20th Thermological Symposium of the Austrian Society of Thermology
What is the place of thermal imaging in medicine ?

17th November 2007, Rosa Saal, Belle Etage, SAS Hotel, Vienna, Parkring 16

Programme

Chair: K Ammer (Austria), Anna Jung (Poland)

9.00 O. Rathkolb (Austria)
Welcome address

9.05 K Ammer, T. Schartelmüller, (Austria)
The value of thermal imaging for the diagnosis of Thoracic Outlet Syndrome
9.25 Discussion

9.30 Jan Hendrik Demmink (Norway)
The Net Temperature Increase In the Context of Ultrasound-Induced Heat.
9.50 Discussion

9.55 E.F.J,Ring A Jung , J.Zuber, P.Rutkowski , B.Kalicki , U.Bajwa (UK/Poland)
Thermometry, Radiometry and Thermal Imaging for Fever Detection in Children.
10.25 Discussion

10.30 J.B. Mercer (Norway)
Dynamic Thermal Imaging and Its Role In Medicine
10.55 Discussion

11.00 Coffee Break

Chair: H.Mayr (Austria), F.Ring (UK)

11.30 K. Ammer (Austria)
Three methods of evaluation of thermal images from patients with suspected Raynaud's phenomenon
11.50 Discussion

11.55 J.R.Harding (UK)
Raynaud's Phenomenon: Cold Hands = Warm Heart, But What About Cold Noses
12.15 Discussion

12.20 E,Stikbakke J.B. Mercer (Norway)
An Infrared Thermal Imaging and Laser Doppler Flowmetric Investigation of Skin Thermal Inertia in the Forearm and Hands Following A Short Period of Vascular Stasis
12.35 Discussion

12.40 R.Vardasca, U. Bajwa (Portugal/Pakistan)
Extracting Outlines Of Hands From Thermal Images
12.55 Discussion

13.00 R Berz (Germany)
Breast thermal imaging: The challenge of the BI-RADS classification
13.20 Discussion

13.25 R.C. Purohit (USA)
The Future of Thermology in Veterinary Medicine
13.55 Discussion

14.00 Close

Abstracts

20th THERMOLOGIOCAL SYMPOSIUM. WELCOME ADDRESS

O.Rathkolb

Austrian Society of Thermology, Vienna

The first Thermological Symposium was organised in Oktober 1988 by the Ludwig Boltzmann Research Institute for Physical Diagnostics (LBF Phys Diag), 9 months before the Austrian Society of Thermology was founded. However, the collaboration between this two institutions lasted until the LBF Phys Diag, ceased all research activities in 2005. Speakers at this first symposium were Prof Ring, who should participate in most of the following Austrian Symposia up to date, Prof Ammer, founding member and president of the Austrian Society of Thermology and Prof Partsch, one of pioneer of thermal imaging in Austria for clinical use in dermatology. The venue was the SAS Palais Hotel which was found to be approriate for other symposia organised by the LBF Phys Diag in the future. Proceedings with all lectures of this symposium were published., being the basement from which the journal Thermologie Österreich derived.

Up to date 19 other symposia followed, four of them included in international conferences (1997 7th European Congress of Thermology, Vienna, 2001 5th International Congress of Thermology, Vienna, 2003 9th European Congress of Thermology, Krakow, 2006 10th European Congress of Thermology, Zakopane). In total, 152 papers were presented at the previous 19 meetings, Authors from 14 different countries (Austria, Belgium, Brazil. Germany, Italy, Norway, Romania, Poland, South Korea, Slovakia, UK, USA,Yugoslavia) all around the world attended. Full length versions of the lectures of the 1st and 3rd Symposium have been published in proceedings, the abstracts of the second symposum appeared in ThermoMed, the abstracts of all other symposia in Thermologie Österreich, European Journal of Thermology or Thermology international.

THE VALUE OF THERMAL IMAGING FOR THE DIAGNOSIS OF THORACIC OUTLET SYNDROME

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In 1993 Schartelmüller and Ammer (1) established a protocol for thermal imaging in patients suspected of Thoracic Outlet Syndrome (TOS). With some modification(2) this protocol is routinely used since 1994 for the thermographically assisted diagnosis of Thoracic Outlet Syndrome. Temperature measurements were also applied as outcome measure in a clinical trial on the effectiveness of exercise therapy in patients with thoracic outlet syndrome (3). Temperature readings from thermal images recorded from patients with thoracic outlet syndrome showed a high degree of inter- and intra-rater repeatability (4).

