21st Thermological Symposium of the Austrian Society of Thermology
Recent Advances in Thermology

15th November 2008, Goldener Saal, SAS Raddisson Hotel, Vienna, Parkring 16

Programme

Chair: Prof Dr Kurt Ammer (Austria), Prof Dr. Anna Jung (Poland)

9.00	*R.Vardasca*, U.Bajwa (Portugal/Pakistan)	Impact of Noise Removal Techniques on Measurement in Medical Thermal Images
9.15	Discussion	
9.20	B.Jesenšek Papež, *M.Palfy,* ZTurk (Slovenia)	Thermal Imaging As A Diagnostic Tool In Carpal Tunnel Syndrome
9.35	Discussion	
9.40	*R.Thomas* (UK)	Minimum Specification for Medical Thermal Imagers
9.55	Discussion	
10.00	*E.F.J,Ring* (UK)	Screening for Fever by Thermography
10.25	Discussion	
10.30	*J. B. Mercer* (Norway)	Infrared Thermography in semi-free ranging domesticated African Elephant (*Loxodonta africana*) - preliminary results from a pilot study.
11.00	Discussion	

11.05-11.35 Coffee Break

Chair: Prim Dr T.Schartelmüller (Austria), Prof Dr F.Ring (UK)

11.35	*K Amme*r (Austria)	Thermal imaging for the diagnosis of primary Raynaud´s Phenomenon
11.55	Discussion	
12.00	TA Buick, KJ *Howell* R. Gush, CP Denton , RE Smith (UK)	A Comparison of Infrared Thermography (IRT) and Full-Field Laser Perfusion Imaging (FLPI) For Assessment of Hand Cold Challenge and Dermal Inflammation
12.20	Discussion	
12.25	*G. Litscher* (Austria)	Thermal imaging and related techniques in acupuncture research
12.55	Discussion	
13.00	*R.Vardasca*, (Portugal)	Symmetry of temperature distribution in the upper and the lower extremites
13.20	Discussion	
13.25	*Adriana Nica* Ana Meila, Clara Dima (Romania)	Monitoring Treatment in Patients after Stroke by Thermal Imaging: Study Design
13.50	Discussion	
13.55	*Carolin Hildebrandt* C.Raschner(Austria)	Thermal Imaging as Screening Tool for Knee Injuries in Professional Junior Alpine-Ski-Racers In Austria
14.15	Discussion	

14.30 Close

Abstracts

THERMAL IMAGING FOR THE DIAGNOSIS OF PRIMARY RAYNAUD´S PHENOMENON

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Primary and secondary Raynaud´s Phenomenon differ in etiology**,** severity and location of symptoms Although about 20 % of patients with primary Raynauds phenomenon may undergo transition to a secondary form of this vasospastic disease, a rough differentiation between primary and secondary Raynaud´s phenomenon can be made by the number of involved fingers. Primary vasospastic disease affects by definition all fingers, but with less severe symptoms. Secondary Raynaud´s may involve some single or all fingers with occasionally severe signs of the transient reduction of perfusion. The diagnosis Raynaud´s phenomenon requires attacks of triphasic colour changes of fingers, however, patients with primary Raynaud´s present often only with blanching and coldness or biphasic colour changes of all fingers.

Between 1st November 2007 and 6-th October 2008 thermograms of both hands were recorded from 85 patients suspected of Raynaud´s phenomenon. After acclimatization for 15 minutes to a room temperature of 24 degrees, the hands were positioned on a table, and images in the dorsal view for both hands were recorded. Then the hands, covered with plastic gloves, were fully immersed for 1 minute in water of 20°C. Immediately after taking off the gloves, and at in interval of 10 minutes 3 other thermal images were captured. Spot temperatures were measured on the tip and over the mid of metacarpal bone of each finger. Gradients were calculated by subtracting the metacarpal temperature from the temperature of the finger. Raynaud´s phenomenon was diagnosed when negative temperature gradients > 1° were detected 20 Minutes after the cold challenge. Involvement of all fingers with thumbs either included or excluded was regarded as primary Raynaud´s phenomenon.

