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Verantwortlicher Schriftleiter:

DDr. Kurt Ammer

Ludwig Boltzmann Forschungsstelle
für Physikalische Diagnostik,
Hanuschkrankenhaus, Heinrich Collinstraße30
A-1140 Wien, Österreich,
Tel: (43 1) 914-97-01 Fax: (43 1) 914-92-64
e-mail: KAmmer1950@aol.com

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Determination of emissivity for building materials using infrared thermography

A. Moropoulou, N.P. Avdelidis, M. Koui, I. Tzevelekos

National Technical University of Athens, Department of Chemical Engineering,
Section of Materials Science and Engineering, Iroon Polytechniou 9, 15780 Zografou, Athens, Greece.

Summary

One of the most important problems that is directly related to infrared thermography is the determination of emissivity values. Little is known about the emissivity of building materials at certain temperatures in the two most commonly used thermal imaging windows. In the present work, the target emissivity of various building materials is determined, in the 3–5.4 μm and 8–12 μm regions of the infrared spectrum. The examined materials, due to their different texture and microstructure, present different emissivity values. Furthermore, the impact of temperature and wavelength on the emissivity values of the investigated materials is considered. The results obtained are compared with emissivity values found in literature.

Key Words: emissivity, building materials, infrared thermography

Bestimmung der Emissivität von Baustoffen mittels Infrarot-Thermographie

Die Bestimmung der Emissivität ist eines der bedeutendsten Probleme im Zusammenhang mit der Infrarot-Thermographie. In den beiden häufig verwendeten Frequenzbereichen der Thermographie ist über das Emissionsvermögen von Baustoffen bei bestimmten Temperaturen nur wenig bekannt. In dieser Arbeit wird über die Bestimmung der Emissivität unterschiedlicher Baustoffe in den Frequenzbereichen von 3–5.4 μm und 8–12 μm des Infrarot-Spektrums berichtet. Die untersuchten Materialen zeigten bedingt durch die differente Grob- und Feinstruktur ein unterschiedliches Emissionsvermögen. Darüber hinaus wird der Beitrag der Temperatur und der Wellenlänge zu den Emissionswerten der untersuchten Materialien dargestellt. Die gefundenen Ergebnisse werden mit den Emissivitätswerten aus der Literatur verglichen.

Schlüsselwörter: Emissivität, Baustoffe, Infrarot-Thermographie

Introduction

Extraction of temperatures or temperature differences with thermography is not possible without knowledge of the target emissivity. There is no infrared camera that can read temperature directly. All cameras interpret the infrared energy coming from the investigated material, which includes emitted, reflected and occasionally transmitted infrared energy (1). Nonetheless, even in a qualitative sense, correct emissivity values are necessary in order to conclusively interpret thermographs (2). Emissivity is an expression used to characterise the optical properties of materials in sense of the amount of energy emitted in comparison with an ideal black body (3). This paper attempts to measure the target emissivity, for a variety of building materials in the laboratory by the means of infrared thermography. The emissivity values are obtained under controlled temperatures, employing dual band infrared thermography (3-5.4 μm and 8-12 μm).

Methods & Materials

Batches of three samples from five basic categories of stones, four basic categories of plasters and two basic categories of marbles were examined in laboratory (Table 1), in order to measure their emissivity values at 0°C and 40°C. The samples were placed into an environmental chamber (Heraeus Votsch CTC-E) for 24 hours at 0°C and 40°C. A non-contact thermometer (Gann IR40) was used only for confirming that the samples were in a temperature equilibrium state in the chamber and not for determining unknown temperature values

Table 1 Samples examined in the laboratory

Sample	Description of the Samples	Porosity
GPSR1	Grey Porous Stone (biocalcarenite) from Rhodes – Type 1	19 %
GPSR2	Grey Porous Stone (biocalcarenite) from Rhodes – Type 2	22 %
YPSR	Yellow Porous Stone (biocalcarenite) from Rhodes	34 %
WPSRC	White Porous Stone (bioclastic limestone) from Crete	19 %
KS	Kapandritis Stone	7 %
P1	Plaster 1 – Grey colour	64 %
P2	Plaster 2 – Beige colour	27 %
P3	Plaster 3 – Whitish colour	35 %
P4	Plaster 4 – White colour	63 %
PM	Pentelic (white) Marble	3 %
KM	Kokkinaras (grey) Marble	1 %

of the samples. Then, the IR camera was adjusted in order to determine the emissivity values of the samples. The procedure followed, is in accordance with the ASTM standard E1933–97 (4). Short wave (Avio TVS-2300 MkII ST, 3-5.4μm), as well as long wave infrared thermography (Avio TVS-2000 MkII LW, 8-12μm) was used, for the recording of the thermographs of the tested materials. Finally, porosity values were determined by using a mercury intrusion porosi- meter (Fisons 2000).

Results & Discussion

The emissivity values at 0°C for the 3-5.4 μm wavelength are presented in table 2, whereas table 3, presents the emissivities obtained at 40°C for the same wavelength. Furthermore, the emissivity values for the wavelength 8-12 μm, at 0°C and 40°C are presented in tables 4 and 5 respectively. In addition, emissivities found in literature are offered in table 6. At this point, it is worth mentioning that very little work has been done on low temperature emittance measurements and thus no quantitative results can be found in literature.

The emissivity values of the samples all showed a wide variation, due to their different texture and microstructure. This implies that emissivity is dependent on the composition of the material(s) to be tested (5). Furthermore, temperature has also an effect on the emissivity of a material (6), whereas emissivity values are different for different wavelengths. This can be clearly seen on the results, where the obtained values present variations depending upon the temperature and the wavelength selected.

Conclusively, correction of emissivity is the way to obtain the correct temperature data of the investigated material(s) and so to properly

Table 2
Average emissivity values at 0°C for wavelength 3-5.4 μm

Sample	Average Emissivity Value
GPSR1	0.67
GPSR2	0.67
YPSR	0.69
WPSRC	0.62
KS	0.69
P1	0.65
P2	0.66
P3	0.65
P4	0.62
PM	0.71
KM	0.71

Table 3
Average emissivity values at 40°C for wavelength 3-5.4 μm

Sample	Average Emissivity Value
GPSR1	0.96
GPSR2	0.92
YPSR	0.73
WPSRC	0.49
KS	0.91
P1	0.58
P2	0.71
P3	0.77
P4	0.59
PM	0.92
KM	0.92

Table 4
Average emissivity values at 0°C for wavelength 8-12 μm

Sample	Average Emissivity Value
GPSR1	0.68
GPSR2	0.67
YPSR	0.69
WPSRC	0.74
KS	0.71
P1	0.73
P2	0.69
P3	0.72
P4	0.67
PM	0.72
KM	0.67

Table 5
Average emissivity values at 40°C for wavelength 8-12 μm

Sample	Average Emissivity Value
GPSR1	0.93
GPSR2	0.87
YPSR	0.81
WPSRC	0.74
KS	0.89
P1	0.63
P2	0.70
P3	0.72
P4	0.69
PM	0.86
KM	0.88

Table 6
Theoretical emissivity values obtained from literature

Material	T (°C)	Emissivity
Limestone	40	0.90 - 0.95
Stonework	40	0.93
L5 Plaster	0 to 100	0.91
Marble (grey)	40	0.93 – 0.95
Marble (white)	40	0.95

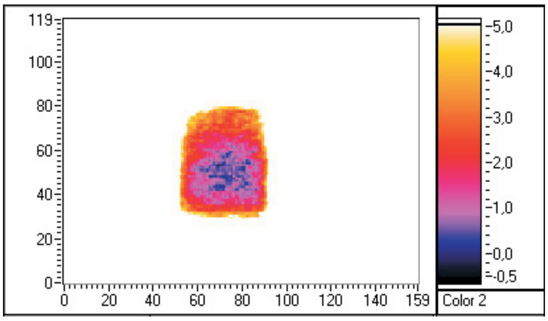

Figure 1
GPSR2 sample using the correct emissivity value

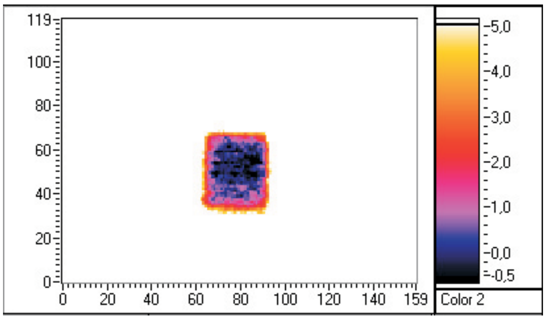

Figure 2
PM sample using the correct emissivity value

interpret the attained thermographs (7). Figures 1 and 2, present two examined materials using the correct emissivity values.

Conclusions

The most reliable method to obtain correct emissivity values for the infrared thermographic system and application is to determine the emissivity of the targets to be tested. Although this approach is not possible during in situ applications (8), samples of the targets can be collected and measured, as in this work, in the laboratory.

Emissivity depends upon aspects such as texture, microstructure, temperature and wavelength. Due to the fact that the investigation concerned with porous materials that have high percentages of narrow pores (9), it can be concluded that the moisture contents vary on different temperature levels. This can have an effect on the emissivity, directly i.e. the different moisture percentage absorbed from the material that changes the texture of the surface, and indirectly i.e. the colour alterations induced from th different moisture levels.

Furthermore, a comprehensive literature investigation indicated that little work has been published on emissivity values for building materials at various temperatures. For that reason, the effects of emissivity at a variety of temperatures should be further investigated, in order to provide a fully referenced emissivity values manual for the building thermographer.

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Address of the author

Prof. Antonia Moropoulou

National Technical University of Athens

Department of Chemical Engineering, Section of Materials Science and Engineering

9 Iroon Polytechniou St.; Zografou Campus,
15780 Athens: Greece

E-mail: amoropul@central.ntua.gr

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Can Numerical Simulation Adjunct to Thermography be an Early Detection Tool?

E.Y.K. Ng, N.M. Sudharsan

School of Mechanical and Production Engineering, Nanyang Technological University;
50 Nanyang Avenue, Singapore 639798

Summary

In this work numerical simulation is conducted on a female breast model to predict the temperature distribution from fundamental thermodynamic principles. It is hoped that surface temperature pattern obtained using thermography along with numerical simulations will provide a valuable idea to the clinician for the interpretation of the thermogram.

Key words: Thermography, Numerical Simulation, Surface Temperature, Breast Cancer

Kann ein numerisches Simulationsmodell gemeinsam mit der Thermographie als frühzeitiges Diagnosewerkzeug dienen ?

In dieser Arbeit wird basierend auf grundlegenden thermodynamischen Prinzipien ein numerisches Simulationsmodell der weiblichen Brust entwickelt, um die Temperaturverteilung voraus zu sagen. Es wird er Hoffnung Ausdruck gegeben, dass das thermographische Muster der Oberflächentemperatur gemeinsam mit der numerischen Simulation dem Kliniker ein wertvolles Hilfsmittel bei der Interpretation von Thermogrammen zur Verfügung stellt.

Schlüsselwörter: Thermographie, numerische Simulation, Oberflächentemperatur, Brustkrebs

Introduction

From the literature review (1 - 26) it is concluded that the use of thermography as detection tool is feasible more particularly as a: (a) risk marker; (b) adjunct tool with mammography; (c) continuous follow up of patients with false positive results as they are at a higher risk; (d) younger patients whose dense breasts yield poorer sensitivity to mammogram and finally (e) those who are afraid about the carcinogenic effects due to mammographic radiation and pain due to breast compression.

A literature review was also conducted on the possible use of a tissue heat transfer and numerical simulation. It was found that, Osman and Afify (27, 28) were the first to present a model to predict the temperature distribution in a female breast from fundamental thermodynamic principles, and the same had several drawbacks. They concluded that the surface temperature might not be related to an underlying tumour. They also observed a cold spot overlying a tumour point source in their model. Although the complex relation between a tumour and the surface temperature is acknowledged, it was seen experimentally by many investigators that a hot spot existed due to an underlying carcinoma. It is hoped that quantification of the surface temperature plots along with numerical models will provide a reasonable idea of the size and location of the tumour.

Methodology

Numerical Modelling

Pennes (29) first presented the human bio-heat transfer equation that described the heat transfer in a human tissue and included the effects of blood flow on tissue temperature on a continuum basis as follows:

$$k\nabla^2 T - c_b w_b (T - T_a) + q_m = 0 \quad (1)$$

where, k and q_m, represent the conductivity and volumetric metabolic rate of the tissue respectively, ($c_b w_b$) is the product of the specific heat capacity and the mass flow rate of blood per unit volume of tissue, T is the unknown local tissue temperature and T_a is the arterial temperature.

Pennes assumed that the thermal interaction took place in the capillary bed and the micro-vessels feeding it. The tissue was assumed to be in an imaginary pool of blood. The blood supplied to the capillaries is assumed to be at the core temperature of the body and the venous return temperature is assumed to be at the local tissue temperature.

Although the Pennes equation provides *reasonable agreement* between experimental and theoretical results by choosing the appropriate blood perfusion rates, however, several investigators have questioned the validity of the assumptions that: (a) the venous return temperature which is an unknown and is approximated to the local tissue temperature; (b) the arterial temperature which is assumed to be at core temperature; and, (c) the local thermal equilibrium occurred at capillary beds and small micro-vessels feeding these beds.

However, based on the authors' justifications presented in (30) the Pennes bioheat equation is used in the present work. The boundary conditions involved are $-k \nabla T = h(T - T_e)$ on the surface and $T = T_a$ in the core region (thoracic wall) where h is the combined effective heat transfer coefficient. However, as the subcutaneous region progresses throughout the body and as the simulation is done only for the breast, the subcutaneous region at the breast base is assumed to be adiabatic.

Osman and Afify (27) developed a numerical model of a female breast that was hemispherical in shape with uniform layer thickness. The model was discretized with tetrahedrons by cutting across the various layers and generating an equivalent conductivity for the elements. The tumour was assumed to be a point source. Although the breast may be assumed to be in hemispherical shape in supine position, the various tissue layers are not of uniform thickness. Moreover, discretization must be done in individual layers and maintain nodal connectivity. This would ensure that the relevant parameters for the tissues can be changed with ease and ensure better control during simulation. A two-dimensional model is developed based on the anatomy of breast presented in Romrell and Bland (31). Figure 1 presents the two-dimensional model. The three-dimensio- nal model is obtained by rotating the above 2D model. Further complexity is brought in by generating a more realistic breast model and is shown in Figure 2.

Table1
NOMENCLATURE

∇	Laplacian Operator		
c	Specific Heat Capacity	[J kg^{-1}. ^{o}C^{-1}]	
C	Constant	[W-day m^{-3}]	
D	Tumour Diameter	[m]	
h	Combined Overall Heat Transfer Coefficient (Convection, Radiation and Evaporation)	[W/m^{-2} ^{o}C^{-1}]	
k	Thermal Conductivity	[W m^{-1} ^{o}C^{-1}]	
q	Volumetric Heat Generation	[W m^{-3}]	
T	Temperature	[^{o}C]	
w	Blood Perfusion Rate	[kg m^{-3} s^{-1}]	
τ'	Time required for tumour to double ist volume	[days]	
θ	Non-dimensional Temperature		
Subscripts:			
a	Artery	e	Environment
b	Blood	m	Metabolic
s	Steady	τ	Transient

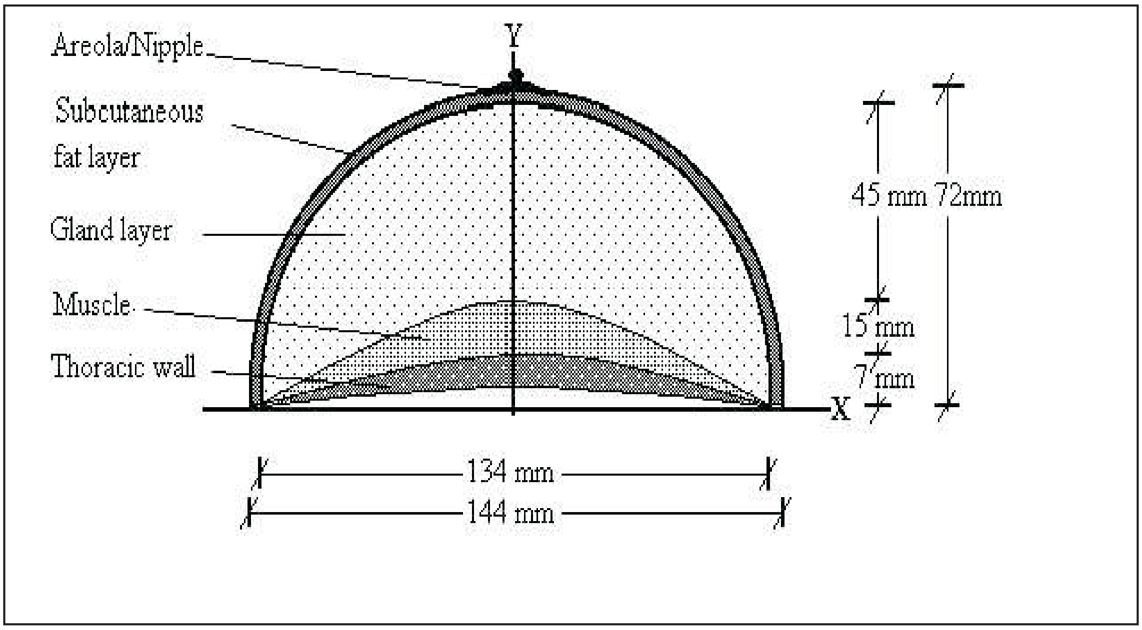

Figure 1: Cross-sectional View of Model of the Breast (Physical Domain)

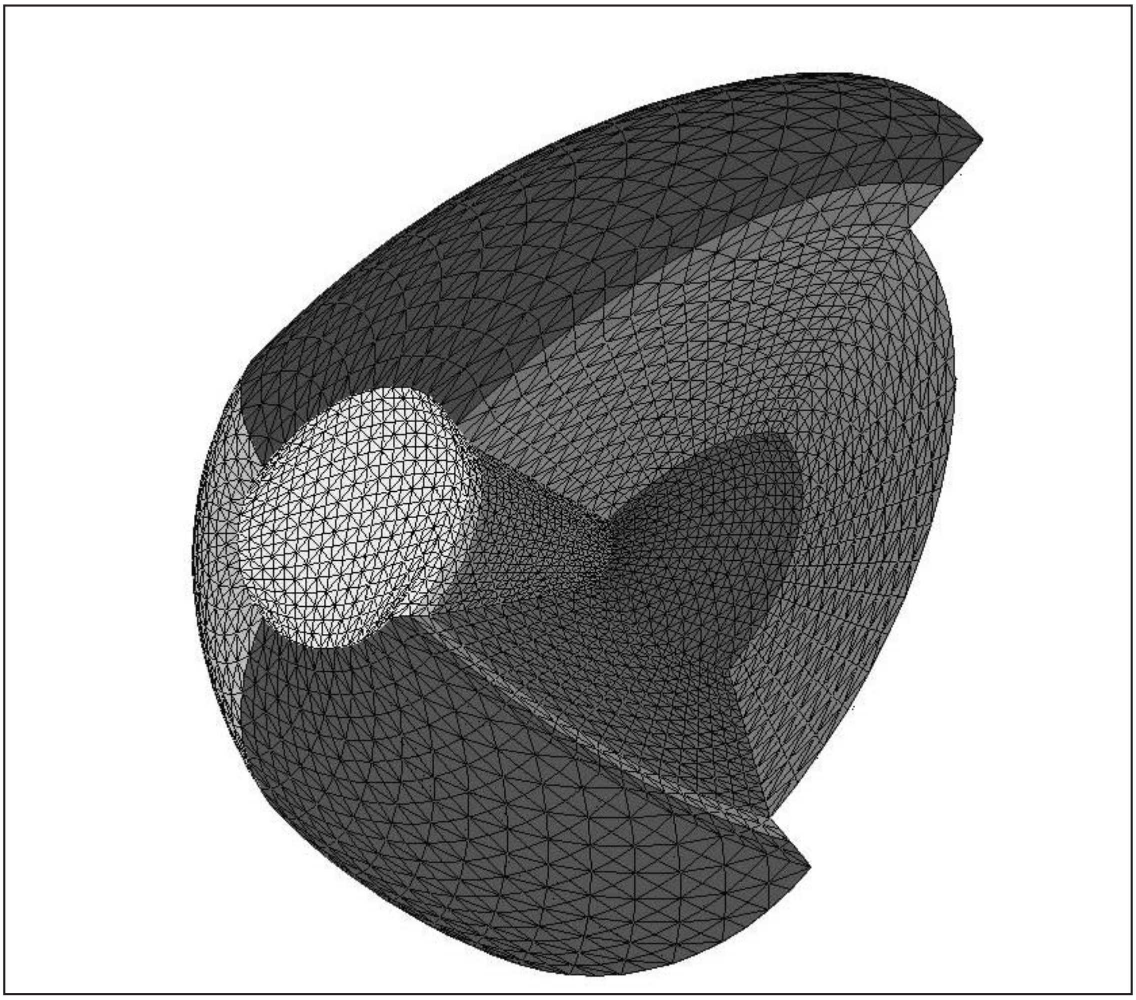

Figure 2: Four-quadrant Numerical Model of a Female Breast (A Quadrant cut-away to show inner Tissues)