About 1000 subjects underwent routinely this investigation, since thermal imaging was included in the diagnostic pathway for TOS. A temperature difference of 0.5 or more degrees between index and little finger in at least two provocative arm positions is regarded to be diagnostic. However, the definition of regions of interest may be time consuming, especially in cases when the contrast between cold finger tips and the image background is low. An alternative method based on the mean temperature value of a line over the finger of interest obtained high degree of agreement with the estabilished way of analysis (5). However, the new method is less time consuming and more robust in images with low contrast between fingers and background**.**

The thermal images of 210 cases (156 females, 64 males) were quantitatively re-evaluated. In 115 image series did not show pathological findings and have been classified as normal (55 on the left hand side, 60 on the right hand side). Definite TOS affecting the little finger was detected in 49 left hands and 44 right hands, a definite cold index finger was observed in 6 hands (3 right and 3 left hand side) only. 102 image series showed temperature changes that indicated a probable TOS on the little finger (48 left hand, 54 right hand). A possible TOS (little finger) was seen in 80 hands (42 left hand, 38 right hand). The remaining cases were 9 times classified as probably TOS (index) and as possible TOS (index) in 15 other cases. There was no significant difference in age between the different classes of TOS, with the exception that patients with probable or definite cold index finger at the right hand side had a higher age as subjects without symptoms or with TOS symptoms at the little finger. At the right hand, males had also less definite and probable TOS symptoms at the little fingers than females.

Thermal imaging is the only method that provides pictorial information of functional changes caused by compression of the brachial plexus. It is a complementary diagnostic test and can be used as outcome measure in clinical trials with patients suffering from Thoracic Outlet Syndrome

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THERMOMETRY, RADIOMETRY AND THERMAL IMAGING FOR FEVER DETECTION IN CHILDREN

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Recent interest in fever detection for airport screening of passengers has shown the lack of data, outside conventional clinical thermometry. Increasing use is now being made of simple ear radiometers for routine clinical temperature measurement. These devices are known to have limitations, and the technique and the variability of the human auditory canal add to the uncertainty of results.

This study has been conducted at the Paediatric Department of a major Hospital in Poland. The aim of this study is to investigate the possibilities of thermal imaging of the face being used as a reliable indicator of fever in children. In the screening context, thermal imaging has many advantages over other methods, given the need for rapid and objective evidence to exclude a travelling passenger with a raised temperature from increasing the risk of spread of infectious disease (such as H5N1 or similar viruses). In earlier reports on the SARS outbreak temperatures over 38^{0}C were classified as febrile, and made to undergo a simple clinical examination and have temperatures confirmed by thermometry.

To date, 106 children aged from 3 months to 16 years have been tested in the clinical using a clinical thermometer in the axillary, under arm position, and thermal imaging of the anterior face. The ambient temperature has been maintained at 22 – 23^{0}C. The subjects were seated before the camera, and in front of a cloth screen. Thermal images were recorded, and regions of interest around the eyes and centre forehead were used. Mean and maximum temperatures from these regions of interest were determined.

RESULTS: In total, 96 of 106 subjects recorded temperatures in the normal range (defined as <37.5^{0}C) axillary, and had no direct disease or clinical problem affecting their temperature. Ten children had raised temperatures >37.5 with 3 being 38°C and over. Forehead temperatures were consistently lower in value than the inner canthi of the eyes.

AFEBRILE CHILDREN			FEBRILE
Anat.site, n=96	Mean temp °C	S D	Temp. Range n=10
Forehead	34.9	0.51	36.3 – 37.2
Inner Canthi	36.4	0.52	37.3 – 38.6
Axilla	35.9	0.81	37.5 – 39.0

A moderate correlation was found between the canthus eye temperatures and the forehead temperatures from the analysis of the frontal face thermograms. r=0.66

Thermal Imaging of the face in children is an efficient means of identifying the presence of fever. Potential artefacts caused by sinus infection, even prolonged crying in children, and may elevate the maximum temperatures recorded over the inner canthi of the eyes. However, the use of a carefully placed clinical thermometer (oral or axillary site) is sufficient to exclude the presence of clinical fever. Further data is being collected on healthy and febrile children. Thermal imaging for screening of travelling passengers may prove to be a suitable and rapid tool, with the inner canthi being the measurement site of choice

THE NET TEMPERATURE INCREASE IN THE CONTEXT OF ULTRASOUND-INDUCED HEAT.

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PURPOSE: Dosage is the energy supplied to the patient's tissue during a session. Ultrasound power is measured and expressed in watt (W) and the energy in watt-minutes (Wmin). The dosage can equally well be stated in Wmin/cm2. The main purpose of the application is to produce a specific temperature in the depth of the tissues. This study tried to show the connection between the energy output of ultrasound and the temperature inside the tissue.