68 females (age range: 14 to 81 years) and 17 males (age range: 17 zo 81 years) were investigated. In total, 47 patients (5 males, 42 females)were diagnosaed as primary Raynaud´s phenomenon, 24 subjects (3 males, 21females) showed involvement of single fingers and the remaining 24 subjects (9 male, 15 females) presented with normal temperature recovery after the cold challenge.

A higher proportion of females than males presented with thermographic signs of Raynaud´s phenomenon. Involvement of all fingers, was a common finding in our sample . Primary Raynaus´s phenomenon was not restricte to young age, as slow recovery of temprature after cold challenge was detected in all fingers in 6/13 patients aged 70 years or older.

THERMAL IMAGING AS A DIAGNOSTIC TOOL IN CARPAL TUNNEL SYNDROME

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INTRODUCTION:Thermography is a type of infrared imaging, capable of detecting radiation in the infrared range of the electromagnetic spectrum (0.9–14μm) and producing images of that radiation. In carpal tunnel syndrome at earlier stages of syndrome vasoconstriction is common, while at later vasodilatation. Consequently, unexpected skin temperatures can be measured at different parts of affected hand.

AIM: The aim of present study was to use a software-based intelligent system for diagnosis of carpal tunnel syndrome. Artificial neural networks, known as a well established data mining technique, were used for thermal image analysis.

METHODS:28 patients and volunteers participated in creating our image database, resulting in 44 images of hands. There were 23 images of hands belonging to patients with the carpal tunnel syndrome of different severities and 21 images of healthy hands. Images were taken with the Avio's Neo Thermo TVS-700 camera with resolution of 320x240 pixels. The software application we developed for the purposes of this study consists of two modules. First module takes care of image segmentation and extraction of temperature readings while the second one performs the image analysis and tries to diagnose the carpal tunnel syndrome.

RESULTS AND DISCUSSION: Classification success rates exceed 75% in most cases. However, it should be noted that only 44 images were at our disposal, which is a very small number, taking into consideration the importance a learning process plays in artificial neural networks development. When operating with such small sets of objects the classification results can be misleadingly good (or bad). Only when our image database will grow considerably a real assessment of results will be possible.

Table : Classification success rate compared to the reference case

no.	Included segments	Success rate (%)
1	all dorsal segments (reference case)	80.6%
2	all segments	74.3%
3	all palmar segments	65.6%
4	all dorsal but 1st finger (thumb)	81.8%
5	all dorsal but 2nd finger	77.3%
6	all dorsal but 3rd finger	81.8%
7	all dorsal but 4th finger	79.2%
8	all dorsal but 5th finger	75.2%
9	all dorsal without 2nd and 5th finger	70.8%
10	all dorsal without 1st, 2nd and 3rd finger	64.5%
11	all dorsal without wrist segments	82.5%
12	all dorsal without metacarpal segments	78.4%

CONCLUSION:The development of thermal imaging technology and involvement of intelligent systems enabled new possibilities which were previously unavailable. It is our goal to research these possibilities and determine whether thermal imaging can be used as a diagnostic tool in nerve entrapment syndromes.

SCREENING FOR FEVER BY THERMOGRAPHY

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A new draft standard ISO/IEC TC 121/SC 3/WG 8-PT1 has been drawn up to provide a working specification for a "screening thermograph". The deployment of infrared imaging in air-

ports and ports began with the SARS outbreak in the Far East, and is still in operation at some airports.

The writing group for this new document have considered the many facets of the technology, and its application where numbers of people have to be screened in a short time. Should a fever pandemic arise, local public health authorities will have the right to enforce restrictions on the movement and travel of anyone with a raised temperature, particularly to an area or country known to be affected by the outbreak of infection.

Two new documents have been prepared; both are based on the standards publication from Singapore (SPRING). The overall requirements are for a calibrated radiometric camera system designed specifically for rapid screening (probably height adjustable), and able to image the area of the frontal face with the highest possible resolution. The area around the eyes, with the specific target of the inner canthi . The standard describes performance tests for the manufacturer, and in a part two document, the deployment, implementation and operational guidelines are described.