Choice of Parameters

The values of thermal conductivity and metabolic rates for the various layers are taken from Werner and Buse (32) and are summarised in Table 1. It is to be noted that these values are for generic tissues. However the tumour blood flow and metabolic heat are obtained from in-vivo studies of Gautherie (15,33,34). The blood flow to tissues is given in terms of millilitres of blood per 100 grams of tissue per minute. 1 ml/100g tissue/minute is converted to 1kg of blood per unit volume of tissue (m^3) per second, using the density of blood and tissues (1060 & 1080 kg m^{-3}). This mass flow rate is multiplied by the specific heat capacity of blood (4200 J kg^{-1} $^oC^{-1}$) to yield 800 Wm^{-3} $^oC^{-1}$. From Gautherie et al. (34) the tumour doubling time and the metabolic rate are related by a hyperbolic function.

$$q_m \tau' = C \quad (\text{W-day m}^{-3}) \qquad (2)$$

C is a constant 3.27 x 106 W-day m^{-3} and τ' is the time required for the tumour to double its volume. The tumour diameter is related to τ' as follows:

$$D = \exp(0.002134*(\tau'-50)) \times 10^{-2}\,m \qquad (3)$$

Therefore a tumour of diameter 10mm will yield τ' =50 days from equation (3) and q_m of 65.4 x10^3 W m^{-3} from equation (3). Similarly for a 15mm tumour (average value taken from (35)), the tumour doubling time will be 240 days and a metabolic rate of 13.6 x10^3 W m^{-3}. In this paper the tumour size considered is 32mm. The appropriate tumour doubling time would then be 595 days and the metabolic rate would be 5.5 x 10^3 W m^{-3}.

The next important parameter is the choice of blood perfusion term. Gautherie (15, 34) conducted in-vivo studies on breast tumours and have estimated the mean effective thermal conductivity, which includes the enhancement in conductivity due to blood perfusion, as 0.511 Wm^{-1} $^oC^{-1}$. With an assumption that the thermal conductivity of the tumour tissue matches that of the glandular tissue at 0.48 W m^{-1} $^oC^{-1}$, the enhancement in conductivity is 0.03 W m^{-1} $^oC^{-1}$. From Priebe (36) it is seen that a variation in blood flow of 150 ml/100g/min equates to 0.05 W m^{-1} $^oC^{-1}$. Therefore in the present case it would yield a mean blood flow of 90 ml/100g /min. The work of Vaupel (37) was referred to and it was observed that the variability in tumour blood flow in a breast would be from 8 to 80 ml/100g/min. However, a blood flow rate of 60ml/100g/min is assumed in this investigation. Table 1 summarises the values for the various tissue regimes.

Numerical Solution

The model was generated using FEMAP (http://www.femap.com/) and the solution obtained using FASTFLO (http://www.cmis.csiro.au/index. html). After attaining a degree of proficiency in the use of necessary tools (FASTFLO and FEMAP) for selected test cases, the bio-heat equation is analysed for various parameters. It was numerically observed that the use of counter-current heat exchange between a major artery and vein over estimates the temperature profile as observed by Charny et al. (38). It was also seen that the blood perfusion source term caused the presence of wiggles in the simulation. The relation between the nodal distance and the blood perfusion source term was then

Table 2
Values of Blood Perfusion, Thermal Conductivity and Metabolic Heat Production (15, 32, 33, 34)

Layers	$(c_b w_b)$	k	q_m
	W m^{-3} $^oC^{-1}$	W m^{-3} $^oC^{-1}$	W m^{-3}
Areola	800	0.21	400
Lower-inner Subcutaneous	800	0.21	400
Lower-outer Subcutaneous	800	0.21	400
Upper-outer Subcutaneous	800	0.21	400
Upper-inner Subcutaneous	800	0.21	400
Lower-inner Gland	2400	0.48	700
Lower-outer Gland	2400	0.48	700
Upper-outer Gland	2400	0.48	700
Upper-inner Gland	2400	0.48	700
Gland Core (All 4 Volumes)	2400	0.48	700
Muscle Core	2400	0.48	700
Tumour (32mm)	48 x 10^3	0.48	5.5x10^3

established. The proper choice of the nodal distance based on the blood perfusion term yielded in a smooth contour. The numerical prediction was also compared with analytical solution for the purpose of validation and benchmarking of the scheme (39).

Analysis of the two-dimensional model showed that there existed a relation between tumour size and location with the surface temperature. Analysis also showed that tumours of different size at different location might yield the same surface temperature. The blood perfusion term also adds in to the complexity (30). In this simulation hot spot was shown instead of a cold region as seen by Osman and Afify (28). In order to optimise the parameters for the identification of tumour signal, a parametric optimisation is performed. The effects of the various parameters are analysed by performing an Analysis of Variance. Surprisingly it was observed that the tumour diameter and depth had a higher effect, whereas the effect of tumour metabolic rate and tumour perfusion are ranked at 10th and 14th position respectively, which are much below the combination of other factors. Next, the parameters are split as controllable and uncontrollable factors. The signal from the uncontrollable factor (tumour size and location) is maximised by using the Taguchi method. Analysis shows that the patient must be well rested and at basal metabolic activity (40). The importance of following strict protocol while conducting thermogram was also discussed by Cockburn (25). The numerical experiment compares well with his observation. Analysis of the two-dimensional model places an inherent limitation that the tumour must be placed exactly at the central axis and should also be hemispherical in shape. This is because the analysis exploits the axi-symmetric nature of the model. The breast is far from two-dimensional and requires analysis in three-dimensions as the tumour can be located anywhere and in certain cases the shape may be arbitrary instead of a sphere. A three-dimensional extension of the two-dimensional model is then performed (41). In this model the presence of numerical noise in the surface temperature distribution was attributed to the low value of the conductivity term that multiplies the second order derivative. This noise is eliminated by modifying the physical domain in the computational domain with mathematical manipulation of the bioheat equation. The predictions match the results obtained in the 2-D model. The tumour temperature predicted in this model is found to compare well with experimental results of Gautherie (33). Analysis of Variance shows that the tumour metabolic rate causes an increase in local temperature, and this effectively increases the venous return temperature (based on Pennes assumption that the venous return temperature is equal to the local tissue temperature). This heat is convected to the superficial region due to blood perfusion to superficial region. This prediction is again in good agreement with the experimental observations of Gautherie (19). The effect of arbitrary tumour shape on the surface temperature and the shift in its orientation is also analysed. The analysis proves that the enhanced perfusion to the superficial region would diffuse the tumour heat causing loss of tumour signature. This reiterates the need for patients to be at basal metabolic state (41).

It is now necessary to test the integrity of the numerical scheme by comparing with experimental results to see if the interpretation can be augmented with the help of numerical simulation. An actual model with four-quadrants is then developed (Figure 2). The model is simulated for various blood perfusion source terms. The flexibility of the model is further proved by simulation selected experimental results.

Experimental Procedure

A pilot study was conducted in the University to obtain field data using high-resolution digital infrared camera (AVIO Thermal Video System TVS-2000 MK II ST). Thirty-four volunteers (age profile between early thirties and late forties) presented themselves for screening under strict protocol and controlled environment.

Examination was done in a controlled air-conditioned room maintained at a temperature of 22^{o}C within a variation of 0.1^{o}C. The humidity was 60-70%. Direct drafts were avoided in the area where the patient was positioned. The screening was carried out during the most stable period of the day from 0900 hrs to 1130 hrs. The necessary consent was obtained from the volunteers, and was briefed of the harmless nature of the experiment to minimise any possible emotional stress. The volunteers were advised to avoid powder, ointments, perfume or any other wipes that may affect the conduction through the skin. The volunteers were given

15-20 minutes for acclimatisation and were provided loose gown that does not restrict the airflow for equilibration and does not constrict the skin surface.

Results and Discussion

Figure 3 presents the thermogram on the left side of a volunteer (38 years) with the corresponding numerical simulation. This volunteer undergoes regular screening and has a normal breast as certified by her doctor. Notice that she has a cold nipple region followed by a slightly warm lower-outer quadrant (arrow A) and a warm upper quadrant. The breast base near the thoracic wall is the warmest. It can be seen that the numerical model matches the actual with appropriate choice of perfusion term.

Figure 4 shows the surface temperature of another volunteer (47 years). This volunteer had been diagnosed with a benign lump in her left breast. She complained of pain and a lumpy feeling in her right breast. Interestingly, it can be observed that she has a relatively hot upper quadrant (arrow B). On the other hand, the relatively cool areola region (arrow A) and a hot upper breast have been simulated in the current numerical model. This was achieved by increasing the perfusion to that region. She is presently seeking the advice of the doctor.

Figure 5 presents the thermogram taken on a volunteer (age 43 years) who had a benign lump removed in 1997 from her right breast. The figure also shows the corresponding numerical simulation. It is interesting to note that this lady has a relatively cool region (arrow B) and a warm upper-outer quadrant (arrow C). Diagnosis could mistake this effect as an abnormality in the upper outer quadrant or probably a fluid collection in that region (arrow B). As it is known that the volunteer had undergone a lumpectomy, this region owing to a scar may be at a lower metabolic rate. This could be the reason that a cold spot is seen overlying that area. This analysis can be termed as 'analysis by elimination'. It is to be noted that the patient history puts to rest several misinterpretations in analysis. It can also be observed that the numerical simulation agrees well with the experimental results by lowering the metabolic rate and perfusion in that region. Although there exists several combinations of parameter to a particular pattern, it is shown that the simulation would help in 'analysis by elimination' where certain possibilities are eliminated.

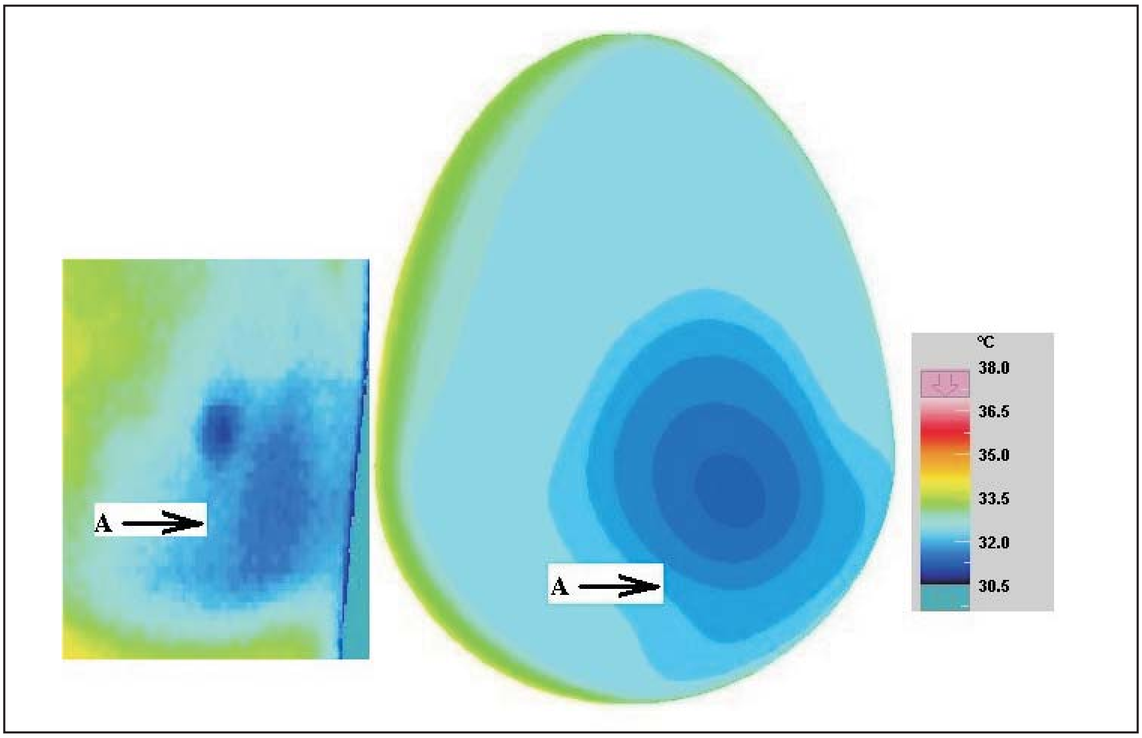

Figure 3:
Normal Thermogram of a Left Breast with Numerical Simulation (Volunteer 1, Age 38 years)

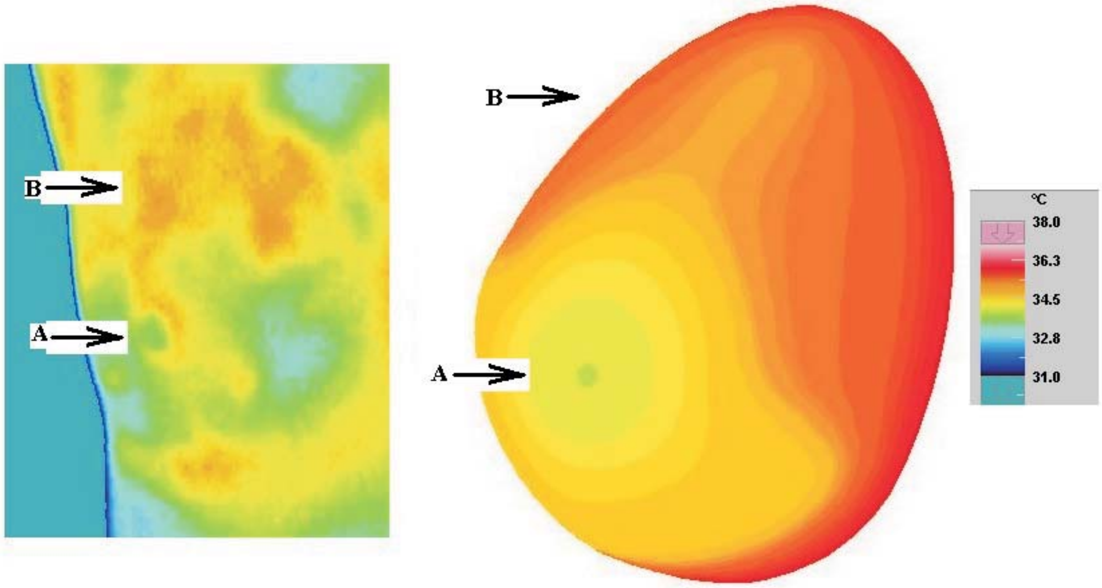

Figure 4:
Abnormal Thermogram of a Right Breast with Numerical Simulation (Volunteer 2, Age 47 years)

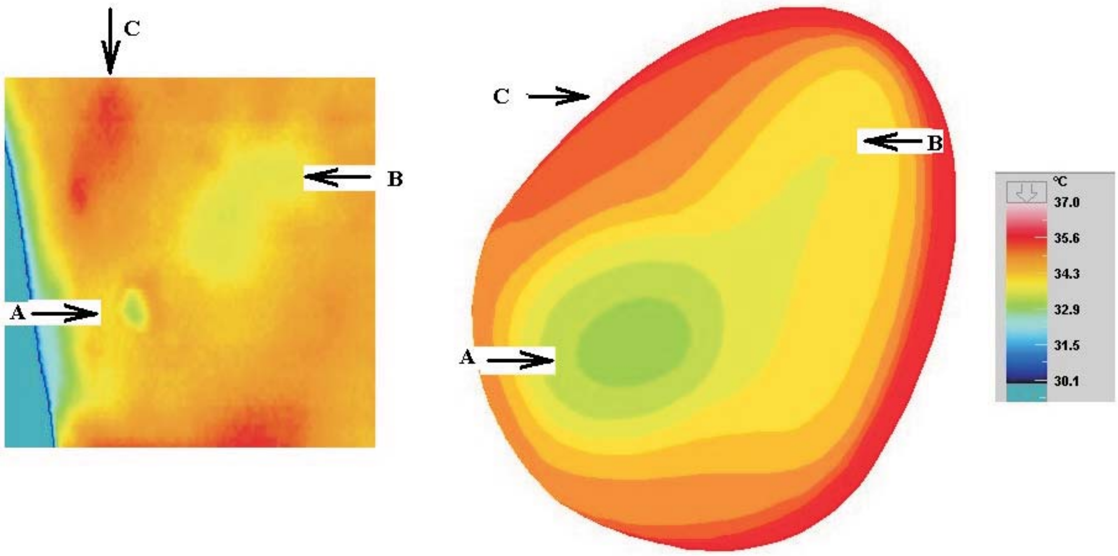

Figure 5:
Normal Thermogram of a Right Breast showing a cold area due to lumpectomy with Numerical Simulation (Age 43 years)

Concluding Remarks

The fact that has been shown by several investigators that the prognosis of patients with an abnormal thermogram is poor and that they might have faster growing tumours, is too important to be ignored. Thermograms can be successful only when a large amount of data can be collected to build up a database so as to enable the incorporation of intelligence. Numerical simulation can aid as an adjunct tool to complement the data obtained. In direct numerical simulation, patterns can be readily obtained (for steady state condition) by varying parameters with ease that would help the investigator to make qualitative assessment. However, it is also necessary to know the length of time the lump existed, the size and history of the lump, history of surgical intervention and/or other treatment, for example radiotherapy, as well as proper physical examination before a conclusion can be made based on the thermal imaging modality. But, it is to be acknowledged that it is far from being a stand-alone detection tool.

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Corresponding Author:

Assoc. Prof. E.Y.K. Ng
School of Mechanical and Production Engineering
Nanyang Technological University
50 Nanyang Avenue
Singapore 639798
E-mail: mykng@ntu.edu.sg
Fax: +65 – 791 1859

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Die thermographische Beurteilung der Hoden von Knaben nach Orchidopexie

J. Sypniewski*, K. Wojaczynska-Stanek, B. Broen***, K. Mandat***

*Klinische Abteilung der Kinderchirurgie in Chorzów , Schlesische Medizinischen Akademie in Katowice

** Klinik für Kinderneurologie der Schlesischen Medizinischen Akademie in Katowice

*** Abteilung der Kinderchirurgie des Zentrums für Pädiatrie und Rehabilitation in Chorzów

Zusammenfassung

In den Jahren 1996 – 1998 wurden in der Klinischen Abteilung der Kinderchirurgie in Chorzów der Schlesischen Medizinischen Akademie in Katowice 228 Jungen wegen Kryptorchismus operativ behandelt. Die Autoren haben aus dieser Gruppe 28 Jungen zufälligerweise ausgesucht. Die Jungen wurden mit der mit Thermokamera AGEMA 570 untersucht. Unsere Ergebnisse zeugen sowohl von der Richtigkeit der operativen Eingriffe bei Kryptorchismus als auch von der guten Brauchbarkeit der thermographischen Untersuchung bei der Einschätzung der Hoden nach Orchidopexie.

