ($p<0.005$). Furthermore, a comparison of finger - palm differences between the groups revealed statistically significant differences for wavelengths greater than 600 nm ($p<0.05$) increasing $p<0.0001$ at 700

nm. When finger skin temperature and colour data were compared no clear relationship could be clearly identified for either subject group. When finger - palm temperature and colour differences were compared in normal subjects they showed only relative finger redness for positive temperature gradients. The connective tissue disease patient data appeared complex with no clearly discernable relationship.

Normative ranges of skin colour have been determined with specific and significant differences detected when compared to the connective tissue disease patient group. Interestingly, no clear relationships between skin colour and temperature data were found at the finger site for either group. Further work is now needed to explore these findings and also to evaluate the diagnostic value of spectrophotometry skin colour measurements in assessing patients with Raynaud's phenomenon.

THE COMPARISON OF THE THERMOGRAPHIC AND HISTOPATHOLOGIC STUDIES OF THE SKIN MELANOCYTIC NEVI

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The aim of the study was to compare thermographic and histopathologic analyses of melanocytic skin nevi. In addition, the mitotic activity of cells was analysed by the expression of Ki-67 antigen in histopathological studies of few melanocytic nevi which showed temperature changes in the thermographic study.

Material and Methods: In total, 160 melanocytic nevi from 35 patients were studied. These included 22 patients with a diagnosis of atypical nevus syndrome. The thermographic analyses were performed using Therma CAM TM SC 500 thermographic camera. The thermograms were analysed using AGEMA Report 5.41 computer programme. The differences between maximal (Tmax) and minimal (Tmin) temperatures within each pigmented lesion were calculated: δT= Tmax-Tmin. In 20 control subjects healthy skin without melanocytic nevi was studied. In the total group of 160 melanocytic nevi, the values of δT coefficients were 1.41 °C. In total 47 melanocytic nevi showed signs of atypy in the clinical and dermatoscopic examination and were treated surgically in the Department of Dermatology and Venereology of Pomeranian Medical University. Subsequently histopathologic examinations of the excisions were performed. For the evaluation of the mitotic activity in 15 melanocytic nevi, the expression of the Ki-67 proliferative antigen was studied histo-chemically. Ten melanocytic nevi with δT>1.41°C and five melanocytic nevi with δT < 1.0 °C were evaluated. Additionally, in five cases of skin melanoma the expression of Ki-67 antigen was investigated.

Results: Mean value of δT coefficient for control group was 0.74±0.128 °C, whereas for 141 melanocytic nevi δT < 1.41 °C and for remaining 19 nevi - δT>1.41 °C. The correlation between atypy in the histopathological examination and increased value of dT coefficients was noticed. For ten melanocytic nevi with δT > 1.41 °C, expression of Ki-67 was 1-9%, for 5 melanocytic nevi with δT < 1.0 °C the Ki-67 expression was 0-0.5%, whereas for 5 skin melanoma - 10-26%.

Conclusions: 1. Melanocytic nevi with δT >1.41 °C in thermographic study shows frequently histopathological signs of cell atypy 2. The elevated values of δT could be caused by the increased mitotic activity of melanocytic skin nevi.

THERMOGRAPHY IN PSORIATIC SKIN LESION EVALUATION.

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Psoriasis is a chronic, non-infectious inflammatory with polygenic component, skin disorder with a prevalence of 1- 2% of the human population worldwide. Increased blood flow resulting from elongation and widening of the vessel lumen together with inflammatory cell infiltrate are key features of histo-pat hological findings of this disease. The above phenomena lead t increased temperature of psoriatic skin lesions.

The aim of the study was to employ thermography in evaluation of skin lesions regression in patients hospitalized at the Department of Dermatology, Medical University of Lodz, Poland.

The study comprised 20 patients with psoriasis vulgaris who were on classical anti-psoriatic regimens. The thermocamera INFRAMETRICS 760 with temperature resolution of 0.1°C was used in the study. The examined patients were prepared undressed for 15 min in a specially designed room before each thermographic examination. Temperature measurements were performed every 7-8 days in a 21-28-day period.

During the treatment process progressing decrease of skin lesion temperature was noted. Dynamic of temperature changes was much higher than the dynamic of clinically evaluated parameters such as erythema, induration and desquamation.

It seems that thermography could become a sensitive parameter of psoriatic lesions progression/regression.

INITIAL RESULTS FROM THE THERMAL IMAGE DATABASE FOR CLINICAL THERMOGRAPHY

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Thermal imaging has been in use in medicine since the 1960's, despite many different applications and studies a normal database is not available. Presented here are the details of the construction of a normal database and a sample of the results.

To construct the database volunteers were recruited and screened for normality using the Euro-Qol (EQ5D) questionnaire, normal subjects were then imaged. Twenty four standard views of normal volunteers were recoded. Standard masks were used in each image to minimise variability in position between the subjects. Normal subjects were divided into categories, for example male's aged 18-30, so that images of the standard views could be combined. Before combining the images of different subjects, the images were warped to allow subjects of different shapes to fit exactly into the standard masks. The combined images provide information about the mean and variability of temperature in the standard views for a given category of normal subjects.

The results for the category of male's aged 18 –30, total body view, are discussed in detail.