RELEVANCE: The study relates the energy output of ultrasound with the temperature, in proportion to the depth, inside the tissue.

PARTICIPANTS: The study used a fresh pig cadaver hind leg, fixed by stainless steel nails to a wooden shelf. The camera was positioned at the end of the shelf to keep a distance of 40 cm to the tissue face. The tissue was equilibrated to 15°C in saline and recorded in a temperature-regulated environment.

METHODS: A ThermaCAM S65HS thermal imaging system of Flir Systems AB was used. Comparisons were made between the net temperature increases using 3MHz continuous ultrasound with 2W min/cm^2, 1W min/cm^2, 0.5W min/cm^2, 0.25W min/cm^2, 0.07Wmin/cm^2 and 0.05Wmin/cm^2 spatial average intensities, respectively. The treatment time was set at five minutes. All thermal images after five minutes were compared with the reference image, being the starting image without insonation.

ANALYSIS: During the actual computerized comparison, every temperature data point from the reference image is "subtracted" from the thermal image. In this way, it is possible to create patterns of relative heating. The temperature difference was measured for every millimeter on a perpendicular line based at the location of the center of the ultrasound applicator.

RESULTS: The study found a maximum temperature difference of 17°C with 2Wmin/cm2 at 0.5 cm depth and that the mean temperature at more then 1 cm in depth of the tissue was 1°C.

CONCLUSIONS: We found that ultrasound induced heat therapy only can insist if the intensity of ultrasound was set to 1Wmin/cm2 or more. It may be questioned whether ultrasound induced heat can bring about the desired temperature increases in the target tissue in order to achieve a beneficial thermal effect.

IMPLICATIONS: Using thermal outcome measurements in clinical trials with ultrasound therapy means that the intensity has to be set at 1Wmin/cm2 or higher with continuous ultrasound.

DYNAMIC THERMAL IMAGING AND ITS ROLE IN MEDICINE

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Infrared thermal imaging in medicine is based on analysis of skin surface temperatures as a reflection of normal or abnormal human physiology using specialized IR-cameras. In a fraction of a second, a large surface area of the human body can be imaged to an accuracy of less than 0.1°C. There are many situations where skin surface temperature can clearly be directly correlated to skin blood perfusion. This undisputable fact forms the basis for the use of thermal imaging in medicine. Asymmetric images may also provide valuable information, with diagnostic value. There are, however, situations where it is difficult to obtain adequate information on the dynamics of skin perfusion, for example from static thermal images. These difficulties can often be overcome with dynamic infrared thermal imaging. The technique of dynamic infrared thermal imaging is based on the relationship between dermal perfusion and the pattern and response of skin surface temperature following the application of a transient local thermal challenges. Rapid physiological changes can be readily registered with the new generation of infrared cameras. The information can be easily analysed using infrared cameras that employ, for example, fire-wire technology. This new development allows real time analysis of radiometric images. Having access to this technology provides an enormous advantage in the use of infrared thermal imaging. This is especially important since being able to measure rapidly changing skin temperatures opens up a whole new field of possibilities for this technique. Examples of the use of dynamic thermal imaging will be presented in both research and routine clinical situations.

THREE METHODS OF EVALUATION OF THERMAL IMAGES FROM PATIENTS WITH SUSPECTED RAYNAUD'S PHENOMENON

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Diagnosis of Raynaud´s phenomenon may be assisted by the results of temperature changes after immersion of hands in water of 20°C. However, a standard for evaluation of temperature changes is not yet established. Francis Ring has proposed a Thermal Index by combining the temperature gradients from the dorsum to the fingers prior and past the cold challenge. Others determined the gradient of single fingers or used the slope of the rewarming curve.

Three methods of evaluation of temperature readings from thermal images were compared in hands of 26 subjects after cold challenge. The cold stress test- tool of the software package C-Therm was used for the calculation of Ring's Thermal-Index. Alternatively areas over single fingers were defined and gradients of single fingers were calculated by substracting the mean temperature of the dorsum from the mean temperature of finger areas (FG1=finger gradient 1) Temperature gradients for single fingers were also determined in the following way: 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 tip (FG2=finger gradient 2). The mean value of the temperature gradients of all fingers of the right and the left hand were calculated.

The difference of both mean temperature gradients of fingers prior, 10 or 20 minutes past cold challenge were compared with the findings of the Thermal Index for the same periods.

Comparison of the thermal index 10 minutes and 20 minutes past cold challenge, obtained a mean decrease of the Thermal Index of 0.32 ± 1,0 at the later measurement. The absolute values of the mean FG1 were 0,93 to 1,28 greater than the related Thermal Index. The differences between FG2 and the thermal index were 0.1 to 1. However, analyzing all thermal indices with non parametric tests obtained no significant differences between the indices. Single measure interclass correlations revealed values between 0.74 and 0.82.