Schüsselwort: Kryptorchidismus, thermographische Einschätzung, Hoden

The thermographic evaluation of boys ´ testis after orchidopexy

In the years 1996 – 1998 228 boys suffering from undescended testicles were operated at the Silesian Academy of Medicine, Paediatric Surgery Clinic, in Chorzów. The authors have randomly chosen a group of 28 boys. They were examined by means of an infrared camera and the results have clearly demonstrated that the surgery was highly sucessful with an excellent outcome. The authors confirmed that thermal imaging is very useful for evaluation the testicular conditions after orchidopexy..

Keywords: undescendent testis, thermography, orchidopexy

Einleitung

Der Hodendeszensus endet beim Fötus grundsätzlich in den letzten Wochen des Embryonallebens, beim Neugeborenen sollen sich schon beide Hoden im Hodensack befinden.

Kryptorchismus ist die häufigste Fehlentwicklung des Urogenitalsystems bei Knaben. Er tritt bei 2-3% der ausgetragenen, bei 15-30% der frühgeborenen männlichen Kinder auf. Bei 15-30% tritt dieser Fehler beiderseits auf (1, 4, 5, 7, 10, 11, 12).

Die Ursachen der Unterbrechung des Hodendeszensus sind bis heute noch nicht völlig geklärt. Diese Störung kann durch die Fehlentwicklung des Leitbandes des Hodens verursacht werden. Eine hormonale Störung als Folge einer unzureichenden Produktion von gonadotropen Hormonen der mütterlichen Hirnanhangdrüse in den letzten Wochen der Schwangerschaft kann ein weiterer Grund für die fehlerhafte Hodenentwicklung sein. Die wahrscheinlichste Ursache des Kryptorchismus ist eine Störung der Produktion des Gonadoliberins im Hypothalamus. Dieses Hormon wirkt über die Hirnanhangdrüse auf die Entwicklung des Hodens und auf seine Senkung ein. Unzureichende Hormonkonzentrationen stören den Prozess des Hodendeszensus.

Die Behandlung des Kryptorchismus soll die samenbildende und hormonale Funktion des Hodens behalten und außerdem das Risiko einer bösartigen Neubildung verkleinern (3, 4, 11).

Die Untersuchung der fehlplatzierten Hoden im Elektronenmikroskop weist erst vor dem Ende des 2. Lebensjahres sekundäre Veränderungen im Hodenparenchym nach, sodass ein chirurgische Eingriff vor diesem Zeitpunkt die Fertilität erhalten kann. Der frühe operative Eingriff verkleinert auch das Risiko einer bösartigen Neubildung der nicht gesenkten Hoden (1, 4, 5, 6, 9, 12).

Der Zweck dieser Studie war die thermographische Beurteilung der Hoden nach einem chirurgischen Eingriff wegen Kryptorchismus.

Patienten und Methoden

In der Klinischen Abteilung für Kinderchirurgie in Chorzów der Schlesischen Medizinischen Akademie Katowice wurden in den Jahren 1996 – 1998 228 Knaben wegen Kryptorchismus operativ behandelt. Aus dieser Gruppe wurden 28 Jungen zufälligerweise ausgesucht. Zur Kontrollgruppe gehörten 20 gesunde Knaben im Alter von 2 bis 14 Jahre.

Tabelle 1
Symptome der operierten Kinder

Nummer	Initialen	Operierte Seite	Zeit nach der Operation
1	Z.K.	rechts	3 Jahre
2	C.D.	rechts	3 Jahre
3	W.M.	links	3Jahre
4	C.R.	links	3Jahre
5	0.p.	rechts	3 Jahre
6	B.M.	rechts	3 Jahre
7	M.R.	links	3 Jahre
8	M.M.	links	3 Jahre
9	S.T.	rechts	3 Jahre
10	S.R.	links	3 Jahre
11	G.A.	links	2 Jahre
12	K.l.	links	2 Jahre
13	K.T.	rechts	2 Jahre
14	S.P.	links	2 Jahre
15	K.K.	rechts	2 Jahre
16	0.A.	rechts	2 Jahre
17	W.P.	rechts	2 Jahre
18	W.K.	rechts	2 Jahre
19	K.T.	links	2 Jahre
20	B.S.	rechts	2 Jahre
21	P.I.	links	1 Jahr
22	P.D.	rechts	1 Jahr
23	M.R.	links	1 Jahr
24	B.D.	links	1 Jahr
25	D.A.	rechts	1 Jahr
26	C.D.	links	1 Jahr
27	0.R.	rechts	1 Jahr
28	K.S.	links	1 Jahr

Die Untersuchung der Hoden wurde an der Klinik für Kinderneurologie der Schlesischen Medizinischen Akademie in Katowice mit einer Thermokamera AGEMA 570 durchgeführt. 1 bis 3 Jahre nach dem operativen Eingriff wurde unter Standardbedingungen die Temperatur der Hoden festgestellt (2, 8, 13). Die Patienten waren vor der Hauptmahlzeit, absolvierten eine 20 Minuten lange Vorbereitung und eine 10 Minuten lange Anpassung an die Temperatur in den Untersuchungsräumen.

Die Temperaturwerte der gesunden und der operierten Kindern wurden mittels t-Test nach Student analysiert. Die Häufigkeit des Auftretens von warmen Arealen im operierten und im nicht operierten Hoden wurde mit Hilfe des exakten Fischer-Test durchgeführt. Als Null-Hypothese wurde angenommen, dass keine Wechselbeziehung zwischen der Häufigkeit des Auftretens der Temperaturerhöhung und dem operativen Eingriff besteht. Ein p-Wert <0,05 verneint die Null-Hypothese und beweist einen signifikanten Zusammenhang zwischen der opera tiven Therapie und den beobachteten Temperaturwerten.

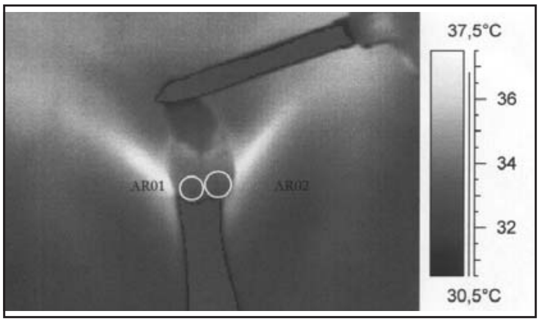

Abbildung. 1.
Hoden eines gesunden Jungen
Temperatur AR01-Mittelwert 33,3ºC,
Temperatur AR02-Mittelwert 33,3ºC

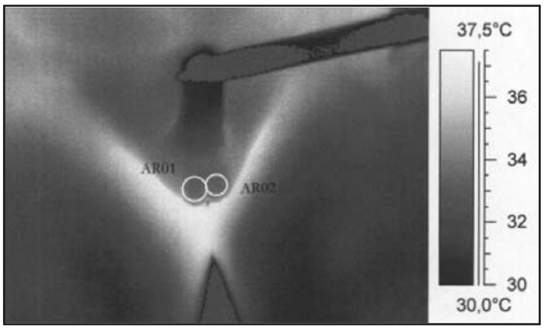

Abbildung. 2
Hoden eines gesunden Jungen
Temperatur AR01-Mittelwert 33,5ºC,
Temperatur AR02-Mittelwert 33,5ºC

Ergebnisse

Bei der thermographischen Untersuchung betrug die durchschnittliche Temperatur des Hodens nach Orchidopexie 32,8ºC, des gesunden Hodens 32,5ºC.

Wir haben erwartet, dass die Temperatur des linken Hodens im Bezug auf seine anatomische Lage niedriger sein wird als die des Rechten (da der linke Hoden im Regelfalle etwas tiefer im Hodensack liegt und damit weiter vom Körper entfernt ist); jedoch war sie für beide Hoden gleich, im Durchschnitt 32,5ºC.

Der durchschnittliche Temperaturunterschied betrug 0,18ºC, Standardabweichung 0,61ºC, kleinster Wert 1,0ºC, größter Wert 1,7ºC: Der t-Test nach Student wies keine signifikanten statistische Unterschiede auf.

Sehr wichtig ist, dass kein Hoden „kalt“ war. Dies würde eine Missfunktion des Hodens bedeuten. Das zeugt von der Wirksamkeit des operativen Eingriffen.

Diskussion

Die von uns durchgeführte Untersuchung hat Pilotcharakter. Dabei wurde versucht, eine Wertung der Thermographie als Beurteilungskriterium einer erfolgreichen Orchidopexie vorzunehmen. In weiterer Folge soll der postoperative Verlauf vom chirurgischen Eingriff bis zur Samenentwicklung untersucht werden.Wesentlich wäre auch der Vergleich der thermographischen Bilder mit den Ergebnissen der ultrasonographischen Untersuchungen und den Ergebnissen der Samenuntersuchung, um mit Gewissheit sagen zu können, dass das Fehlen hypothermischer Zonen in der Thermographie die Möglichkeit einer Dysfunktion des operierten Hodens ausschließt.

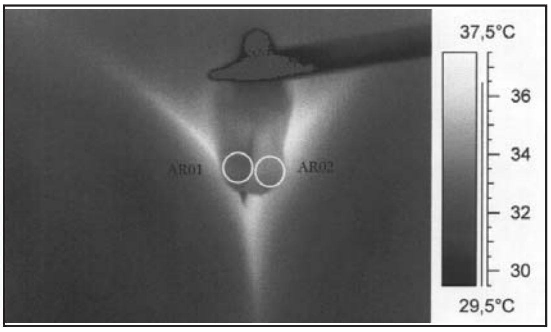

Abbildung 3.
Hoden eines Jungen 3 Jahre nach beiderseitiger Orchidopexie Temperatur AR01-Mittelwert 33,1ºC, Temperatur AR02-Mittelwert 33,9ºC

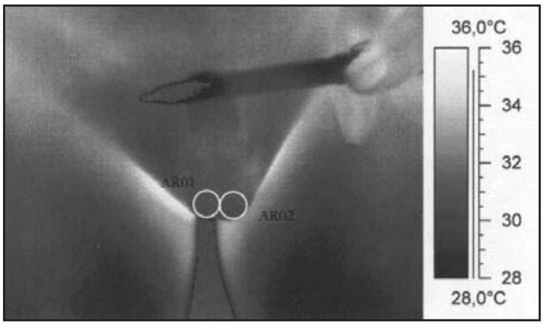

Abbildung 4
Hoden eines Jungen 1 Jahr nach rechtseitiger Orchidopexie Temperatur AR01-Mittelwert 30,8ºC, Temperatur AR02-Mittelwert 30,9ºC

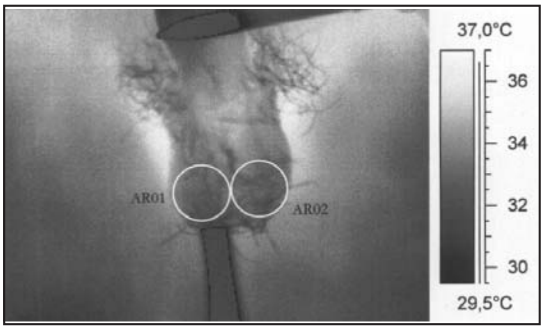

Abbildung 5
Hoden nach rechseitiger Orchidopexie Temperatur AR01-Mittelwert 33,0ºC, Temperatur AR02-Mittelwert 33,0ºC

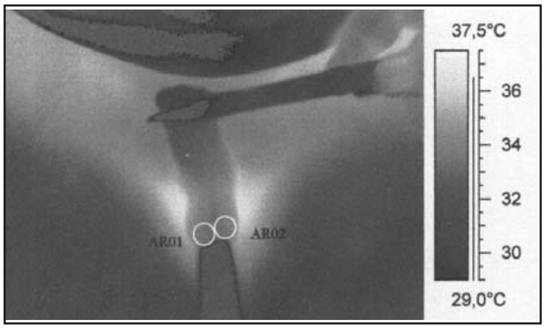

Abbildung 6
Hoden eines Jungen 3 Jahre nach beiderseitiger Orchidopexie Temperatur AR01-Mittelwert 33,6ºC, Temperatur AR02-Mittelwert 33,7ºC

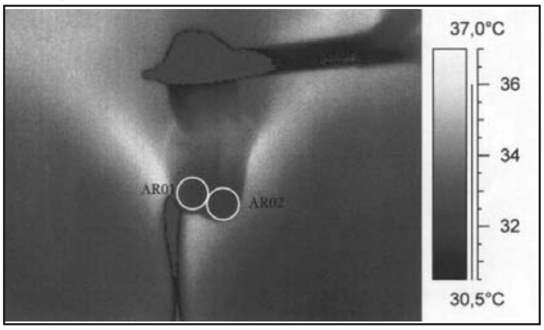

Abbildung 7
Hoden eines Jungen 2 Jahre nach linkseitiger Orchidopexie Temperatur AR01-Mittelwert 32,3ºC, Temperatur AR02-Mittelwert 32,2ºC

Fazit

Die thermographische Untersuchung kann zur Beurteilung Einschätzung des funktionellen Erfolges einer Orchidopexie eingesetzt werden.

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Kontaktaddresse des Autors:

Dr. Jacek Sypniewski

Kliniczny Oddzial Chirurgii Dzieciecj

ul. Truchana 7

PL-41-500 Chorzow

E-mail: barbrock@mp.pl

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8th European Congress of Thermology 3rd Congress of the Italian Association of Thermology, September 8-9, 2000

Palazzo Arzaga
Carzago di Calvagese della Riviera, Brescia (Italy)

Under the auspices of
Provincia di Brescia
Regione Lombardia

President

Dr. Giorgio Dalla Volta
Head of the Neurological Department
Istituto Clinico Città di Brescia
Via Gualla 15 – 25123 Brescia (Italy)
Phone: +39 030375 7777 Fax: +39 030 290474
e-mail: dalla@numerica.it

Scientific Secretariat

Cesare Bonezzi (Pavia, Italy)
Giorgio Dalla Volta (Brescia, Italy)

Organizing Secretariat

Essepi Studio srl
Via Costalunga 14
25123 Brescia (Italy)
Phone: +39 030 382336 – Fax: +39 030382653
E-mail: essepist@tin.it
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Thursday, September 7th, 2000

19.00 Welcome cocktail

Friday, September 8th, 2000

9.00-9.10 Opening of the Congress G. Dalla Volta - *Italy*

9.10-9.30 **Main lecture:**
The development of Infra-red thermography -F.J.Ring – *United Kingdom*

9.30-10.20 What's New in Thermology

Chairmen: F.J. Ring – United Kingdom, R. Berz - Germany

9.30-9.40 Radiothermometry as method for early diagnosis and control of effectiveness of treatment diseases. L. Pasmanik – *Russia*

9.40-9.50 Emerging Uncooled Infrared Technology N. Diakides - *U.S.A.*

9.50-10.00 New methods for mathematical analysis of medical IR-Images
I. Benkö – *Hungary*

10.00-10.10 Reguvision : Regulation thermography by thermal imaging
R. Berz – *Germany*

10.10-10.20 A searchable archive of thermal imaging for medicine papers on CD ROM
B. F. Jones – *United Kingdom*

10.20-10.50 Headache and Trigemino-Vascular System

Chairmen: G. Dalla Volta – Italy, S. Govindan – U.S.A.

10.20-10.35 Headache: a way to test the trigeminal nervous system
G. Dalla Volta - *Italy*

10.35-10.50 Monitoring cold patch in clinical practice: an update
S. Govindan - *U.S.A.*

10.50-11.15 COFFEE BREAK

11.15 –11.50 Physiology of Thermography

Chairmen: C. Bonezzi - Italy; S. Govindan – U.S.A.

11.15-11.30 Evaluation of rapidly changing thermal phenomena in the living body through image-processing of a high-speed far-infrared camera
K. Mabuchi – *Japan*

11.30-11.40 The efficacy of infrared thermography in human work and exercise physiology D. D. Pascoe – *U.S.A.*

11.40-11.50 Time recovery image: a diagnostic imaging technique based on dynamic digital infrared thermography A. Merla - *Italy*

11.50-12.35 PAIN SESSION

Chairmen: Young-Soo Kim – Korea, G. Dalla Volta - Italy

11.50-12.05 Thermographic findings of the spinal cord tumors
Young-Soo Kim - *Korea*

12.05-12.20 Trigeminal neuralgia G. Dalla Volta - I*taly*

12.20-12.35 Thermography in diagnosis and treatment of pain C. Bonezzi - *Italy*

13.00 LUNCH

14.30-15.45 Osteo-Articular Session

Chairmen: K. Ammer - Austria, F.J. Ring – United Kingdom

14.30-14.45 Cold fingers induced by keyboard operation K. Ammer - *Austri*a

14.45-14.55 Diagnostis of lumbar osteochondrosis at different stages of disease
S. N. Kolesov - *Russia*

14.55-15.05 The application of thermography to patients with various spinal disorders
A. Prastowski – *Poland*

15.05-15.15 The thermal image of the spine in children and adolescents
A. Prastowski – *Poland*

15.15 -15.25 Clinical application of thermography in osteoarthritis of the hip
R. Kanie – *Japan*

15.25-15.35 The thermal footprint – a pilot study T. Maca – *Austria*

15.35-15.45 The determination of normal temperature values of finger joints
K. Ammer – *Austria*

15.45-16.00 Temporal Mandibular Syndrome

Chairman: S. Govindan - U.S.A.

15.45-16.00 Thermography and orofacial pain: a new diagnostic tool
S. Ciatti – *Italy*

16.00-16.10 Thermal Studies in Sleep

Chairman: S. Ciatti - Italy

16.00-16.10 Microcirculation imaging in sleep disorders S. Govindan – *U.S.A*.