The optimal imaging technique requires the subject to be positioned close to the camera system, looking directly ahead. The designers of the screening thermograph may use an audible and /or visible alarm if the subject has a raised temperature. Any subjects who fail the normal test, are likely to be subjected to a clinical screen, and clinical thermometry used to confirm the presence of fever.

As each installation will require the camera to operate continuously, uncooled detector systems are considered to me more suitable, to avoid expensive refurbishment of the cooling system. Many adjustable settings on a commercial thermal imaging system will need to be inactivated. One example is the emissivity setting, which should be fixed, and not capable of being accidentally changed by an inexperienced operator. An external reference source is also specified, as a visible check on the sable operation of the camera.

A glossary of terms is included in the document, and many aspects of the draft documents refer to existing standards for electrical safety, and those affecting medical instrumentation. The screening thermograph is described as a clinical device.

IMPACT OF NOISE REMOVAL TECHNIQUES ON MEASUREMENT IN MEDICAL THERMAL IMAGES

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Medical infrared (IR) images are sensitive to noise. It affects directly the temperature measurements of the objects in a scene. There are documented noise removal techniques that have good performance on digital images but will produce different results for each technique on temperature readings from thermal images.

Twenty noisy images were selected from a database and after being processed with several noise removal techniques, the result was statistically analysed. That analysis includes maximum temperature, minimum temperature, mean temperature and standard deviation of same region of interest and Root mean square error, Signal to noise ratio and cross correlation coefficient of each resultant image. In the end all techniques are compared and graded.

This investigation shows that all techniques produce different results, the recommended method for improving medical thermal images are the Median, Mean and Wiener filters. Results however suggest that noise filtering should only be applied when specifically needed.

INFRARED THERMOGRAPHY IN SEMI-FREE RANGING DOMESTICATED AFRICAN ELEPHANTS (*LOXODONTA AFRICANA*) - PRELIMINARY RESULTS FROM A PILOT STUDY. *

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Infrared (IR) thermal images of semi-free ranging domesticated African elephants were taken at selected intervals over a 24 hour period during summer (March). The animals belonged to a small herd consisting of 5 adults and a 6-month old juvenile housed at the Letsatsing Game Reserve, North West Province, South Africa. The reserve includes a visitor's centre situated beside a wallow plus stabling and maintenance facilities. The adults are used for elephant back riding safaris that run only in the morning and late afternoons. The herd spends much of the rest of the day-light hours browsing naturally, pursuing a lifestyle similar to wild elephants. At night time the animals are kept in individual concrete stalls in an open sided high roofed stabling area. In addition to recording IR-thermal images, body core temperature in 2 individuals was continuously measured using ingested temperature data loggers. The data loggers were recovered from the faeces following a passage time through the intestinal tract of ca. 42 and 72 hours respectively. Meteorological data, including air temperature, black globe temperature and solar radiation were continuously measured from a local field station. Written details of the animals behavioural patterns were also recorded throughout the daylight hours. The IR-images were taken using a FLIR ThermaCam S65 and FLIR SC3000 cameras (FLIR Systems AB, Boston,MA, USA). All images were electronically stored and afterwards processed using image analysis software ThermaCAM Researcher Pro 2.8 SR-1 (FLIR Systems AB). IR thermal images of the elephants were taken at different times of the day and included activities at the wallow, while grazing in the bush, before and after the rides, and in the stables shortly before sunrise and shortly after sun-down. Preliminary results will be presented in which the thermal state of the animals as shown in the IR-thermal images will be related to both body core temperature and the meteorological data throughout the 24 hour period.