Using a threshold of –4.0 for a diagnostic thermal index, the highest number of cases with Raynaud's phenomenon were identified with TG2, followed by TG1 and the C-Therm derived Thermal Index

In conclusion, after cold challenge a high correlation was found between the Thermal Index determined by the dedicated tool of the software package C-Therm and an alternatively calculated Thermal Index based on the temperature gradient of single fingers. However, the Thermal Index derived from the temperature gradients of single fingers may by more sensitive for diagnosis than the Thermal Index generated by the C-Therm software package.

RAYNAUD'S PHENOMENON: COLD HANDS = WARM HEART, BUT WHAT ABOUT COLD NOSES?

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Infra-Red Imaging of the hands and wrists is the accepted gold standard test for confirming or excluding Raynaud's Phenomenon, and is one of the most widely performed investigations in medical thermology. It can help differentiate between primary Raynaud's Disease and Raynaud's Phenomenon associated with connective tissue disorders such as systemic lupus erythematosis (SLE), scleroderma, Sjogren's syndrome and rheumatoid arthritis etc.

A fresh approach to the investigation of Raynaud's Phenomenon will be described and discussed.

In addition to the standard thermal imaging of the hands & wrists, images of the face were obtained at baseline following temperature equilibration, & skin temperature of the nose & forehead compared subjectively & objectively in 55 Patients attending for thermological assessment of clinically suspected Raynaud's Phenomenon. It was found that:

- Patients with no evidence of Raynaud's Phenomenon usually have a normal nose temperature.
- There is a very strong association of symmetrical Raynaud's Phenomenon with a cold nose.
- There is a less strong association of asymmetrical Raynaud's Phenomenon with a cold nose.
- Comparison of nose & forehead temperature may be a useful adjunct to conventional assessment of Raynaud's phenomenon.

AN INFRARED THERMAL IMAGING AND LASER DOPPLER FLOWMETRIC INVESTIGATION OF SKIN THERMAL INERTIA IN THE FOREARM AND HANDS FOLLOWING A SHORT PERIOD OF VASCULAR STASIS

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Infrared thermal imaging examinations of patients suffering from cold extremities are well described. In many cases the starting point is warm extremities that are subjected to a cold thermal challenge. The thermal pattern and rate of recovery is then used for aiding the diagnosis. In many cases the patients arrive at the examination room with cold extremities and it may take some time to induce a vasodilatory state, often involving a variety of heating regimes, before the examination can commence. We wished to investigate the possibility of using reactive hyperemia as a test method for examining the circulatory status in patients with cold hands. In this pilot study seven healthy students of both sexes have so far been tested. The Regional Ethical Committee approved the experimental protocol.

During the experiments, which were carried out at room temperature, the normally clothed subjects sat in a comfortable stool while resting their hands (palm down) on a thin grid made of nylon netting placed 3 cm above an electric heating plate maintained at ca 39°C. Following a 15 minute control period to establish base line values a conventional blood pressure cuff, which was placed over the right upper arm, was inflated to 230 mmHg for a period of 3 minutes. The resulting changes in skin surface temperature of the lower arms and hands following cuff release (skin flushing) were continually recorded for a post-ischemic period of 5 minute by an infrared camera (Flir Therma CAM S65HS, Flir Systems, USA). In addition, skin perfusion was continually measured using 2 laser Doppler flow probes, one located dorsally near the centre of the right lower arm and the other located close to the dorsal tip of the 2nd right finger. In each subject the responses to the 3-minute ischemic period were tested 3 times. Preliminary results showed a good correlation between changes in fingertip temperature measured thermographically and changes in skin perfusion measured with the laser Doppler probe. However, on the underarm there were many situations when an increase in skin blood flow following the ischemic insult was evident from the laser Doppler measurements (reactive hyperemia) without a concomitant change in skin surface temperature. In one subject with cold hands it was not possible to induce a clear hyperaemic response indicating that our approach may have limited clinical value.

The results, furthermore, indicate that caution must be taken when using infrared thermal imaging to measure temperature changes associated with skin flushing in the proximal extremities

EXTRACTING OUTLINES OF HANDS FROM THERMAL IMAGES

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Extracting object outlines in thermal images is a difficult task because of the frequently "shapeless" nature of objects when their temperature is in parts close to that of the background. Although a human operator can in many cases produce a reasonable manual segmentation this can be difficult and very time consuming when complex objects such as hands are analysed. Hands are physiologically those parts of the body (together with the feet) where body heat loss is highest, which makes it likely that they assume the temperature of the environment and are thus difficult to identify in the infrared domain. From all parts of the body hands are most difficult to segment. As a correct outline is needed for studying certain diseases such as arthritis, neuro-musculoskeletal injuries or circulatory pathology, exact segmentation, however, is required.