16.10-16.30 COFFEE BREAK

16.30-17.35 Thermographic Detection of Modifications Induced by Treatment

Chairmen: G. Orlandini - Italy, Young-Soo Kim - Korea

16.30-16.45 Thermographic changes caused by surgical interventions for pain
G. Orlandini – *Italy*

16.45-16.55 Thermography and sympathetic skin response to assess the effects of sympathectomy: a case report R. Bettaglio - *Italy*

16.55-17.05 Clinical application of D.I.T. Imaging as predictive factor for successful outcome of chymopapain chemonucleolysis in lumbar disk herniation Young-Soo Kim – *Korea*

17.05-17.15 Radiothermometry in patients treated for lumbar hernia S. Kolesov – *Russia*

17.15-17.25 Thermographic detection of the effects of "Oxybral SR" in parachutists G. Rodan – *Romania*

17.25-17.35 Thermodiagnostics in acupuncture A.M. Ovechkin – *Russia*

17.35-18.05 Dermatological Session

Chairmen: A. Di Carlo - Italy; K. Ammer - Austria

17.35-17.55 The diagnostic value of thermography in dermatology A. Di Carlo - *Italy*

17.55-18.05 Infrared thermography for the assessment of localized scleroderma in children K.J. Howell – *United Kingdom*

18.05-18.15 Breast Cancer

Chairmen: M. Anbar – U.S.A.; K. Ammer - Austria

18.05-18.15 Effect of cancer on the dynamics of autonomically controlled cutaneous microcirculation M. Anbar – *U.S.A.*

Saturday, September 9th, 2000

9.30-10.40 Vascular Session

Chairmen: A. Di Carlo - Italy, A. Jung - Poland

9.30-9.45 The value of telethermography in the study of vasculopathies A. Di Carlo – *Italy*

9.45-10.00 Thermography in monitoring peripheral vascular diseases A. Jung – *Poland*

10.00-10.10 Role of thermography in diagnosing lower limb venous incompetence S. Ciatti – *Italy*

10.10-10.20 Thermal imaging in screening diagnosis of crural varices in adolescents A. Jung – *Poland*

10.20-10.30 Dynamic digital telethermography: a novel approach to the diagnosis of varicocele A. Merla – *Italy*

10.30-10.40 Infrared image in HNP patients associated with obstruction of femoropopliteal artery Ho-Yeong Kang– *Korea*

10.40-11.25 Forensic Medicine

Chairmen: D. Camaioni - Italy, G. Pari - Italy

10.40-10.55 Evaluation of chronic pain in legal medicine and medical insurance
G. Pari – *Italy*

10.55-11.10 The significance and validity of objective tests in legal medicine and medical insurance D. Camaioni – *Italy*

11.10-11.25 Medico-legal applications of thermography: three clinical cases
G. Miranda – Gran Canaria, *Spain*

11.25-11.45 COFFEE BREAK

11.45-12.00 Veterinarian Application

Chairman: G. Dalla Volta - Italy

11.45-12.00 Thermography in the diagnosis of neuro-vascular diseases in the various animal species R.C. Purohit – *U.S.A.*

12.00-12.25 Surgery Applications

Chairmen: I. Fujimasa - Japan, F.J. Ring – United Kingdom

12.00-12.15 Clinical trials of thermal coronary angiography system
I. Fujimasa - *Japan*

12.15-12.25 Heat loss by abdominal cavity exposure in rats
M.L. Brioschi – *Brazil*

12.30 Closing Ceremony

13.00 LUNCH

Secretariat desk

The secretariat desk will operate in the congress area according to the following timetable:

Thursday, September 7h. 18.00 – 19.00

Friday, September 8h. 8.00 – 18.30

Saturday, September 9h. 8.00 – 18.30

Language

The working language of the Congress is English. No simultaneous translation will be provided.

Coffee breaks and lunches

Coffee breaks and lunches will be served in the congress area and will be offered to all registered participants. Tickets will be included in the congress folder.

The Organizers are grateful to the following companies for supporting the organization of the Congress

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Abstracts

Development of Infra Red Thermography

EFJ Ring

Royal National Hospital for Rheumatic Diseases, Bath &
University of Glamorgan, Pontypridd UK

The story of infra red imaging began 200 years ago when William Herschel in England discovered heating rays beyond the visible red of the spectrum in 1800. Forty years later his son John made a thermal image from solar radiation and called the result a thermogram. The technique became usable during the 1940's and released from military research in 1959. In the early 1960's several infra red imaging systems were built in Europe and the USA for medical research. The main application for the early systems was in the diagnosis of breast cancer. They used a single element detector, made from indium antimonide, and the scene was mechanically scanned to create a two dimensional image. Large and slow, these camera systems were often difficult to use, had limited spatial and thermal resolution, and thermograms were difficult to quantify.

Subsequent developments brought new IR detectors with improved performance, and increased speed of mechanical scanning. Cadmium mercury telluride detectors were introduced with a broader spectral sensitivity. This led to the first high speed and high resolution scanner using a SPRITE strip detector, and dramatic improvements in image quality from the multi-element detectors. Today, a new generation of focal plane array detectors of different materials, provide even higher resolution than previously obtained, with growing prospects for applications, and reducing costs.

In medicine, the emphasis slowly moved away from breast cancer studies, with the advent of mammography and ultrasound imaging. Dermatology, peripheral vascular diseases, and rheumatology continued to have centres in different parts of the world, with clinically useful work, especially for quantitative monitoring of treatment. Interest in the thermal effects of neurological disorders on skin temperature patterns, and the subsequent establishment of normal ranges for thermal symmetry in skin temperature, widened the applications. Increased temperature and decreased temperatures have slowly become part of the clinical reason for using the technique.

The computer, and image processing, has considerably advanced electronic imaging systems. Increased education in thermal physiology is still required in medical training. Dynamic stress tests for thermal imaging techniques are still under development. The oldest of these is probably the cold stress test to the hands which has been developed in different forms since the 1970's. Chemical and mechanical tests are also used in to induce a response in skin temperature recorded by infra red imaging. Networking of digital imaging in medicine is now developing, thermal imaging is ready for inclusion in multi modal patient database records.

Radiothermometry as Method for Early Diagnosis and Control for Effectiveness of Treatment the Diseases

S.Kolesov, L.Pasmanik, Yu.Tkachenko,
A.Troitsky, I.Ulianichev

23/1 Gagarin Ave., Nizhni Novgorod 603022, Russia;
E-Mail : newned@unn.runnet.ru

The course of many diseases of the internal organs is manifestated by changes of their temperature due to disorders of circulatory and metabolic processes. Often, local temperature abnormality is one of the first reactions of the living body to disease, when nother manifestations are absent or minimal. For this reason the methods, based on detection of the normal skin surface temperature are very important for the early diagnosis of some diseases.

In some cases the information can be detected by measuring temperature in the infrared band. The infrared camera receives the thermal picture of the skin layer of 0,1 mm depth and can detect the pathological processes in the superficial tissues. This may also apply in internal organs when there are connections between skin and the organs, which carry the information from affected organ to autonomic innervated areas or corresponding biologically active points.

In the middle 70s Russia began constructing the equipment and methods to detect the deep temperature – radiothermometry. Radio- thermometry diagnostics, similar to thermal imaging, is based on the measurement of the the spectral density of the power of electromagnetic emission of heated body, but in the ultrahigh frequency band. This method has a reduced spatial resolution of the thermal picture but can receive the information from the depth up to 150 mm.

The present report describes the physical basis of radiothermometry, the relationship of the measured spectral density of the emission's power with distribution of deep temperatures inside the biological tissues. The description of the RT-17 radio- thermometer is presented, which is in mass production in Russia and is certified for medical radiothermometrical diagnosis. Some results of application of the radiothermometry diagnosis in oncology, traumatology, neurosurgery and neurology, burns, ophthalmology, gastroenterology, angiology and cardiology are reported.

Emerging Uncooled Infrared Technology

Nicholas A. Diakides; Raymond Balcerak *

Advanced Concepts Analysis, Inc. Falls Church, VA , USA

*Defense Advanced Research Projects Agency Arlington, VA ,USA

A revolution is underway in infrared imaging technology. Many of the legacy systems, which incorporate cryogenically cooled linear arrays, mechanically scanned across the scene to form an image, can now be replaced by two dimensional detector arrays that do not require cryogenic cooling. This fundamental change in the design and operation of the imaging system has dramatically expanded the market and brought high quality thermal imaging within the grasp of the average consumer. Two noteworthy changes in system design form the underpinning of this new technology, providing the user with both improved performance and lower cost. These are the two-dimensional array or staring infrared technology, and the detector that operates without need for cryogenic cooling. The transition from scanning to staring infrared imaging initiates a major technology shift, with substantial impact on improved image quality, system simplicity, and cost reduction. The elimination of the cryogenics significantly reduces power and system cost.

These factors lead to new applications, in both the commercial and military markets, with medical imaging being only one of the potential new applications. The improvements in image quality and cost reduction offered by the staring uncooled infrared technology have the potential to provide the physician a diagnostic aid, readily available at reasonable cost. This paper reviews the critical steps in development of this novel infrared imaging technology, and focuses on the status of the uncooled infrared cameras.

New methods for mathematical analysis of medical IR-images

I. Benko[1], G.J. Köteles[2], G. Németh [3]

1Technical University of Budapest, Department of Energy, H-1521 Budapest, Hungary;

2"Frédéric Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene, H-1775 Budapest, POB.101.,Hungary;

3"Haynal Imre" University of Health Sciences, Dept. of Radiotherapy, H-1389 Budapest, POB.112, Hungary.

The application (advantages and limitations) of IR-images and their diagnostic and documentation value are determined in medical practice by the following main features:

1.the type of the clinical phenomenon investigated,

2.consideration of rules of IR-optics during the IR-image-taking,

3.proper selection of ambient parameters.

Having those optimal conditions mentioned above, the IR-image will contain important information on thermal character of the skin surface temperature concomitant to the illness. As a consequence, the evaluation of IR-images, the thermal physical characteristics and interpretation will contribute to the diagnostic value of IR-images.

The present paper is dealing with two mathematical methods of evaluation:

the application of the distribution curve of temperature histogram for process monitoring,

the mathematical filtering of IR-images to reveal the sites of highest temperature or of the largest temperature alterations.

Lacking reliable dosimetry, the physician considers the nature and severity of signs and symptoms, the protracted expression of the injury, and the timing and differential expression of injury in various tissues when deciding treatment options and prognosis.

In summary, the thermographic measurements have proved to be useful tools in diagnostic and prognostic senses of the medical handling of local radiation injuries in a rather wide dose-range. We have found a definitive, non-invasive method to determine the extent and magnitude of a local or partial body radiation injury.

In addition, numerous techniques can be utilized to evaluate circulation in an affected area and to try to determine the volume, depth, and area of tissue affected. Angiography, radionuclide imaging, and non-invasive techniques such as impedance plethysmography, magnetic resonance imaging, ultrasound. Techniques capable of evaluating superficial blood flow and tissue perfusion have clinical value for the physician who must counsel the patient and make critical decisions regarding medical or surgical treatment.

REGUVISION -Regulation Thermography by Thermal Imaging

Reinhold Berz.

D-89077 Ulm

Regulation Thermography (RTG) and IR- Thermography by remote sensing camera systems have a long history in medicine. They are characterised by different approaches to the patient and to the diagnostic procedure.

The contact-free method of thermography by IR-cameras, which may be known under Agema's trade name "thermovision", frequently has been and is still used in rheumatology, neurology, orthopaedic and venous diseases, senology etc. Usually the measuring process starts after the patient's acclimatisation in a room of about 21°C. Dynamic registration is rarely found .

In contrast, Regulation Thermography mostly uses contact measuring systems such as thermistors or thermocouples, sometimes IR-bolometers. The main characteristic of this technique is the dynamic aspect: After the recording "comfort heat" skin temperature distribution directly following unclothing, the patient is exposed to a gentle cold stress (environmental temperature of about 21°C) for 10 to 15 minutes. Then the next registration of the "regulated heat" follows. Sometimes, e.g. after injection of vascular actives substances, a third registration occurs. So the thermal pattern before and after the cold stress, and the delta-t, the difference between the first and the following recorsings in each measured area is very important.

ReguVision™ combines the advantages of the two methods. The accuracy of modern FPA-IR cameras with their 2-dimensional picture of the thermal pattern is used for a more exact and reliable measuring process in Regulation Thermography.

As a very sensitive, but non specific method the use of ReguVision™ is focussed on deviations of the thermal and regulatory patterns. Normal results stand for healthy systems. Irregularities can be seen as a sign for developing pathological processes. So ReguVision™ is an ideal method for detecting early deviations of the status of health as well as controlling therapeutic interventions.

A Searchable Archive of Thermal Imaging for Medicine Papers on CD-ROM.

B F Jones, E F J Ring

School of Computing, University of Glamorgan, Pontypridd, CF37 1DL, UK. (e-mail : bfjones@glam.ac.uk)

Infrared thermal imaging has been applied to medical research since 1960 in several research centres in Europe, the USA and Japan. Its great attraction is that the process is non-invasive since it captures an image of the natural black-body radiation from the patient. Considerable work was undertaken into the study of a number of diseases such as rheumatoid arthritis where joints may be inflamed and peripheral vascular disease where an increased density of blood vessels may cause hot spots on the skin surface.

During this period, several important basic principles of thermal imaging were established, such as the thermal symmetry inherent in a healthy subject. The volume and quality of this work was such that two peer reviewed Journals were established. The European Association of Thermology was formed in 1972, and the first Journal dedicated to the subject, ACTA THERMOGRAPHICA, was published in Italy by an Editorial Board chaired by Prof. Pistolesi. Some years later, the Journal was discontinued and the American Academy of Thermology published a larger format and glossy Journal of Thermologv together with the International Bibliography of Thermology. Both were dedicated to human body temperature and thermal imaging. This Journal was also discontinued some years later.

Neither Journal is readily available in libraries, and the wealth of reference material is in danger of being lost. The US National Technology Transfer Center and the BMDO agreed to fund the production of a CD ROM to disseminate this material to researchers in medical thermal imaging. The information is also available via the World Wide Web pages at Glamorgan, though the speed of access is slow. It is important to avoid 're-inventing the wheel' during the resurgence of interest in medical thermal imaging prompted by the availability of the advanced infrared cameras that have been developed by the US military over the last twenty years.

Prof. G F Pistolesi of the Istituto di Radiologia. University Degli Studi di Verona, Italy, has given permission for the papers in ACTA THERMOGRAPHICA to be made available on CD ROM and we acknowledge their original source. Likewise, the President of the Academy, Sheng Tchou, MD, reported that the Executive Council of the American Academy of Thermology unanimously gave permission for the inclusion of papers horn the Journal of Thermology in the CD ROM. We give full credit of ownership to the Academy.

The papers on the CD ROM are held in portable document format (PDF) so that the papers can be searched for keywords; the appropriate Adobe Acrobat Reader software is included on the CD. The colour images are held in GIF format. The CD ROM is being produced in small quantities to order and is available from the authors at cost.

Headache: A Way To Test The Trigeminal Nervous System

Giorgio Dalla Volta

Neurological Department of the Istituto Clinico Città di Brescia; Brescia .Italy

For many years infra red thermography has been used in the clinical practice to help in the problem of differential diagnosis of various types of headache.

This safe diagnostic tool can differentiate migraine headache where there is an asymmetrical thermal pattern in the fore- head of the patient, from other forms, such as tension headache, where the thermal pattern is symmetrical.

The cutaneous area where attention is focussed during the examination is the forehead where the two vascular systems, the flow coming from the internal carotid artery through the ophtalmic artery and the external carotid artery through the superficial temporal branch, join together through the arterio-venous shunts and the meta-arterioles .

We know that the regulation of this system is under the control of the autonomic nervous system comprising,both the vasocostrictive sympathetic system coming from the superior cervical ganglia and the vasodilative parasympathetic system. This comes from the superior salivatory nucleus through the vidian nerve and spreads itself through the sphenopalatin ganglia in the three trigeminal branches.

In some cases , as in migraine, the trigeminal nerve can interact with the vasomotor tone regulation releasing antidromically some vasodilatatory substance such as the CGRP (calcitonin gene related peptide) VIP (vasoactive intestinal peptide), substance P, NO (nitric oxide) that are able to change the way to conduct the pain sensation to the cortex, to modify the vessel tone of the cutaneous microcirculation and to change the permeability of the vessels walls provoking the neurogenic sterile inflammation which is the end of the pathogenetic process of the migraine .

This is the so called Trigemino-vascular system that does not follow the distribution of cutaneius sensory innervation along the trigeminal branches , but is mainly carried through the ophtalmic and to a lesser extent through the second branch.

All these systems (the sympathetic , parasympathetic and the trigemino vascular one) have a co-ordinated action on the control of the microcirculation in the facial region.

When, after therapy, we repeat the thermography examination on the patient we are able to detect the modifications occurred to the cutaneous micro-circulation and the new balance of all these forces modified by the efficacy of therapeutical drug intervention..

If the patient has a resolution of the migraine, we will be able to detect the disappearance of the asymmetry of the thermal pattern in the forehead and we can consider it as a prognosticr factor.

We can also test the efficacy of any pharmaceutical product used for the release of headache by detecting the modification of the thermal pattern of the forehead of the patient e.g. after the use of a subcutaneous injection of Sumatriptan in a migranious patient.

We dynamically test these systems after the application to a migranious patient of a cold or warm stimulation , after forced breathing (hyperpnea) , a prolunged oxygen or CO2 breathing , after a shock or a painful stimulation to the body, to try to understand the different way that migraine reacts from a healthy system.

Monitoring Cold Patch In Clinical Practice - An Update

Srini Govindan, M.D.

American Academy of Thermology, 40 Medical Park, Suite 304, Wheeling, WV 26003

Relationship of Thermal asymmetry to cranial perfusion was recognized by Wood (1). The cold patch representing a fixed vascular state was reported by Lance (2). Dr. Swerdlow and Dr. Dalla Volta (3,4) have focused on its relevance to migraine diagnosis, management and clinical course. Cold patch indicates vasomotor instability (5) in the area under the regional control of the Ophthalmic Division of Trigeminovascular System. The biological response characteristics of the cold patch have been examined with induced hyperoxia and hypercarbia (6). The cold patch is altered by vasoactive drugs Betablockers and Calcium blockers. It is also sensitive to Estrogen and CPAP treatment.

Infrared imaging allows us to use cold patch clinically by providing the ability to monitor vasomotion and arteriovenous shunting (7)under tri- gemina l/neurovascular control. Cold patch is an area with altered extracranial CBF.

Thermography meets the extracranial CBF measurement criteria, by its ability to

1) Image and monitor the primary vasoactive response of the individual, based on pre-existing vasomotor tone (8),

) Evaluate the biological limit of vasomotion i.e. Vasoconstriction/Vasodilation,

3) Provide the methodology to document the effect of agonistic and antagonistic drugs on vasomotion under the regional control of Trigeminovascular System,

4) Understand the control processes that may occur in response to dynamic conditions by using a protocol involving changing rather than static conditions such as superimposed cerebrovascular/vasomotor and pharmacological challenge protocols and

5) Visualize functioning AVAs in real time. This has clinical and research applications in migraine, panic attacks and sleep disorders.

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Evaluation of Rapidly Changing Thermal Phenomena in the Living Body Through Image-Processing of a High-Speed Far-Infrared Camera

Kunihiko Mabuchi*, Katsuya Kondo**, Naoto Kakuta*, Akimasa Kouno*, Takumi Yonezawa*, Hiroyuki Ishigaki**

* Center for Collaborative Research, The University of Tokyo 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8904 JAPAN

** Dept. of Mechanical and Intelligent Eng., Himeji Institute of Technology 2167, Shosha, Himeji, Hyogo Prefecture, 671-2201 JAPAN

Recent advances in high-speed far-infrared thermal cameras have made it possible to dynamically visualize and evaluate fast-changing thermal phenomena in the living body such as changes in the skin blood flow or consequent constriction and dilatation of blood vessels due to changes in the autonomic nervous function. This study aimed to develop a program for a computerized high-speed infrared thermal imaging system that can produce dynamic imaging with respect to changes in the skin blood flow or the function of the autonomic nervous system.

The experiments were performed using healthy male subjects. Several kinds of physical stimulation (e.g. cooling of the skin, electrical stimulation to peripheral nerves, etc.) were given to the subjects, and a time series of far-infrared images was taken by a high-speed far-infrared camera (Thermal Vision Laird 3ME, Nikon) before, during, and after the stimulation.

In order to evaluate the dynamic change in the distribution of skin temperature caused by the stimulation, a time series of subtraction images was then calculated by subtracting a control image (taken just before the stimulation) from each of the original time sequential images, and after being processed by temporal smoothing and spatial filtering. This time series of subtraction images was displayed dynamically using either a 3-dimensional display method or a conventional 2-dimensional.

Time delay since a stimulation was given to the living body until the skin temperature began to change, is also very important index for evaluating the autonomic nervous function because it reflects the conduction velocity of the nerve signal as well as the time needed for the blood vessels to respond (i.e., constrict or dilate) to the nerve signal. We, therefore, calculated the time delay at each pixel by investigating the change in the skin temperature before and after the stimulation at each pixel from the time sequential thermal images, and displayed the spatial and temporal mapping of this time delay using either a dynamic displaying method or a static colour image.

The former data-processing method enabled the dynamic temporal changes in the skin temperature and its spatial distribution (which represents dynamic changes in the skin blood flow, dynamic changes in the autonomic nervous function, etc.) to be recognized clearly and intuitively; the latter displayed the spatial distribution of the functions with respect to conduction of nerve signals the response (i.e., constriction or dilatation) of the blood vessels to the nerve signals.