THERMAL IMAGING AND RELATED TECHNIQUES IN ACUPUNCTURE RESEARCH

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Quantitative thermal imaging is becoming an important method in acupuncture research. Using infrared thermography we evaluated the effects of changes in peripheral temperature during the initial phase of manual needle and laser acupuncture under standardized conditions. According to Traditional Chinese Medicine (TCM), the combination of the acupoints Neiguan (Pe.6) and Quchi (LI.11) leads to a general increase in energy and is applied when circulatory problems in the upper extremities are present (1,2). In this presentation, examples of thermography and related techniques, e.g. laser Doppler imaging (LDI) for measuring changes of microcirculation, will be demonstrated. In addition, a new method for moxibustion will be introduced. Thermography and LDI were used to standardize this innovative method.

There are many possible uses of thermal imaging in the field of TCM in general and acupuncture research in particular, but there are still methodological limitations of this modern measuring procedure. The validity of the method for proving meridian structures according to the view of TCM must be considered critically and analyzed scientifically (3,4).

Thermographic methods such as infrared cameras and other high-tech methods like LDI are effective tools for the visualization of effects in acupuncture research which support demystification of this ancient medical treatment method.

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A COMPARISON OF INFRARED THERMOGRAPHY (IRT) AND FULL-FIELD LASER PERFUSION IMAGING (FLPI) FOR ASSESSMENT OF HAND COLD CHALLENGE AND DERMAL INFLAMMATION

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IRT is a well-established technique for the assessment of the response of the hand to cold challenge (1) and of dermal inflammation (2), as it offers full-field dynamic imaging of skin. However, the radiometric measurement of skin temperature is only a surrogate for the dermal microcirculation – a parameter of interest: many factors besides blood flow can influence skin temperature, and these limit the utility of IRT as a microvascular tool (3).

Full-field laser perfusion imaging (FLPI) is a newly-available commercial technique offering many of the advantages of IRT (full-field image, fast dynamic response), but, in contrast, the signal is derived directly from red cell blood flux in the skin (4). The utility of FLPI for the assessment of cold-induced peripheral vasospasm or dermal inflammation is, as yet, to be evaluated.

The two techniques were used simultaneously for the assessment of hand cold challenge (water at 15°C for one minute) in 3 healthy subjects. We also used the two devices to record the inflammatory skin response at the forearm of a healthy subject after a light scratch. We will present a narrative comparison of IRT and FLPI.

FLPI shows promise as a microvascular imaging tool, and indeed may have benefits over IRT for the assessment of skin inflammation. Larger studies of the utility of FLPI in healthy and diseased subjects are now required. Potential applications, benefits, and limitations will be discussed.

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SYMMETRY OF TEMPERATURE DISTRIBUTION IN THE UPPER AND THE LOWER EXTREMITIES

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Infrared thermal imaging is being increasingly utilised in the study of neurological and musculoskeletal disorders. In these conditions data on the symmetry (or the lack of it) of skin temperature provides valuable information to the clinician. The last major study on thermal symmetry, however, was made in 1988 and no studies have been carried out with the current generation of higher resolution cameras, especially none that compares total body views with close-up regional views in both anterior and dorsal visualisations.

In this study skin temperature measurements have been carried out using thermograms of 35 healthy subjects. Measurements were obtained from an infrared camera using the CTHERM application developed at the authors' research unit. CTHERM is capable of calculating statistical data such as temperature averages and standard deviation values in corresponding areas of interest on both sides of the body. Results show that in healthy subjects the overall temperature symmetry difference was at most 0.25ºC ± 0.2ºC in total body views and 0.2ºC ± 0.15ºC in regional views. Total body views and regional views produced comparable results although better results were achieved in regional views. Using a high-resolution camera the study achieved better results on thermal symmetry in normal subjects than previously reported. Symmetry assumptions can therefore now be used with higher confidence when assessing abnormalities in specific pathologic states.

MONITORING TREATMENT IN PATIENTS AFTER STROKE BY THERMAL IMAGING: STUDY DESIGN

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INTRODUCTION: Romanian medical thermography started 30 years ago in oncology, but in the late 3 years extended to other medical domains as functional investigation of thyroid, diabetes etc.