It is the aim of this study to investigate which of the many edge detection algorithms known from literature produce the best performance in these images. In order to study the effect pixel noise can have on this process a homomorphic filter was used prior to edge detection. This filter is suitable as it allows pixel noise produced by the imaging system to be modelled as an additive term to the original image.

From our existing database of 35 volunteers thermal images of 5 hands with the lowest hand/background contrast were selected to test 10 different edge detection algorithms. Images were processed by an application scripted in Matlab software, both with and without prior noise filtering.

For the extracted edges both a visual (subjective) and a quantitative (objective) analysis were performed. Both assessment methods concluded that the best outlining results are achieved when using a probabilistic based (Canny and Shen-Castan) edge detector together with homomorphic noise filter pre-processing.

BREAST THERMAL IMAGING: THE CHALLENGE OF THE BI-RADS CLASSIFICATION

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There is widespread use of infrared thermography examination devices for medical purposes in several European countries, going back to the 1970s. Recent generations of infrared cameras, representing a significant part of these devices, are now able to measure temperatures with a suitable geometrical and thermal resolution and with sufficient stability and reproducibility.

All medical devices with measurement functions are class one devices according to the European Medical Devices Directive (MDD) and the national legislation (e.g. in Germany Medizinproduktegesetz). In addition, every user of medical equipment has to ensure that medical devices are CE certified (in Germany Medizinprodukte-Betreiberverordnung). Class one devices have to comply with this directive and legislation and therefore have to CE certified as a medical device. This is much more than just to have a CE sign fixed to any IR camera (which of course every IR camera has). A medically valid CE certification is characterized by a CE sign followed by the code of the national certifying body.

As long as there was no infrared examination device in Europe meeting these criteria, a lot of physicians and clinics used infrared technology for medical purposes, not bothered by legislation. But now the situation has changed: In August 2007 the first medical infrared examination systems have been fully CE certified according to the medical devices directive.

InfraMedic (Germany) presented its infrared examination equipment MammoVision™, ReguVision™ and FlexiVision two years ago at the Vienna Thermological Conference. These systems now are CE certified meeting the MDD criteria. Mammo-Vision™ is dedicated to breast examinations, but it does not compete, rather it complements traditional breast imaging methods. MammoVision has high specificity in detecting women with extremely low risk of bearing or actually developing breast cancer through measurements from the breast surface temperature. MammoVision uses a sophisticated area definition (patented grid), semi-automated evaluation and the BI-RADS analogue assessment system BIRAS (Breast InfraRed Assessment System) to calculate the extent of enhanced breast metabolism as an indicator for benign or malignant breast conditions, completed by a detailed breast vascularity rating.

Now that there is a CE certified medical infrared examination system available, physicians and clinics using not CE certified infrared equipment are in danger of conflicting with European and national legislation. They will have to demand that their infrared equipment supplier achieves medically valid CE certification for their systems. Equipment bought not too long ago could have to be taken back by suppliers failing to get medical CE certification.

THE FUTURE OF THERMOLOGY IN VETERINARY MEDICINE

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Infrared thermology has been used in veterinary medicine since the early 1960's. In early 1970's and 1980's significant scientific advances were made in both human and veterinary medicine. Lack of portable equipment limited its use in universities and teaching hospitals in veterinary medicine. Availability of advanced portable equipment in 1990's provided a valuable asset for advancement of thermology in the field practice of veterinary medicine. At the same time lack of acceptable standards for the use of equipment in medical practice created mistrust for the use of infrared imaging in veterinary medicine. To resolve this issue, would require the help of qualified medical and veterinary thermology scientists to institute following future practices for its use, are:

1. Standards for equipment to be used in medical and veterinary practice.

2. Training courses for veterinary professionals by qualified thermology scientists.

3. Guide lines for use of new equipments applicable in veterinary and medical practice.

4. Converting the old high quality thermology data, to be transported in the new usable format, so as not to duplicate the animal studies which have already been done.

5. Efficacy of its early detection of impending problem will allow veterinary and medical personal to enhance their diagnostic capabilities.

In conclusion, the future use of this technology will require qualified medical and veterinary professional to provide quality education and continuing education courses to bring recent advances in thermology in the field of practice.This may also require offering and teaching of continuing education courses to medical and veterinary professional personal.