These results suggest that physiological functions of the living body (e.g., the functions of the circulatory system, the autonomic nervous system, etc.) and abnormalities represented by rapidly changing thermal phenomena could be evaluated using this program.

The Efficacy of Infrared Thermography in Human Work and Exercise Physiology

D.D. Pascoe[1]; R.C. Purohit[2]

1 Department of Health and Human Performance,

2 College of Veterinary Medicine

Auburn University, Alabama U.S.A. 36849

The use and potential of infrared thermography as an evaluative tool in work and exercise physiology has not been fully realized. The non-invasive determination of skin surface temperatures can provide the researcher with an understanding of physiological responses to work and thermal stressors. Furthermore, infrared thermograms can provide a clinical diagnosis for various medical conditions. To demonstrate the efficacy of this non-invasive methodology, the purposes of this presentation are threefold:

1) Discuss the factors (equipment, environment, work physiology, vasoactive substances, and medical conditions) which can compromise the accuracy of the infrared data being collected.

2.) Discuss our research related in work physiology related to cutaneous blood flow as a thermo- regulatory response to thermally challenging work situations and regional variations in skin temperature in response to changing work environments. Infrared measures will be contrasted to the use thermistor skin probes which can have detrimental effects on the skin surface temperature measurements.

3.) Provide our research and case studies which demonstrate the clinical diagnostic importance of infrared imaging (use of the cold stressor test for carpal tunnel syndrome, diagnosis of athletic injuries, and the bilateral/contralateral sympathetic response to thermal cold stress). It is hoped that this overview will serve as a catalyst for researchers in the area of work and exercise physiology to promote the use of infrared thermography as a evaluative tool for skin surface thermal responses.

Time Recovery Image: A Diagnostic Imaging Techinque Based on the Dynamic Digital Telethermography

A. Merla*, L. Di Donato*, G.L. Romani*·**

*Dept. Clinical Sciences and Bioimaging, University "G.d'Annunzio", Chieti, Italy; email:amerla@socrate.itab.unich.it

**I.T.A.B. Institute Advanced Biomedical Technologies, University "G.d'Annunzio", Chieti, Italy

A new diagnostic imaging technique based on the Dynamic Digital TeleThermography is described.

Using all the functional information related to the local thermoregulatory process, this technique is able to detect and to classify the stage of some disorders that alter the normal displays of the local thermoregulatory system.

The presence of changing pathological factors can be enhanced by means of an induced thermal stress and recorded by the differentiate dynamics of the thermal recovery exhibited by healthy or pathological area. The recording of these different recovery dynamics – performed by means of digital thermographs characterised by a very short acquisition time - can provide a new useful imaging tool, especially to validate and to follow up specific rehabilitative processes.

It is possible to characterise healthy and damaged or referred pain areas just by means of the time constant related to local thermal recovery following thermal stresses. Then the thermal recovery time constant becomes a fundamental characteristic of each human body district and, consequently, of damaged or not damaged areas. It is then possible to locate the skin manifestation of the disease, to evaluate its severity using, rather than the static thermal skin distribution imaging, an image (*tau image*) that reports the point time constant, conveniently converted in colour level, associated with the thermal recovery following a thermal controlled induced stress on the interesting area. The DDTT measurements were carried out by a Digital Tele-Thermographic Camera AEG 256 PtSi, 8-14 nm, temperature measurement noise 0.02 K.

The *tau* images resulting from the recovery curves provides a wide range of information that, for the sample cases followed in our studies (12 second-class muscular lesions, 6 epicondilitis, 2 deep vein thrombosis, 10 tendon-pathologies, 12 SSc Raynaud), are closely confirmed by ultrasonographic and clinical examination.

It is possible, by means of our method, to evaluate the evolution of the clinical situation following rehabilitation therapy, since it is possible to compare the different *tau* images registered at different moments of the therapy.

Moreover it is possible to detect and describe the dynamic effects of any vessel-agent substances by comparing the tau images obtained before and after the treatment.

Thermographic Findings of Spinal Cord Tumours

Young-Soo Kim, Yong-Eun Cho, Ho-Yeol Zhang

Spine Center, Department of Neurosurgery, Yongdong Severance Hospital, Yonsei University College of Medicine, Yongdong P.O. Box 1217, Seoul, 135-270, Korea

Spinal cord tumours have a variety of motor and sensory symptoms, but the thermographic findings are not known well. The purpose of this study was to evaluate the correlations between the thermographic find- ings and neurological signs and radiologic findings.

We analysed 136 spinal cord tumoor patients who had been operated from 1995 to 1999 in Yong- dong Severance hospital. We evaluated pre- and postoperative thermograms, radiologic findings and neurologic deficits.

The results were as follows: Thermograms of epidural tumours (33 cases) with neurologic deficit show an ipsilateral hypothermia. Postoperative thermograms show the reduced thermal differences. Thermograms of the intradural extramedullary tumours (52 cases) with Brown-Sequard syndrome show the hypothermia in the motor weakness side. In the schwannoma, ipsilateral hypothermia is the most likely sign(84%) in thermograms. In intramedullary tumours (11 cases), symmetric hypothermia shows below the paraparetic level. In the cauda equina tumours (45 cases), both legs show hypothermia in the large tumours with total nerve root compression and ipsilateral thermatomal hypothermia shows in the small, one nerve root compression tumour. In the conus medullaris tumours(5 cases), hypothermia shows in the painful leg.

In conclusion, thermograms of the spinal cord tumours show hypothermia in the motor weakness area than the sensory deficit area. Hypothermia along the thermatome shows in most cases of the schwannoma.

Trigeminal Neuralgia

Giorgio Dalla Volta

Neurological department of the Istituto clinico, Città di Brescia; Brescia ; Italy

The trigeminal neuralgia is a disease that affects 3,5 / 100.000 new patients every year in the United

States and have a big social impact caused by the intensity and the frequency of the pain.

The pain is like "a shock attack " and makes the patient anxious due to the fact that he never knows when it starts: it comes out of the blue! .

The pain predominantly affects the second branch of the trigeminal nerve, the right side more than the left side of the face and may occur a hundred times a day lasting few minutes but can manifest itself for some weeks at a time.

The pathogenesis could be a demyelination of the nerve in the dorsal root entry zone which develops automatic epileptic- firing from the caudalis nucleus transmitted like a pain signal to the cortex. These antidromically provoke CGRP (calcitonin gene related peptide) and other substances discharge from the nerve developing the C nociceptors sensitivity responsible for the well-known phenomena of the trigger zone.

In the cutaneous trigger area a mechanical stimulation, even if subliminal (like to touch or to wash the area) let to reduce the threshold of cutaneous nociceptors determining an afferent pain sensation secondary to a not painful stimulation (cross modality receptor threshold modulation).

This theory combines the concept that the trigeminal neuralgy might be considered as a trigeminal neuropathy and that the phenomena of the trigger area should be considered as an area of allodynia, which is typical for a neuropathic disease.

The use of thermography in this pathology permits to distinguish between the primary form of the disease where a hot spot is found corresponding to the trigger zone and the secondary, where we can find a cold area in the cutaneous territory of the nerve ending of the affected branch due to an irritation of the nerve and of its autonomic pathway .

We illustrate with some images of a trigeminal neuropathy due to a multiple sclerosis , some others due to a compression of the nerve in the posterior cavity of the brain caused by a tumour and images of a preganglia compression in the cavernous sinus due to a carotid aneurism .

It is also possible to show what happens to the thermal pattern of the face after stimulation of the trigeminal nerve with an electrical impulse during a thermo-rizotomy applied to a patient with an intractabile neuralgic pain.

Thermography in diagnosis and treatment of pain

C. Bonezzi – Italy (no abstract)

Cold fingers induced by keyboard operation

K.Ammer

Ludwig Boltzmann Research Institute for Physical Diagnostics (Director: O.Rathkolb, MD), Vienna, Austria

Background: A decrease of finger tips temperature was described after keyboard operation in some healthy subjects and in patients who complained of pain during type writing.

Aim of study: To investigate the frequency of cold fingers induced by typing on a keyboard

Method: All subjects acclimatized for 10 minutes with bare arms to a room temperature of 24°C. The hands of 20 females were investigated by thermal imaging (Agema 870 or NEC San-ei Thermotracer) before and after keyboard operating at a fast typing speed for 15 minutes. The temperature of the forearm, of each single finger tip and metacarpo- phalangeal joint was determined. The results were compared to temperature changes of 40 hands of 15 women and 5 men after performing the "fist manoever", which is part of the protocol to detect patients suffering from thoracic outlet syndrome.

Results: The skin temperature of the forearm increased in nearly all subjects after keyboard operation. Only 3/20 subjects presented with higher temperature readings after typing. The difference of the finger tip temperature before and after this test was up to 6.0 degrees in individual fingers. After performing the fist manoever the mean skin temperature of the forearm decreased by 0.2. Cold finger tips, present in 43 fingers prior to opening and closing the fist, were shown in 56 fingers after the test.

Conclusion: Cooling of the finger tips after typewriting seems to be a regular occurance. This might be due to exposure to vibration, which results in vasospasm of the finger arteries This occurs despite the fact that the heat production of the forearm extensor muscles should be followed by vasodilation to remove the local excess of heat.

Diagnostic of Lumbar Osteochondrosis at Different Stages of Disease

Kolesov S.N., Volovik M.G., Priluchni M.A.

23/1 Gagarin Ave., Nizhni Novgorod 603022, Russia;
E-Mail : newned@unn.runnet.ru

The introduction of thermovision into the set of clinical tests for lumbar osteochondrosis makes it possible to solve different aspects of the causes of the pain syndrome. In the early stages of dystrophic process this method can show both reflexy and compression syndro- mes, s used to optimisef the treatment. In the case of disc herniation and discradicular conflict it is possible to detect the correlation between the hernia and radix, to estimate the functional deficiency of the compressed radix. Examination was made using TV-04 infrared camera (Russia).

Thermographic examination includes the estimation of particularities of infrared emission of lumbar area, front and back surfaces of some parts of the feet. On the basis of this research and its dynamic changes after functional tests it is possible to answer following questions :

to confirm the presence of some reflex syndromes : radicular, myotonic, neurodystrophic;

to make a differential diagnosis between reflex and compressive radicular syndrome;

to detect the nature of formation of different types of vertebral syndromes with lumbar inflammation (compressive, aseptic-inflammatory, dyshaemical, dysfixation).

In the case of intervertebral hernia thermal imaging can precisely determine the herniated area and number of affected radices. Topical diagnostics of disc-radicular conflict is carried out according to following principles :

qualitative and quantitative estimation of thermal picture of the feet, that allows to detect the radicular syndrome;

presence of areas of pathological decrease in the infrared emission on one or both lower extremities;

the correspondence of areas of decreased temperature with innervated area of concrete spinal radix;

quantitative estimation of the decrease in infrared emission in these areas (according to thermal asymmetry and temperature gradient along the extremity).

The specific types of disturbance of infrared emission of the feet in case of lateral, medio-lateral and medial intervertebral hernias were found. The precision of this method for the diagnosis of disk-radicular conflict was 82 %, including two- evel hernias.

The Application of Thermography in Patients with Various Spinal disorders*.

Szymon Dragan[1] , Henryk Konik[1] , Robert Koprowski[2], Adam Prastowski[1] , Robert Frec[1]

[1] The Clinic and Department of the Orthopedics of the Medical Academy in Wroclaw (Head of Clinic: Prof.. Dr hab. N. med. Andrzej Wall)
[2] Institution of Computer Systems of Steering in Sosnowiec (Head of Department: Dr hab. Zygmunt Wróbel)

*The treatments were made within the confines of The National Examination Programme „Diagnosis and prognosis of the course and treatment of scoliosis in children and adolescents by means of thermal imaging”

In this paper we analyse the distribution of temperature near the spine of the children and adolescents with idiopathic scoliosis and adolescent Scheuermann’s disease after surgical treatment, before and after corrective exercises. The examination was performed with the Camera AGEMA 470 in a standardized microclimate condition after a period of thermal adaptation. The recorded thermograms were processed depending on the level of the scoliosis of the spine. For scoliosis up to 30° the course of the spine axis was set fully automatically, i.e. the registered thermographical picture was interfaced to the personal computer. Secondly the specially written programme automatically set out the distribution of temperatures , that we are interested in. In patients with scoliosis of 30º the user sets the course of the spine axis manually, on the thermal image.

Results: Patients with idiopathic scoliosis showed temperatures differences between the concave and the convex side of 0.5-0.15 ºC. The change of the temperature difference in the patients before and after rehabilitation exercises was recorded.

The Thermal Image of the Spine in Children and Adolescents*

Szymon Dragan[1] , Henryk Konik[1] , Robert Koprowski[2], Adam Prastowski[1] , Robert Frec[1]

1The Clinic and Department of the Orthopedics of the Medical Academy in Wroclaw (Head of Clinic: Prof.. Dr hab. N. med. Andrzej Wall.
2Institution of Computer Systems of Steering in Sosnowiec (Head of Department: Dr hab. Zygmunt Wróbel)

*The treatments were made within the confines of The National Examination Programme „Diagnosis and prognosis of the course and treatment of scoliosis in children and adolescents by means of thermal imaging”

This paper presents the results of temperature measurement of the spine of healthy children and adolescents. 150 subjects (85 girls and 65 boys) in the age of 11 to16 years (mean age :14.5 years) were examined.

The examination was performed with the camera AGEMA 470 under standard microclimate conditions after a period of thermal adaptation.

The recorded images were exposed to preliminary picture processing aimed to filter the artefacts by removing the background.

Secondly, the axis of the spine is automatically set in full. One both sides of the axis the average spread of the temperature in the range of 7 cm has been marked. This examination revealed symmetrical distribution of temperature on both sides of the spine.

Clinical Application of Thermography in Osteoarthritis of the Hip

Ryoichi Kanie

Department of Orthopaedic Surgery and Rehabilitation Medicine, Nagoya City University Medical School, Nagoya 467-0001, Japan

Temperature changes on the surface of the human body are known to be a sensitive reflection of pathological conditions within the body, and provide a useful information. Thermo- graphical examination and its clinical application in various joint diseases have been found useful in deciding appropriate treatment and in follow-up evalua- tion of such cases. Patients with osteoarthritis complain of pain, motion and gait disturbance of diseased hip joint and muscle atrophy on the gluteal region. In this study, the skin temperature was measured pre- and post-operatively in the gluteal region with osteoarthritis of the hip. As a result, it was made clear that the skin temperature on the diseased side was lower than on the healthy side. When both sides were diseased, the more severely affected side had a lower temperature. The average temperature of each side and the temperature difference between the two sides were calculated by our improved method, in which the measured area could be surrounded freely within a polygon. From 50 cases diseased on one side, it was recognised that the temperature difference had a correlation to the severity of symptoms using the hip- functional evalution score. In operated 20 cases, the decrease in the temperature of the skin was lessened and became smaller over time. With regard to the mechanism involved in these findings, it is believed that a major role may be played by local circulatory insufficiency caused by gluteal muscular atrophy and hip joint pain. This diagnostic method using thermography is very useful not onry for assessing the severity of the symptoms, but also for evaluating post-operative recovery from this disorder.

The Thermal Footprint – A Pilot Study

Thomas Maca, Francis Ring °

General Hospital and Univ. of Vienna, Dpt. Medical Angiology, Austria.

° National Royal Hospital for Rheumatic Diseases, Dpt. of Clinical Measurement, Bath, U.K.

Introduction: Regular function of the feet is essential for sustained walking mobility. Besides hereditary foot deformations, other anomalies such as the diabetic foot need to be detected early .

Aim of the Study: The technical feasibility of thermal imaging of the imprint from the soles of the feet on the ground is investigated, to study an easily accessible method for screening foot anomalies.

Patients and Methods: 10 control subjects (5 men: age 53 and 5 women age: 47) without a history of recent disease or medication were thermo- graphically examined..

During adaptation to the standardised ambient temperature (22°C) subjects remained sitting with their legs positioned on a chair in horizontal posture to avoid contact with their bare feet. Investigation began with taking a thermogram of the plantar feet. Then, on standing within a marked area on the floor, a dynamic procedure of 2 footsteps within 1 second followed. A contiuous set of images were recorded with the FLIR thermovision of the thermal footprints on the hard vinyl ground of the examination room.. In the same way infrared images were also examined after 1 minute standing.

Results: The thermal imprint of the foot on the ground releases heat energy which is correlated to the basic temperature of the foot sole. The duration of the temperature decline on the floor is directly associated with the time of contact and the body weight (pressure) applied. The contour of the thermal footprint resembles the orthopaedic foot.

Conclusions: The thermal image of the human footprint imaged by infrared thermography produces a considerable amount of information which should be help- ful in routine medical diagnostics.

The Determination of Normal Temperature Values of Finger Joints

K.Ammer

Ludwig Boltzmann Research Institute for Physical Diagnostics (Director: O.Rathkolb, MD), Vienna

Background: Symmetric involvement of body regions occurs frequently in inflammatory rheumatic diseases. In this case, the knowledge of normal values of the affected area is useful for correct interpretation of thermal images.

Aim of the study: to determine the normal temperature range of the finger joints.

Methods: We investigated the hands of 140 subjects by thermal imaging. 37 patients presented with symptoms of painful osteoarthritis, 21 patients were diagnosed as arthritis. 22 patients suffered from carpal tunnel syndrome (confirmed by nerve conduction studies in all cases), 8 patients presented with symptoms of thoracic outlet syndrome and 10 patients showed Raynaud´s phenomenon in individual fingers. The remaining 42 subjects did not have clinical signs of a joint affection.

Joint swelling and tenderness of the metacarpophalangeal (MCP), and the proximal (PIP) and distal interphalangeal (DIP) joints were recorded. With the exception of 35 non-symptomatic subjects, a cold water test was performed in all patients and the pattern of temperature recovering was observed. The normal range of temperatures was defined by the mean value plus the two-fold standard deviation. The distribution of the temperature readings of each finger joint was related to clinical symptoms such as tenderness and swelling.

Results: In non-symptomatic joints the highest temperature values have been found over the joints of the thumb and the lowest readings on the little finger. The standard deviations were in the range of 1.5 to 2,0 °K. The longitudinal temperature gradient from the MCP to the DIP joint was between -0.3 and 0.4 °K.

Most of the tender joints showed higher temperature readings than non-tender joints. However, the tender interphalangeal-joints of the ring-finger finger presented with slightly lower temperatures than non-tender joints.

The temperature of all swollen joints and some of the tender joints recovered faster than the other joints after a cold stress test.

Conclusion: The approach of defining normal values by the mean ± 2 standard deviations is not useful for temperature readings from thermal images. Although an overlap in temperatures of tender and non-tender joints exists, hyperthermic changes can be detected by either the disturbance of symmetric temperature distribution from side-to side or by changes of the temperature gradients along individual fingers.

Thermography and orofacial pain : a new diagnostic tool

S. Ciatti [1] G. Mauro [2]; P. Mannelli[3].;F. Frosini °; A. Fanfani.[4;] S. Fanfani [4] V. Leoni [1]

1 Studio Ecografico - Prato- Italy; [2]Mantova – Italy; [3]Studio Dentistico -Prato-Italy; 4 Istituto Fanfani -Firenze -Italy

Objectives: The aim of this study was to assess the use of infrared electronic emission thermography (IEET) in the clinical evaluation of asymmetrical orofacial pain.

Methods:Two operators examined 36 patients (F 22 / M 14; mean age 47.9).

The first one performed a clinical functional examination of the stomatognatic system following Hansson's protocol with the aid of a specific software (PAINTAC ®).

The other operator, a radiologist, performed IEET in a double blind setting, using a PM300 ThermaCAM system (Inframetrics Billerica Ma. U.S.A) with a temperature range of 5°C (32.5 - 37.5°C) and 10°C (28.5-38.5°C); the emissivity of the system was 0.83.