The patient with stroke has central motor deficiency and peripheral vascular anomalies. Vegetative vascular reactivity is followed by an adaptation response, peripheral thermoregulation, under the command of neuro-vegetative, metabolic, systemic and local factors.

SAMPLE: Our study has had in view a group of 10 patients with stroke, hospitalized in the University Clinic of National Institute of Rehabilitation, Physical Medicine and Balneology Bucharest, Romania. We used thermography to observe the thermic differences between the right and left limbs of the patients and the thermic dynamic before and after the treatment.

METHOD: The patients were clinico-functional evaluated and respecting the inclusion criteria: time after the acute cerebro. vascular event, localisation of symptoms, ability to stand or walk, treatment modalities (respecting a homogene pharmacologic and non-pharmacologic treatment). The patients were evaluated

analyzing the predominant pathology of the upper and lower limb, right or left dominant limb and the parameters Barthel-Index, FIM, Motility Index, strength of the maximum affected muscles of the upper and the lower extremity.

We captured the thermal images of the body according to the Glamorgan Protocol before and after the treatment and we statistical process the dates.

Even if the study was on a small number of patients it showed the thermic differences by the motor hemi body deficiency and two patients had more important thermic (and X-rays) differences showing reflex reaction in algic complex syndrome type II.

For Romanian Medical Rehabilitation this clinical study opens a new perspective for functional stroke investigation.

THERMAL IMAGING AS A SCREENING TOOL FOR KNEE INJURIES IN PROFESSIONAL JUNIOR ALPINE-SKI-RACERS IN AUSTRIA

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INTRODUCTION:Knee injuries, especially ACL ruptures, represents a major problem in professional alpine skiing. According to TECKLENBURG K.(2005) et al 53,8% of all female skiers in the Austrian Junior National Team have sustained an ACL rupture. The incidence of ACL ruptures in male skiers is slightly lower.

Although it is important to improve rehabilitation methods for the treatment of knee injuries, preventing is even better.

In recent years, *Thermal Imaging* has been successfully utilized in the field of veterinary medicine by detecting locomotion injuries in race horses and to monitor the health status (HARPER D.L. 2000).

However, despite similar anatomy and physiological pattern, only few investigations have been conducted for the prevention and detection of knee injuries in athletes with *Thermal Imaging*.

AIM: The general aim of the study is therefore to investigate the use of *Thermal Imaging* as an appropriate assessment in terms of knee injury prevention and diagnostic in young alpine ski racers. Knowing that the temperature distribution of the knee in healthy subjects is highly symmetrical from the right to the left side, our specific purpose is to evaluate interindividual local temperature variations in conjunction with reported symptoms, knee pain and previous injuries.

It is assumed that ski racers knees are exposed to much physical stress during their competition season. Therefore the analysis of a pre- and postseason measurement is required and may enhance the detection and localisation of thermal changes before they become clinically.

METHODS: In the first stage a pilot study with 53 students was carried out to establish an appropriate protocol, to define a reference of normal thermogramms including the typical range and distribution of knee temperature and last but not least to define the region of interest and most suitable standard view. An infrared camera (TVS 500EX) and the appropriate software (iReport) was provided from the Germany company GORATEC GmbH.

After an acclimatisation period of 20minutes an image of the anterior/posterior and medial/lateral aspect of both knees were recorded. The thermal environment remained under constant conditions.

The findings and the definition of the best conditions from the first part of the study will be used in the second stage, in which 50 young ski racers (male and female, 14-19 years) from the "Skigymnasium Stams" will be tested. A questionnaire, the examination by a physiotherapist and the medical history, obtained from a sports medicine specialist, will complete the findings of the images.

RESULTS/DISCUSSION:By means of some case studies from the first testing period of non injured and previously injured subjects, local temperature variations and thermal anomalies in conjunction with the medical history and the best standard view of the knee will be discussed.

Furthermore, based on a few examples from patients suffering on an acute ACL rupture or knee injury, thermal imaging as an outcome measure of monitoring the magnitude of injury will be discussed.