Thermograms were obtained using a profile and a frontal pose, according to the Guidelines of the Neuromuscolar Thermography Academy.

Clinical and thermographic findings were then compared using a statistical analysis (Fisher test).

Results: Among the clinically examined group 24 out of 36 patients were positive for TMD (66.6%). The remaining 12 (33.3%) were negative.

All TMD patients referred asymmetrical (side) facial pain.In the TMD patients group:18 (75 %) suffered from myogenic pain. 6 (25 %) suffered from arthrogenic or cervical origin of pain. Thermography showed an asymmetric thermal pattern in 21 out of 24 TMD patients (87.5%). Thermal asymmetry was found in 2 out of 12 non-TMD subjects (16.6%).

Statistical analysis (Fisher test) was performed on these findings and revealed high significance (p = 0.0001).

Conclusions:Facial thermography was proved to be useful in the evaluation of asymmetrical facial pain. There was a statistical significant difference regarding facial thermical asymmetry in TMD patients vs. non-TMD subjects.

Microcirculation Imaging in Sleep Disorders

Srini Govindan,

American Academy of Thermology, 40 Medical Park, Wheeling, WV 26003

Thermography can image cranial microcirculation in real time and monitor alterations in vasomotor activity (1). Loeppky studied autonomic cerebrovascular dysfunction in sleep apnea and emphasized the significance of clinical studies with appropriate autonomic pharmacological agents on CBF autoregulation in sleep apnea. Hayakawa indicated that increased CBV during sleep apnea is from increased CBF and extracranial factors. Langanke described that the venous return increases during obstructive sleep apnea. Extracranial AV shunting can increase venous return without glucose utilization. Siebler postulated on the structural differences between cerebrovascular receptors and re - spiration sensitive neurons and its relevance to sleep apnea. Underwood localized the sites in Dorsal Raphe Nucleus for regulation of alteration in cerebrovascular flow, ie. vasoconstriction and vasodilatation.Trigeminal stimulation causes release of neuropeptide in to and increase in extracranial flow (2). Literature indicates the role of Trigeminovascular and Neuropeptide related events in sleep and extracranial flow (3, 4, 5).

Preliminary clinical case studies in narcolepsy and sleep apnea have documented vasomotor alterations in cranial microcirculation. Extracranial vascular receptors respond differently from intracranial vascular receptors to induced hypercarbia and CPAP (6). CPAP sensitive intra and extracranial vasomotor reactivity has been reported in sleep apnea. Normal nonsleep apnea control and sleep apnea patients benefitting from CPAP show extracranial facial AV shunting in the area under the regional neurovascular control of Ophthalmic Division of Trigeminovascular System (7). Thermography images CPAP sensitive microcirculation changes/AV shunting in sleep apnea patients. This may explain the cranial hemodynamic changes sensitive to CPAP. Confirmation of this by studies done in a larger number of patients may help us understand the neurovascular pathophysiology of microcirculation in sleep disorders.

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Thermographic changes caused by surgical intervention for pain

Guido Orlandini

Centro Terapia del dolore e cure palliative Ospedale di Tortona ASL 20 , Piemonte, Italy

Aim of Investigation: The aim of the investigation is to study the thermographic changes induced by some operations for pain. Operations were both neuro-ablative, specifically Percutaneous Radiofrequency Trigeminal Rhyzotomy (PRTR) and Percutaneous Cervical Cordotomy (PCC) and neuro-additive, specifically Spinal Cord Stimulation (SCS).

Patients and Methods: A series of patients affected by trigeminal neuralgia undergoing PRTR, various type of cancer pains undergoing PCC and chronic nerve root pain undergoing SCS were tested with t infra red thermography (IRT) 1-2 day before surgery and 1-2 days after. Trigeminal neuralgia patients were studied by TTG using one anterior and two lateral (right and left) views. Cancer pain patients were studied in a total body view and by sections of the body region(s) involved in pain (thoracic, abdominal, low back, limbs or perineum). In case of PRTR and PCC, two kinds of thermographic changes were considered: 1) changes directly induced by the operations, regardless of the previous pathologic findings; 2) changes induced by the operations on previous pathologic findings. Patients affected by chronic nerve root pain were studied by IRT with one anterior and one posterior view. Post opervative IRT was taken both with on and off-stimulation.

Results and Discussion: In case of PRTR thermographic changes induced by the operation there was a reduction of the cold area found pre-operatively. With regard to PCC, the thermographic pre-operative findings on the pain site were not significantly changed by the operation. If, in the event of superficial tissutal nociceptive pain, a warm area was found pre-operatively, as an expression of local nociceptors activation, the same was found post-operatively also. Similarly, if a cold area was found pre-operatively, the same was post-operatively observed. What was a paramount appearance of post-operative IRT was a warm area diffused to the whole homolateral to PCC hemisoma, more evident at the level of hand and foot. This is the expression of cordotomy-induced sympathetic block on the operated side. Finally, as for post-SCS IRT, it must be noted that thermographic changes do not occur if SCS is ineffective for the control of pain.

Thermography and Sympathetic Skin Response to Assess the Effects of Sympathectomy: A Case Report

Bettaglio R., Miotti D., Buonocore M., Demartini L., Paulin L., Bonezzi C.

Unit of Pain Therapy and Palliative Care IRCCS, Maugeri Foundation, Institute of Pavia, Italy

The success of sympathectomy is clinically difficult to assess objectively and usually judged in term of patient's improvement.

Aim: this case report tested the hypothesis of possible use of Thermography and Sympathetic Skin Response (SSR) in assessement of sympathectomy effects.

*Case history:*a man suffering from chronic throublesome palmar hyperhidrosis underwent a bilateral, localized, endoscopic resection of the second thoracic sympathetic ganglion. After the operation the hyperhidrosis was significantly reduced, but he began to feel distal paresthesias and thermal allodynia in the upper limbs and excessive throublesome compensatory sweating of the trunk and lower limbs.

We evaluated the patient fifteen months afterward the operation and symptoms were still present. Neurological exam was normal apart from mild heat hyperesthesia in the distal portion of upper limbs.

Methods: after equilibration period of twenty minutes in a room at constant 22°C, the patient was evaluated with thermography.

SSR was evoked by auditory , alerting stimuli and recorded simultaneously from palm and sole bilaterally. The amplitude of SSR in the palm and sole was measured and palm/sole ratio was calculated.

Results: thermography showed the thoracic thermal level with upper part of the body warmer than the lower.

Sympathetic skin response reduction in palm/sole ratio was observed clearly.

Conclusion: the results observed in this clinical case indicate that Thermography and SSR seem to be objective, simple, non invasive tools to assess the success of thoracic sympathectomy.

More studies are needed to confirm this hypothesis.

Clinical Application of Digital Infrared Thermographic Imaging as a predictive factor for successful outcome of Chymopapain Chemonucleolysis in Lumbar Disc Herniation

Young-Soo Kim, Yong-Eun Cho, Ho-Yeol Zhang

Department of Neurosurgery, Yongdong Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

Thermography is a very sensitive diagnostic tool to detect the pain in lumbar disc herniations and is well correlated with postoperative clinical result. Among various treatment methods, chymopapain chemonucleolysis is a minimally invasive, easy surgical option for soft lumbar disc herniation. It is very important to predict the surgical outcome by chemonucleolysis preoperatively.

Pre- and postoperative thermal imaging in the successful outcome group (group 1, 118 patients) and a failed group (group 2, 26 patients) after chemonucleolysis in lumbar disc herniation. Have been analyzed. Preoperative and postoperative thermal differences and pain scores in VAS were compared in each group to evaluate the efficacy of DITI in prediction of successful outcome.

Preoperative thermal difference was 0.72 ± 0.32°C in group I and was 0.22± 0.10°C in group II. They showed significant difference statistically ($P<0.05$). In group I, , thermal difference was reduced from 0.72 ± 0.32°C to 0.32± 0.16°C and 0.28± 0.16°C, respectively 1 week after and 1 month after chemonucleolysis. But in group II, the thermal difference was increased to 0.60 ± 0.29°C after operation.

Regarding to pain score, there was no statistical difference between two groups as 7.04 ± 2.27 in group I and 6.80 ± 1.30 preoperatively. After operation, pain score was improved to 2.59 ± 1.06 1 week after and 1.92 ± 0.75 1 month after in group I. In group II, the pain score was aggravated to 7.88 ± 1.25 after operation.

In conclusion, the patient who has significant thermal difference(> 0.7°C) in thermography with moderate to severe pain could be a good candidate for chemonucleolysis. DITI could be a useful tool to predict the successful outcome of chemonucleolysis in lumbar disc herniation patients.

Radiothermometry in Patients Operated with Lumbar Hernia

Morozov I.N., Kolesov S.N., Orlova M.E.

23/1 Gagarin Ave., Nizhni Novgorod 603022, Russia
E-Mail : newned@unn.runnet.ru

The RT-17 radiothermometer (Russia) operating at the wave length of 175 mm was used to evaluate vertebral syndrome for optimisation of the exercise therapy in patients operated for inter- vertebral hernia of lumbar area. 34 patients were examined. An integratedemission temperature (IRT) along the midline (above spinal processes of L1-S1 vertebrae) and along right and left para-vertebral lines were measured. Tests were performed before, during and after rehabilitation treatment. The influence of exercise therapy on IRT was researched.

All patients with the above pathology had a decrease in the deep temperature in comparison either with normal or with temperature measured on the level of non-affected intervertebral disks. It was found, that the values of thermal asymmetry correspond to severity of vertebral syndrome and to time passed since surgical operation. Strong correlation was found in comparison to thermal asymmetry above L4-L5, L5-S1 vertebrae with severity of pain syndrome (k=0,8), with level of operation (k=0,7) and average temperature along paravertebral lines with the time passed after surgical operation (k=0,6).

At the beginning of rehabilitation course the average temperature along paravertebral lines and midline was decreased. After exercise therapy thermal asymmetry decreased at all the levels with maximum on L4-L5 and L5-S1 segments. At the end of the treatment, average temperatures increased and the increase of thermal symmetry on the level of operated vertebrae was found in 71 % cases.

Radiothermometry permits to make an objective quantitative evaluation of the severity of pain syndrome, to control the exercise therapy procedures as one of the methods to confirm their success. After proper treatment the average IRT values become normal.

Thermographic Detection of Modification Induced By Oxybral SR in Parachutists

Rodan Gheorghe, Patru Spataru; Ilie Capanu °, Eugen Necula °, Ioachim Babita °

National Institute for Aerospace Research,
77538, bd. Iuliu Maniu, nr. 220, sect. 6, Bucharest, Romania
° National Institute for Aeronautical Medicine, 70786, str. Mihai Vulcanescu, nr. 88, sect.1, Bucharest, Romania

The subject of our paper is related to the modification induced by pharmacological treatment and re - presents the continuation of our work concerning the thermographic detection of modification induced by hypobaric or hyperbaric stress in pressure chambers on pilots, parachutists or divers. Previous results have been encouraging and helped us to develop the experiment in observing the modification induced on a similar test group, by the administration of a drug, used for cerebral circulation and function enhancement - OXYBRAL SR (GLAXO-WELLCOME). This drug is known to have a selective vascularl-regulating effect on the circulation in the cephalic extremity blood.

20 parachutists, subjects of a simulated jump in the pressure chamber, formed the test group. The simulation consisted from an ascent to 5500 m (with pressure decrease) followed by a jump (with a quick pressure increase), during the same time as a real jump. The drug was administrated during 10 days (1 /day). The same number of parachutists with no drug administration formed a second group.

The results showed an increase of temperature of the cephalic extremity in the test group, even before the pressure chamber test. This increase accentuated after the test. The same time the temperature of limbs decreased, for a long period after the test.

The members of the second group showed a different pattern of temperature variation. Generally, after a lapse of time it was a general increase of temperature.

The statistical analysis of the results made possible to continue to build an evaluation method of the physical preparation level of the jumpers.

Thermodiagnostics in Acupuncture

Ovechkin A.M.

23/1 Gagarin Ave., Nizhni Novgorod 603022, Russia,
E-Mail : newned@unn.runnet.ru

The method of infrared thermography allows to follow the distribution of the temperature on the body skin surface in the form of a thermal picture. It is very interesting to apply thermal imaging for the elavuation of the status of acupuncture structures on the human body.

On the basis of the long experience in the application of the thermal imaging in clinical acupuncture practice it is possible to state, that :

1. With the help of thermal imaging one can detect the location of acupuncture point on the patient's body surface at the moment of inspection. This is important, because the acupuncture points often change their location in pathological conditions.

2. The high temperature above the acupuncture point may help to estimate its functional condition. It can be used to make a correct and objective choice on how to influence the point.

3. During the treatment procedure one can look at the changes in the temperature above the acupuncture point. It can answer the question of whe- ther the treatment manipulation is correct or not.

4. In many diseases there are special changes of the skin temperature above some acupuncture points. This data served as the basis for the development of many methods of thermal imaging reflex diagnostics (for immunodeficiency condition, arterial hypertension, dysmenorrhea etc.).

Thus, the thermal imaging method is very informative and helpful in the acupuncture practice. Examination of the infrared emission above the acupuncture points allows to detect its precise location, functional condition and to execute the control during treatment, that increases the clinical effectiveness of acupuncture.

The Diagnostic Value of Thermography in Dermatology

A. Di Carlo

Istituto Dermatologico S. Gallicano – IRCCS – Rome

Summary. The paper presents the main applications of infrared thermography in the field of dermatology, highlighting in particular the results obtained in dermatological oncology. The sensitivity of the method is significantly increased by the use of the original *thermostimulation* method, which, in the opinion of the Author, should accompany the thermographic examination.

Melanomas and other skin tumours

Introduction Infrared thermography was first used in dermatology by Brasfield, who in 1964 reported the elevated hyperthermia of cutaneous melanomas (1). The observation was subsequently confirmed in Europe by other Authors, in particular in Italy by Ippolito and Cristofolini, who defined some characteristic thermographic aspects of skin melanomas (2-7). These were defined as follows:

1.Presence of a perilesional hyperthermic halo with an elevated gradient whose edges extend well beyond the clinically evident lesion, elliptical in shape and extending towards the regional lymphocentres with a characteristic thermal flame morphology, or, when located in the limbs, of lymphocentric hyperthermic stria;

2.The lesion in itself may be non-hyperthermic, in particular when its surface is affected by hyperkeratosis or vegetant ulcerative events that can modify the emission coefficient (8);

3.Such a pattern is also present in the case of achromatic melanomas while it is not apparent in the case of other benign pigmented tumours (pigmented basalioma, seborrheic warts, etc).

The same authors also reported numerous cases of so-called *false negatives,* lesions without the hyperthermic halo (24%) (6), thereby raising doubts as to the validity, also in economic terms, of using this method in this particular field. These can occur both with melanomas "in situ" or with a thickness < 0.75 mm Breslow, and also in the case of tumours located in hyperthermic anatomical sites, because of the presence of large surface blood vessels (e.g. groin and armpit areas) or a cavitation effect (e.g. below the breast). These severely limiting aspects can be readily overcome by using thermostimulation and reproducible parameters such as temperature-cooling times and thermal recovery times after thermostimulation (9,10). This techniques excludes the false negatives, as numerous cases have shown that in all melanomas with a Breslow thickness > 1 mm, a halo was present with rapid thermal recovery (< 30 sec) compared to the values of the surrounding skin (>2 min, with a thermostimulation of +5°C x 20"). Moreover, the negative cases after thermostimulation corresponded histologically to melanomas which were "in situ" or had a thickness < 0.75 mm (true negatives) (10,11). The origin of perilesional hyperthermia, so important for a proper diagnosis, is yet to be clarified. Histological examinations conducted by various authors and by ourselves have not evidenced neoplastic cells in transit in these locations, but rather the presence of immunocompetent cell populations.

These data formed the basis for a recent study of a group of melanomas observed in the last few years at the Istituto S Gallicano in order to evaluate any correlation between the degree of gradient (and hence the rapidity of the TRT) and Breslow thickness.

Materials and methods. The equipment consisted of an AGA 870 telethermograph with related software package and a Surgicon thermostimulator (range 0-50°C) with a heatprobe of +5°C x 20". The respective TRT were considered for each lesion. More recently (1994-98) at the Istituto S. Gallicano - IRCCS of Rome, 203 patients with a clinical-thermographic diagnosis of melanoma, surgically removed, were examined.

The sample consisted of 89 male patients aged 16-84 years, average 40.4 years, and 114 female patients aged 14-87 years, average 47.6 years, subdivided into: SSM 134 cases, LMM 1 case, ALM 22 cases, MN 46 cases, of which 11 achromatic.

Results: The thermographic exam performed using the thermostimulation technique highlighted in 195 cases the characteristic pattern of rapid TRT (< 30") (healthy skin = = 2'). Clinically, they were 46 NM, 128 SSM, 1 LMM, and 22 ALM. In particular the MN have, in addition to the halo, always revealed lymphocentric pseudopods. The remaining 8 cases recorded normal TRT. These corresponded histologically to: In Situ Melanoma (ISM) (3 cases), and SSM with a Breslow thickness < 1 mm (3 cases) ALM with a thickness < 1 mm (2 cases).

When the TRT recorded for each of the 203 cutaneous melanomas were compared with the corresponding Breslow thickness, this revealed a significant correlation of shorter TRT with greater thickness (r = 0.92).

Discussion. The results of our study highlight the constant presence of the hyperthermic halo, also in cases of achromatic melanomas, and in the majority of cases of hyperthermic pseudopods, especially in the NM. Also of considerable interest is the finding of false negatives only in cases of ISM or ALM with a thickness < 1 mm, the significance of which may be of considerable prognostic value.

As regards the epithelium, our thermographic study data highlight two facts: first, the basalioma in all its morphological expressions is generally hypothermic; second, hyperthermia may indicate a mixed form, the hyperthermia being due to the spinaliomatose part of the lesion (mixed epithelium). Actinic keratoses also show a hyperthermic pattern. As regards spinocellular epithelium, the thermographic picture in all cases was one of hyperthermia, in some cases limited to the lesion, in others extending to a lymphocentric irregular perilesional area. Lastly, in dermatological oncology it is not rare to observe Paget's mammary disease: the cutaneous lesion often appears hyperthermic and with thermostimulation it is possible to highlight not only the hyperthermic area of the lesion itself, but also that of the deep tumour which appears rapidly (15-20 seconds after the end of the thermostimulation +5°C x 20 sec) while the areas not affected by the neoplastic lesions remain hypothermic.

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Infrared Thermography for the Assessment of Localised Scleroderma in Children

[†]G Martini, KJ Howell, [*]KJ Murray, [‡]RE Smith and CM Black

Centre for Rheumatology, Royal Free and University College Medical School, London;
†Dipartimento di Pediatria, Università di Padova, Italy; *Department of Paediatric Rheumatology, Great Ormond Street Hospital for Sick Children, London; ‡Department of Medical Physics, Royal Free Hospital, London

Localised scleroderma is a rare connective tissue disorder, frequently of paediatric onset, characterised by fibrosis of the skin and of the underlying tissue. Joint contractures, subcutaneous fat loss, atrophy and loss of muscle bulk are typical complications as well as growth failure of the affected area, particularly the limbs.

Retrospectively, we have compared clinically-assessed lesion activity with thermography on 17 patients who have attended the Royal Free Hospital since 1993 (11 females, 6 males; average age at onset 6.5 years, range 1-15 years). In total, 25 lesions were assessed and 48 thermal images were included in the study. A number of patients attended for thermography on multiple occasions, and several skin lesions were often imaged.

Each patient sat lightly clothed as appropriate at an ambient temperature of 23°C for fifteen minutes prior to thermographic evaluation. Thermal images of each affected area of skin were then recorded, along with a control image of the contralateral limb where necessary. Two of us (GM and KJM) were provided with details about the skin involvement of each patient. We were however unaware of which lesions were considered clinically "active" by the examining physician at the time of thermography. We independently assessed each thermal image, judging the skin lesion thermographically "positive" or "negative" on the basis of a temperature rise in the affected area of >0.5°C with respect to the contralateral or adjacent site. A comparison of thermography assessments with clinical lesion activity is shown below for both observers.

GM	Thermography +ve lesions	Thermography –ve lesions
"Active" lesions	21	2
"Inactive" lesions	5	20

KJM	Thermography +ve lesions	Thermography –ve lesions
"Active" lesions	20	3
"Inactive" lesions	5	20

A comparison between both rheumatologists of the assessment of the thermal images is tabulated below.

Thermography	Assessed +ve by GM	Assessed –ve by GM
Assessed +ve by KM	25	0
Assessed -ve by KM	1	22

Thus thermography has a specificity of 80% and a sensitivity in excess of 90%. We conclude that infrared thermography has potential for the assessment of disease activity in paediatric localised scleroderma, since it correlates well with contemporaneous clinical observations of lesion activity. Assessment of thermal images also appears to be highly reproducible between different observers.

Effect of Cancer on the Dynamics of Autonomically Controlled Cutaneous Microcirculation

Michael Anbar, Lorin Milescu, Cheryl Brown, Aleksey Naumov

Departments of Physiology & Biophysics and Surgery, School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY 14214, USA

Cutaneous perfusion is controlled by the autonomic nervous system with endothelial nitric oxide (NO) acting as an intermediary chemical messenger. NO is a messenger in a chain of steps that ends with smooth muscle relaxation and vasodilatation. NO can also independently inhibit vascular contraction, enhancing its vasodilatory function. The production of endothelial NO is ***intermittent*** in indirect response to pulses of neuronal acetylcholine. The intermittent nature of NO induced vasodilatation results in a corresponding modulation of skin perfusion, which in turn, is manifested as modulation of skin temperature. This temperature modulation, that is generally of the order of 0.001°K, can be monitored and quantitatively analyzed by highly sensitive, ultra-fast and stable focal plane array infrared cameras. On the other hand, many cancerous cell lines produce NO ***continuously*** by inducible NO synthase (iNOS) in quantities larger by orders of magnitude than the transient quantities of endothelial NO. The production of NO by cancer cells is essential for the survival and proliferation of malignant disease. When some of the cancerous extravascular NO diffuses into blood vessels, capillaries in particular, it saturates the endothelial NO receptors and interferes with or eliminates the neuronal control of vascular tone. This results in attenuation of modulation of perfusion and, consequently, of temperature. The latter attenuation is demonstrable by dynamic area telethermometry (DAT) and we have shown that it can be highly effective in the detection of cancerous lesions. We have demonstrated this in clinical studies of several cancers, breast cancer in particular. In the latter case, we were able to demonstrate in a preliminary study a sensitivity of cancer detection >93% at a specificity of >93%. The detection technique involves the accumulation of >1000 thermal images at a rate of 100 images per second, fast Fourier transform analysis of temperature modulation of subareas 2 x 2 mm, and computerized analysis that produces a single diagnostic parameter that also entails the level of confidence of the diagnosis.

The Value of Infrared Thermography in the Study of Vasculopathies

A Di Carlo

Istituto Dermatologico S. Gallicano – IRCCS – Rome

Microangiopathies

Thermography has rapidly become established in the vascular field by virtue of its ability to highlight the functional state of the skin's microcirculation (1-4). Indeed, in steady thermic conditions (air temperature 21°C, UR =50%, air speed < 0.2 m/sec, absence of other IR sources), skin temperature is determined directly by the flow of the papillary derma or surface skin blood flow, equal to 25% of the overall skin flow (nutritive flow). Damage to the capillaries of the papillary derma is at the root of numerous microangiopathies, both systemic, such as diabetes or scleroderma, and loco-regional, for example chronic radiodermatitis and photo-ageing (2). Moreover, as the skin blood flow is in itself greatly reduced compared to that of other organs (= 4% of cardiac output, muscles and kidneys = 20%), the relative alterations, above all in the initial phase are not easily detected by direct thermographic observation. Thermostimulation (parameters: +5°C/ +40°C) can be used to evaluate, through the time taken to return to the steady state or TRT or *thermal clearance,* the functioning of skin microcirculation. In diabetic subjects, it has thus been possible to highlight marked differences in the TRT after thermostimulation (+5°C x 20") which appear significantly prolonged in the case insulin-dependent diabetes compared to those subjects with reduced glucose tolerance or with insulin-independent diabetes. In photo-ageing and chronic occupational radiodermatitis, various clincial-evolutive aspects have been distinguished on the basis of differences in TRT after thermostimulation (+5°C x 20"), and hence of the degree of damage.

Of particular importance in the clinical and experimental fields is the possibility to study the effects of vasoactive drugs and of the transcutaneous absorption of cosmetic products. In fact, the absorption of an ordinary cosmetic product can, depending on its particular chemical-physical composition, produce a vasoactive effect by restricting perspiration and so result in a increase in temperature of the tissue beneath, with important effects on skin blood flow. Thermography with thermostimulation is also useful in the study of the "potency" of topical corticosteroids, as it enables the "blanching" effect to be measured objectively, so overcoming problems associated with using an observer's subjective assessment. This has important clinical-therapeutic consequences, as it enables a proper "posology" of topical drugs.

In routine clinical matters, thermography with thermostimulation appears to be of particular value in photobiology for determining the minimum erythemal dose (MED), of great advantage for studying phototypes, and in allergology for the evaluation of epicutaneous tests in order to diagnose allergic contact dermatitis, given its particular pattern, characterised by a hyperthermic aspect with lymphocentric pseudopods (5).

Macrocirculation

Thermography is also useful in the macrovascular field for the paraclinical examination of surface angiopathies, e.g. varicose veins, varicocele, tuberous and tuber-cavernous angiomas, arterial-venal fistulas, temporal arteritis, cephalea and the so-called cellulite (panniculite angioedemato- fibrosclerotica). In this last case, we have defined evolutive stages characterised by small, medium-sized and large hyperthermic areas, with the as yet unexplored possibility to undertake a rational evaluation of the possible effectiveness of proposed pharmacological and/or physical therapies (6,7).

In conclusion, telethermography, especially where used in conjunction with thermostimulation, is a method with considerable value in dermatology; in view of the particular role of the skin as an "external" organ, which allows the infrared technique to show its real validity.

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Thermography In Monitoring of Peripheral Vascular Diseases

A Jung[1], J. Zuber[1], B. Kalicki[1], B. Wiecek[2], S. Zwolenik[2], S. J. Klosowicz[3].

1 Pediatric and Nephrology Department of Clinical Hospital, Military University School of Medicine, Warsaw, Poland.
2 Thermography Department, Institute of Electronics, Technical University of Lodz, Lodz, Poland.
3 Crystals Physics and Technology Section of the Institute of Applied Physics MUT, Warsaw, Poland.

Abnormalities of the vein system can occur in the early period of life. Beside clinical recognition, they need nother diagnostic methods of imaging to confirm the presence. Apart form Doppler ultrasonography, other methods of imaging the venous-flow are invasive methods.

The advantage of thermography is safety of the procedure in contrary to venography, which introduces the greater risk for the patient. On the other hand, Doppler ultrasonography may not be useful in search for changes in small venous vessels. Plethysmography used in those cases is burdened with high percentage of false positive results. Thermographic investigation is used in venous flow tests for diagnosis (e.g. thrombosis of venous vessels), detecting the varicose veins of the lower limbs, spermatic cord, and diagnosis of arteriovenous fistula patency.

The maintenance of the permeability of arteriovenous fistulas is an important problem in hemodialised patients. Despite the clinical observation of fistula, the Doppler ultrasonography is used in questionable situations. Also the thermographic examination gives a possibility of determining with high accuracy limitations or lack of vascular permeability. It is also helpful in monitoring the quality of flow .

Some cases are presented showing different types of venous pathologies, in which a thermographic investigation was used to ascertain the diagnosis, and in the monitoring control after hospital discharge.

The studies were done by the Inframetrics ThermaCAM SC 1000 camera. The obtained data were processed with the ThermaGRAM 95 Pro software of Inframetrics.

Role of Thermography in Diagnosing Lower Limbs Venous Incompetence

S.Ciatti; D. Chiti; F.Frosini; S.Fanfani; A.Fanfani; V.Leoni

Studio Ecografico Dr. Stefano Ciatti ; Prato; Italy

Purpose: To determine the applications of infrared thermography (IRT) in diagnosing lower limbs venous incompetence.

Methods: Over a period of two years we examined 40 patients presenting with lower limbs venous incompetence using a Colour-coded sonography (CCS)-Kretztechnik 530D US system and a focal planar array thermography system (PM200 Inframetrics).

Results: CCS accurately defines the competence of both sapheno-femoral junction (SFJ) and sapheno-popliteal junction (SPJ) but is limited in the mapping of the incompetent perforating veins; IRT proved to be an excellent adjunctive test to complete qualitative and quantitative assessment of the various perforating veins and their eventual incompetence. The techniqueprovided a panoramic view of both lower limbs in standing position, in anterior, posterior and oblique views. Using IRT, vascular reflux is well visualised at its origins as well as at its ends documenting the sight of the first competent valve. Extension over time of reflux, surgical cure and post-surgical follow-up could be documented.

Conclusions: CCS and IRT are best used as complementary methods for he study of varicose veins of the lower limbs. In this way, especially for surgical planning, documentation of patency and competence of the deep venous system, morphology of SFJ and SPJ, competence of both SFJ and SPJ is obtained by means of CCS. A panoramic view with documentation of varicosities and extent of reflux is best depicted by IRT.

Thermal Imaging in Screening Diagnosis of Crural Varices in Adolescents.

A Jung[1], J. Zuber[1], B. Kalicki[1], B. Wiecek[2], S. Zwolenik, S. J. Klosowicz[3].

1 Pediatric and Nephrology Department of Clinical Hospital, Military University School of Medicine, Warsaw, Poland.
2 Thermography Department, Institute of Electronics, Technical University of Lodz, Lodz, Poland.
3 Crystals Physics and Technology Section of the Institute of Applied Physics MUT, Warsaw, Poland.

Pathology of the venous system poses a significant danger of thrombus formation and its complications. Statistics on this problem do not include children. However ,deep vein thrombosis is diagnosed in only 1/1000 of inhabitants of the USA. Abnormalities of the venous system can occur in the early period of life. In addition to clinical identification there is a need for diagnostic imaging methods such as Doppler ultrasonography, since other methods of imaging venous-flow are invasive.

Aim: Thermal imaging in a screening examination of varicose veins of the lower limbs.

Material and methods: The examination was performed in 44 young healthy man (aged 15-30 years, 38 females and 6 males). The studies were done by the Inframetrics ThermaCAM SC 1000 camera and photography with a digital camera.

Results: In the physical and photographic examination all patients failed to show abnormalities in peripheral veins of the lower limbs. Thermal imaging registered the crural varices in 6 / 44 (13,6%) patients.

Conclusion: Thermal imaging is a useful and non-invasive method in screening examination of crural varices.

Dynamic Digital telethermography: A Novel Approach to the Diagnosis of Varicocele

A. Merla*, A. Ledda***, L. Di Donato*, G.L. Romani*,**

*Dept. Clinical Sciences and Bioimaging, University of, Chieti, Italy; email:amerla@socrate.itab.unich.it
**I.T.A.B. Institute Advanced Biomedical Technologies, University of Chieti, Italy
***Villa Pierangeli Clinic, Pescara, Italy

At present, the diagnosis of varicocele is mainly performed through the symptomatic evaluation and EchoColorDoppler (ECD) analysis. The latter is commonly considered as the gold standard. Static Contact Thermography has been sometimes used for the same purpose, but with modest results.

New possibilitiesare presented by the Dynamic Digital TeleThermography (DDTT) approach. In fact, DDTT combines specific surface temperature distributions, related to the hyperthermia induced on the testicle by the disease, to the corresponding dynamics of thermal recovery after thermal induced stress.

It's also possible to evaluate the compensating effects that sometimes occur.

70 volunteers (age 18÷35, average 21±2), issued their informed consent and

1)that did not have a previous clinical history

2)that were negative to the clinical evaluation to ascertain the presence of varicocele at the time of the military recruitment,

were examined according to the following protocol approved by the Ethical Committee: after static thermographic evaluation of the scrotal temperature, clinical examination, ECD and DDTT analyses were carried out to ascertain the presence of a sub-clinical varicocele when a difference on the 2 emiscrota temperatures occurred greater than a prefixed warning threshold.

The DDTT test performed by means of a Digital TeleThermographic Camera AEG Aim 256 PtSi, 8-14 ?m, temperature measurement noise 0.02 K.

For each volunteer, and for each hemi-scrotum, the thermal recovery curves and the related time constants were calculated and analysed. In presence of the warning threshold, if significantly different thermal recovery was observed, as revealed by differences of the recovery time constant greater than a prefixed value, the presence of varicocele was hypothesised.

According with the method described above, in 27 cases (38%) out of 70 the presence of sub-clinical varicocele was supposed. The ECD and clinical examination confirmed the presence of the varicocele at various stages in all the 27 cases. In 2 out of 27 a compensated varicocele was detected.

The DDTT may provide significant additional information to the investigation of harmful varicocele in the testicle function, particularly in the sub-clinical phase. DDTT can also be useful for the identification of compensating varicocele, where the ECD is of minor advantage. Moreover, by means of the rewarming curves, the DDTT gives additional information about the thermoregulation properties of the scrotum.

Infrared Image in HNP Patients Associated With Obstruction of Femoropopliteal Artery

Ho Yeong Kang, Sang Ho Lee

Wooridul Hospital, Seoul, Korea

Purpose: It is rare that patient who complain of low back pain with leg pain are diagnosed as HNP associated with partial obstruction of femoropoplietal artery. This study was designed to identify specific findings of infrared imaging in patient with NHP associated with partial obstruction of femoropopliteal artery.

Method: Four patients were reviewed. NHP was diagnosed by CT, MRI or myelography. Obstruction of vessels was evaluated with Doppler sonography.

Results: In all patient, the magnitude and area of decreased body temperature was more predominant due to vascular obstruction of than herniated disc.

Conclusion: We must consider associated vascular occlusion in patients with disc herniation when there is a large area of low temperature (especially ankle and foot) and proximal an increased temperature area, not concordant with root thermatome.

Evaluation of Chronic Pain in Legal Medicine and Medical Insurance

G. Pari, *P.P.Balli, °C.Lore'

Pain Clinical Physiopathology Module, AUSL Rimini

*Legal Doctor, Health Director of the Sol et Salus Nursing Home in Rimini

° Department of Legal and Social Medical Sciences (Director Prof. Paolo Martini) Università degli Studi, Siena

Introduction

Doctors have always been asked to mitigate pain, and today this work is ever-present in the medical practice: in 1991 the European Parliament Commission for environmental safeguard, public health and consumers' protection judged pain as unnecessary and ominous, as it can attack human dignity, and therefore must be fought with all means and in particular with adequate medicines; very recently (1995) the World Health Association established, among the patients' rights to dignity, that the way of mitigating suffering has to conform to the current state of knowledge.

Legal medicine has not remained unaffected by this subject, and has analysed some of its specific aspects. We can mention for example:

- from the ethical point of view, the lawfulness of treatments, in particular following favourable evaluation by the highest catholic Church authorities (Pius XII, 1957; Cor Unum Papal Council, 1981) with regard to both the treatment of suffering, while distinguishing ordinary from extraordinary methods, and the use of analgesic drugs during the terminal phase of an illness;
- from the deontological point of view, the duty to inform, to the extend provided for by the new medical deontology code; the validity of the consent expressed by a person in a condition of serious need and therefore dependent from whoever can intervene to mitigate suffering;
- from the evaluation point of view, the subjectivity of pain expression and possibility of simulation, above all in specific fields such as industrial accidents and legal military medicine.

With regard to the bibliography on these matters, reference should be made to the legal medical treatises which, in various chapters, deal with the above-mentioned matters, in particular connected to the ethical, deontological and valuationl fields. As for the specific matter of physiopathology and pain therapy, after reviewing the main Italian legal medical magazines, we would like to mention the contribution by Cagliesi Congolani and Graev in 1986, and the numerous contributions by Lorè.

Over the past few years, pain research has been widely developed, and has lead to a complete review of the entire discipline. Now also legal doctors can and must take advantage of whatever is offered by the new definitions and techniques in order to face the problem in a new light.

Chronic Pain

Persistent Pain, that is to say chronic pain, which requires a specific medical diagnosis and treatment, falls within the scope of the legal doctor's interests, indeed certain situations now occur rather frequently and involve various fields.

A few examples can be given, which are very different in terms of frequency and extent of the injury:

- On one side the frequent case of distortion of the cervical spine, the so-called whiplash, which so often follows road accidents having various degree of seriousness and even more varied dynamic mechanisms; on the other side lesions to the nervous plexus, which are rarer but much more complex and often subject to delicate specialistic surgery.
- CRPS(Complex Regional Pain Syndromes) may arise during the course of traumatic or surgical lesions to cause complications, and are often underestimated...
- There may be surgical iatrogenic lesions, for example nerve lesions in case of plastic surgery for inguinal hernia (and in this case we are talking about nerve lesions which are not directly connected to surgery carried out with good technique) or painful syndromes resulting from surgery carried out on nerve structures or structures very close to the same, as in the case of slipped disc or carpal tunnel syndrome.
- A further particular example is also represented by the neurological lesions existing in the syndrome from vibrations or in repeated microtraumas, situations which can be referred to work pathology where pain sensitivity alteration represents a fundamental symptom (Rodriguez, 1997).

Interdisciplinary Collaboration

Collaboration between the pain specialist and legal doctor,(who due to this work is used to be confronted with specialists from various medical disciplines), becomes therefore indispensable in order to clearly define the specialist's fields of intervention and responsibility in clinical practice.

It is only through this collaboration that the legal doctor's work can be successful in cases where it has the objective of proving or excluding the presence of pain-illness in relation to a juridically relevant antecedent, and thus can avoid, as far as possible, the condition of having to believe or not believe the patient's subjectivity, which would inevitably imply an inadequate evaluation of the pain resulting from the clinical history.

It can be remarked that the case history, objective examination and image diagnostic assessments are fundamental but not decisive in terms of pain objectivity.

However, nowadays, pain study resources, both diagnostic and therapeutic, are available which allow much better accuracy to be achieved in objectivity, by measuring the alterations in progress, comparing symmetrical regions and evaluating lesion development over time.

Infrared thermography has been mentioned, and also neurometry among neurophysiological investigations; these are non-invasive repeatable and reproducible investigations, certainly adequate for clinical and legal medical evaluation, even with repeated studies.

Consideration should also be given to pharmacological tests, which are carried out for diagnostic reasons and cannot be reproduced for a mere legal medical purpose, taking into account their intervention character.

The documented therapeutic treatments, in particular analgesic drugs administered in the spine and continually by means of infusions for neuro-mod ulation, nerve blocks, and neurostimulator implants, also take on considerable importance as indirect indications of the presence of pain and its clinical relevance, requiring those specialist treatments as therapy.

The cases of somatic pain and somatoform pain disorders, the diagnosis of which concern psychiatry, are also known and defined (Dell'Osso and Lomi, 1989); with these the competence of the pain specialist is however helpful, in order to exclude the presence of a neurogenic component and to point therapy and evaluation in the right direction.

A further extremely important element regarding the definition of pain-illness, is the prognosis which allows the pain specialist to classify, for example, neuropathic alterations as permanent; in this case the prognosis corresponds to the legal medical concept of permanent illness, since pain will not diminish but probably show progressive accentuation over the time of residual life, which may even be for many years.

From these considerations, it is therefore obvious that continuity exists between legal medicine and clinical disciplines which, although having different scopes, can work together to investigate biological reality and pathology, thus providing benefit for the patient and society.

Legal Medical Aspects

The legal medical considerations which have already been pointed out about pain, can be applied to pain-disease.

There are no doubts about the ethical lawfulness of pain treatment, also with the use of analgesic drugs which act on the central nervous system, and also when treatments continue for years, and even if we find ourselves in an almost experimental field, since the long-term effects of pharmacological and electric neuromodulation treatments are not entirely known yet;

- The duty to inform is particularly important, both for prognosis and possible long-term consequences (iatrogenic pharmacological dependence, toxic complications), as well as for the frequent need to involve the members of the family in continuous prolonged home nursing;
- The acquisition of consent shall respect the autonomy of the person who is subject to treatment, but shall in fact represent the expression of the therapeutic pact between patient and doctor, resulting from a real therapeutic alliance which should overcome both a condition of paternalistic prominence of the doctor's role and a mere intellectual work contract regulated by the Civil Code laws.
- In terms of evaluation, it is to be stated beforehand that a causality connection must always be proved between the illness or the current outcomes and the juridically relevant antecedent being examined; this assessment may not rarely become complicated by the coexistence of intriguing situations such as, for example, repeated traumas which have followed each other in the same location, that is to say surgery carried out in consequence (or due to) a trauma.
- Neuropathic pain, which is as far as possible objectivised through the collaboration of the pain specialist, is taken into careful consideration within various legal medical valuational fields. We can provide a few examples:
- *The penal context* where, referring to art. 683 of the Penal Code, when the pain is consequent to a personal lesion, the length of the illness must include its entire clinical development, until clinical stabilisation is reached; in the case of considerably serious permanent outcomes, reference may be made to permanent weakening of an organ or to a probably incurable illness, with consequent aggravating circumstances. It is to be noted that blows (art. 581 Penal Code) refer to acute pain, not chronic pain;
- *the civil context* where, following a biological injury referred to a specific anatomic part or nerve function, therefore a part independent from moral injury, a proposal may also be made in specific cases for a possible invalidity for a specific work activity;
- *The private insurance context,* including the increasingly widespread medical policies, where an injury is objectivised and measured, therefore conforming to the usual contractual forecasts;
- *The social insurance context*, where the presence of pain-disease aggravates the outcomes of industrial accidents and interferes with the working capacity protected by Social Security provisions.

The significance and validity of instrumental tests in legal medicine and medical insurance

Camaioni D., Evangelista M.

Università Cattolica del Sacro Cuore – Roma (Catholic University of the Sacred Heart – Rome) . Anesthesiology and Intensive Care Institute

The fact that in legal medicine and medical insurance it is generally found that pain alone is hardly ever considered sufficient in determining or confirming a condition of illness has led the authors to a number of considerations. These are related to the need to identify diagnostic methods and procedures intended to objectivise and quantify the effective impact that pain can have in determining and configuring an indemnifiable damage.

In other words, and above all in the light of the new concept of health (see the definition given by the WHO), the need to deal with the impairments deriving from the inability to resume any kind of activity, non just work, beyond the period of illness because of pain persistence, entails a review of the definition of pain, which is no longer seen as a symptom accompanying an illness but as a separate illness, as in the case of chronic pain.

The problems involved in pain definition are relatively easy to solve whenever there are documentary records of their association with anatomical and/or functional lesions, having a causal nexus; on the contrary, a solution is rather more arduous to find whenever the pain experienced is not imputable to documented lesions. Can this issue be ascribed to an insufficient solution due to the limitation of the currently available diagnostic methods, or instead should it be referred to a "functional" cause and therefore, because of its own nature, transient and unconnected with documented organic alterations?

What has been concisely explained here can be found in the everyday work of the pain therapist and, especially in the context of chronic pain, it indicates the need for instruments able to provide objective evidence for painful syndromes which, although not having diagnostic, univocal or shared evidence, are of such magnitude that they bring the patient to serious levels of social and professional invalidity.

Within such context, and following the premises above, the purpose of this contribution is to highlight the usefulness and validity of infrared thermography in diagnosing and monitoring the major painful syndromes concerning legal medical matters. It has been specifically chosen not to provide a close examination of such methods as the NMR, CAT, Radiographs, EMG etc., which in any case can already be found in numerous specialistic texts.

The first point to be made is the fact that infrared thermography does not exclude but integrates and completes the diagnostic procedures in order to determine that a damage has occurred, either in a civil, social insurance, social security or, *extrema ratio*, penal context.

Thermography values are correlated to normal neuronal and vascular, therefore metabolic activity; consequently, unlike other methods, thermography provides a "dynamic" view of a situation which cannot be achieved by other techniques.

In the same way as other methods, it is not able to provide an "iconographical image of pain" but finds its rational use in its ability to reveal physiopathogenetic conditions correlated to painful syndromes, described by characteristic thermal alterations; these provide thermal maps suggesting microcirculation alterations (vasoconstriction / vasodilation) which result from dysautonomia and traumatisms of the nervous, muscular, bone, circulatory and cutaneous systems.

When pathological events occur, the consequent neuronal, vascular and metabolic modifications are able to determine alterations of cutaneous and local temperature which can be revealed by means of infrared thermography; this instrument can also reveal the vascular, thermal and/or metabolic modifications, in distant or counter-lateral locations with respect to the area of the original lesion, which constitute the epiphenomenon of neurovegetative reflex mechanisms.

Considering the numerous indications for the use of thermography in legal medicine and medical insurance, as well as the limited space available here, the subject cannot be treated exhaustively; however, the Authors deem it useful to describe two pathological pictures where thermography is recognised in relation to its usefulness and validity.

Table 1 at the end of this contribution can be consulted to complete the information given.

Finally, some specific operational characteristics (such as rapidity of execution, absence of damage to the patient, test repeatability) are worth mentioning, as they prove to be particularly useful when dealing with legal, medical and insurance problems with regard to a logistic perspective.

Thermography and Neuropathies

With reference to what has been explained above, the role of thermography in recording cutaneous thermal variations on a neurological basis proves to be indisputable and extremely accurate, to the extent that numerous authors use this method to reveal and process physiopathogenetic information and data about painful neuropathic syndromes.

Its usefulness in the legal medical context derives from the constant dermatomal distribution of thermal variations; moreover a chronology of the damage (and therefore a legal medical "time-related" evaluation) can be established by observing hyperthermia during the acute phase, followed by hypothermia in the chronic phase. Each of the two typical thermal pictures referring to neuropathic pain can, in turn, be subdivided in two further stages, (Hot I-II) and (Cold I-II), which correspond, functionally speaking, to more or less total involvement of the structures concerned. The Heat I phase can be associated to complete interruption of all nerve fibres which corresponds, clinically speaking, to loss of sensitivity in the dermatoms innervated by the injured nerve; at the same time absence of ANS control can be detected. This clinical picture is repeatable sympathetic or complete nerve block, in both cases with local anaesthetic. This is followed by the Heat II phase, also called ABC syndrome (Angry Backfiring C-Nociceptors) which represents a painful syndrome caused by a trauma of the afferent somatic pathways. Ochoa has associated hyperalgesia to the sensitisation of polymodal C-receptors: the hyperthermia detected in these cases is to be associated to neurosecretion with antidromic direction, which can be detected in hyperactive nociceptors.

The Cold I phase finds its etiopathogenetic moment in the sympathetic denervation which induces hypersensitivity in the circulating catecholamins, and is at the base of the vasospasm in the region being investigated.

A hyperactivity in the SNS determines, thermographically speaking, a cold area (Cold II) and can always be associated to an irritative prickling or partial nerve lesion or neuropathy from compression.

Thermography and Reflex Sympathetic Dystrophy

Otherwise defined as Complex Regional Pain Syndrome, this painful illness with chronic invalidating progression, derives its aetiology from traumas which can cause a dysfunction of the autonomous nervous system. The late phase, which is easy to diagnose, is unfortunately refractory to therapy. Up to now thermography, thanks to its capacity to highlight thermal variations resulting from microcirculation alterations from dysautonomia, represents the elective test for the initial phases; it can also be the solution factor in modifying the natural history of this disease, since it can establish an early therapy. Thermal map normalisation provides evidence of recovery.

Table 1
Pathologies for which a thermological test is suitable
(modified by Castorina F. and Colleagues)

Cranial nerves and vases
Lower or upper limbs for traumas or vascular pathologies
Study of the nervous nociceptive system, afferent and efferent
Neuropathic pain
Moles, Nerves, Melanomas
Reflex sympathetic, post-surgery, traumatic, etc. Pain Dystrophies
Herpes Zoster and Post-Herpes Neuralgias
Headaches

Medico Legal Applications of Thermography: About Three Clinical Cases.

Miranda G*, Hernandez B , Robaina F

Instituto Canario de Ciencias Neurológicas. *Hospital Insular Universitario de Gran Canaria. Menendez y Pelayo 8.
Las Palmas de Gran Canaria. 35010. Spain.

Our group has been working for three years in "Legal and Forensic Medicine". We show three cases where the thermographic results have been determinant to confirm doubtful diagnosis or to determine if it is a chronic or an acute lesion.

Thermography: Agema 900 Thermovision equipment has been used. Our laboratory presents an ambient temperature of 21ºC, free of external hot sources, and patients stay for 20 minutes before starting the test. Previously all the patients received a paper with instructions abut the preparation for the thermographic examination.

Case nº1: 34 years-old female; housewife, who suffered a traffic accident with politraumatism. One month later she was diagnosed by electromyography, of a severe partial injury in the left sciatic nerve . Seven months after the accident we explored the patient finding vasomotor , sudomotor and motor disturbances, also allodynia and hyperalgesia. The limb showed signs of vasoconstriction and coldness of the skin. We noticed in the thermogram a general decrease of skin temperature in the whole inferior left limb. Thermal asymmetries ranged- between 1ºC - 2ºC . A complex regional pain syndrome, (CRPS) type II or causalgia, was diagnosed. After thermography, a Neurostimulator was implanted, improving the clinical symptoms and produced rewarming in the leg.

Case nº2: 49 years-old female, with an intraspinal pump of morphine due to a CRPS type I in her left superior limb. It is surprising that she presented no functional limits and no alterations in her reflexes, being able to work according to the national health rules. In the thermogram, we verified the presence of a global hypothermic pattern in the whole left superior limb. Thermal asymmetries, higher than 1ºC, confirmed the presence of CRPS I. We also made a Sensorial Quantitative Test where we could verify thermal allodynia to cold. The Th was decisive to give a definitive working inability to the patient.

Case nº3: 42 years-old male, heavy drinker. He suffered an accident in a bus, hitting his left knee against the front seat. After the injury, the patient started feeling pain and had problems to walk. The radiological studies showed a femoral head necrosis. The insurance company indicated that this lesion was previous to the accident and not a consequence of it. We made a thermogram, where we could see a hypothermic pattern in the affected limb. Thermal asymmetries ranged between 1-2 ºC. After thermography, the insurance company accepted that the patient had suffered a reactivating of a former lesion and therefore, he had to receive medical cares.

Thermography in the Diagnosis of Neuro-Vascular Diseases in the Various Animal Species

Purohit RC[1], JH Humburg[1], J. Schumacher[1], DD Pascoe[2]

1Department of Large Animal Surgery and Medicine and
2Department of Health and Human Performance
Auburn University , AL 36849 U.S.A.

The skin surface temperature in mammalian species is well regulated by neurohormonal and vascular system. Changes in skin blood flow caused by associated vascular and nerve injuries can be easily quantified and documented using a noninvasive thermography technique. Mapping of skin surface temperature can be made in response to exercise, systemic medication and also in response to heating and cooling of the body extremities. Understanding of physiological mechanisms by which thermal gradient and patterns changes in response to external and internal environment are essential component for obtaining a reliable diagnostic thermograms.

In our clinical studies when animals were presented with painful conditions, changes in associated skin surface temperature were documented by infra red thermography. Problems associated with cervical, thoracic and lumbar area injuries were successfully documented and differential diagnoses was provided by thermography when x-rays and myelograms failed to provide definitive diagnosis. This diagnostic value was further enhanced by obtaining thermograms, before and after exercise, after administration of phenothiazine tranquilizer acetylpromazine in differentiation between the vascular vs nerve injuries. Thermography has been very efficacious for the diagnosis of peripheral neuro-vascular diseases in all animal species studied thus far in our clinic.

Clinical Trials of Thermal Coronary Angiography System

Iwao Fujimasa, Hideo Nakazawa, Shiaki Kawada

National Graduate Institute for Policy Studies (GRIPS);
2-2 Wakamatsu-cyo, Shinjyuku-ku, Tokyo, 162-8677, Japan

The main purpose of the research is to display coronary arterial network at grafting operation of coronary artery with a non-invasive method. Recent advances of medical infrared imaging devices, especially small non-cooling instruments with high frame speed, give rise to revive some clinical applications. The TCA system was composed of a far-infrared camera (FIR camera), Thermal Vision LAIRD S270 (Nikon), and a video camera, Handyscope HVS-10 (Aishin Cosmo Co. Ltd.). The FIR camera has an image sensor with 410,000 picture elements of PtSi Shottky-barrier charge-couple-device cooled with a Stirling engine, and has a camera head of 140(W) x 390(D) x 175(H) mm in size and 9.2 kg in weight. The FIR camera and the video camera were mounted on an aluminum board and were assembled into an optical head system. The fused images were displayed on television monitors in an operation theatre through a camera control system. Image and control signal between the optical head and the camera control system, which contains digital thermal images (via IEEE 244 interface), thermal video images (as NTSC), visible images (NTSC), and control signals for camera head (via optically modulated RS-232C interface), was connect an electrically shielded line of 20 m in length. The TCA system has been installed in a cardiac operation room since October 1999. The optical head system was mounted on a moving arm for monitoring devices under the ceiling. Three coronary bypass graft operations with median section of sternum were applied for the feasibility study. Required specificity for the TCA system obtained from the feasibility study is summarized as follows:

1) Minimum requirement of temperature sensitivity for describing coronary artery network precisely is 0.15°C.
2) Adequate number of picture elements is more than 100,000 pixels.
3) Minimum field time should be less than 1/30 sec.
4) Minimum working distance from the surface of operation table to the optical head should be more than 0.8 m.
5) Visible image should be overlapped temporarily for finding location of coronary artery and be discriminated them from other vessels.
6) Temperature range of cardiac muscle surface limited 30°C ~ 37°C and that of coronary arteries without cooling on extra corporeal circulation shows 34°C ~ 35°C.
7) Temperature of cardiac muscle surface during anastomosing coronary bypass graft using cardioplegia method fell less than 23°C at first and gradually increase to 27°C. After releasing the coronary clip, high temperature coronary artery image appeared in periphery regions of the artery.
8) Viability of the cardiac muscle was able to evaluate by the comparison of surface temperature between the pump-on base line image before anastomosing and after.
9) As the optical head system is installed on high untouchable place, a long interface cable for controlling devices and gathering data should be developed. Every manipulation procedures for controlling the optical head should be done in remote place (ca. 20 m from the camera head).

Heat Loss From Abdominal Cavity Exposure In Rats

ML Brioschi, D Colman, JVC Vargas, LC von Bahten, C Nakagawa, M Cimbalista Jr

General Surgery Department of Hospital Universitário Cajuru - Pontifícia Universidade Católica do Paraná (HUC-PUCPR) and Mechanical Engineering Department of Universidade Federal do Paraná (Demec-UFPR).

Heat loss leading to hypothermia is common during surgery, particularly when a body cavity is exposed.

The aim of this paper was to analyse heat loss from the abdominal cavity exposition in rats and estimate the ratio of heat loss from non-peritoneal surface (NPS)and peritoneal surface (PS).

Eighteen Wistar rats were used, weighing 0.247 ± 0.054 kg, divided into three groups:
I) no exposure;
II) minimal exposure; subjected to median xiphopubic laparotomy
III) maximum exposure; subjected to median xiphopubic laparotomy with maximum bowel exposure.
We obtained the thermal image from the peritoneal surface with an AGEMA550. Heat losses were 0.95±0.34 W, 1.53±0.25 W, 2.73±0.74 W respectively for groups I, II, III ($p<0{,}001$; ratio=1:1.6:2.8). The heat losses from the SNP between the groups weren't significantly different: 30.19±3.52 W/m^2; 36.29±1.24 W/m2 and 31.61±5.14 W/m^2 respectively for groups I, II, III. The same occurred with heat losses from the SP: 446±189 W/m^2 and 374± 109 W/m^2 for groups II and III, respectively. It is concluded that abdominal cavity exposition heat loss in rats results in hypothermia proportional to surface exposition, and the ratio of heat loss from non-peritoneal surface (SNP) and peritoneal surface (SP) was 1:13.

News in Thermology

3rd Polish Congress of Thermology

As reported in the last issue of this journal, the Polish Society of Thermology will organize their 3rd Congress in Djerba, Tunisia, from September 21-28, 2000.

This meeting will continue the series of sucessful conferences of Polish experts in thermal imaging, which started two years ago in the Tatra mountains near Zakopane. In addition to the pleasant environment of the mediterranian island Djerba, a Certification Course on "Practical application of thermal imaging in medical diagnosis" will be organized.

For further information contact the organizing Committee at

Pediatric and Nephrology Clinic;
Central Clinical Hospital
Military University, School of Medicine;
Szaserow 128 str,
00-009 Warsaw-60, Poland

Tel/fax + 48 22 6817236

12th International Conference on Thermal Engineering and Thermogrammetry (THERMO)

from the 13th to 15th of June, 2001
in the OSSKI Center (Törley Palace), Budapest XXII (Budafok) Anna u.5.

Objectives

The developments of measurement theory and technologies help the energy-conscious design of thermal engineering equipment and processes as well as the better understanding of thermal phenomena in living organisms.

The Conference will cover topics both the field of theory and application including new measurement concepts; transducer technique; thermal mapping; contact , optical and IR imaging; biomedical and biotechnological applications; thermal informatics, automatic methods and systems for industrial energy management and process control; heat loss detection and analysis; heat and mass transfer, utilization of alternative energy, thermophysical properties and the common practice of thermal engineering.

This Conference will provide the latest information on the above topics together with a good opportunity for personal discussion among experts in the field of energy conservation, control of energy release and loss, protection of human environment, medical and veterinary applications, remote control through infrared sensors .

Organisation of the Conference

The language of the conference and abstracts is English. Oral presentations of papers and a poster session will be organized. Duration of each presentation will be limited to 15 minutes and additional time for discussion will also be provided.

Venue

The conference is hosted by the OSSKI Center (Törley Palace, Budapest, XXII. (Budafok), Anna u. 5.) located in the vicinity of the famous Budafok wine cellars.

Information

Application Forms should be sent to:
Dr.Imre BENKÖ,

MATE Secretariat, House of Technology,III. 318., H-1372 Budapest, POB. 451., Hungary.
Fax: +361-353-1406 Phone: +361-332-9571.
E-mail: mate@mtesz.hu

For any further information please contact the following address:

Dr.Irme BENKÖ,

Technical University of Budapest (BME), Department of Energy.(DoE) H-1111 Budapest, Müegyetem rkp. 7, D.208, Hungary, office phone. +361-463-2183
BME Fax: +361-463-1110,
DoE Phonelfax: +361-463-3273 or -463-3272.
E-rnail:benko@eta.enrg.bme.hu

Thermal Imaging at the World Congress 2000 on Biomedical Engineering in Chicago

This year´s conference of the IEEE continued the tradition of including sessions on infrared imaging in the programme. The Biomedical Engineering Congress, held in Chicago in late July, accepted 13 contributions related to infrared imaging, .

Two Mini-Symposia, each with three lectures, were highly appreciated by the attendants and achieved a high rank in the evaluation with respect to the scientific content and the educational value of the presentation.

Well known experts in the field from Europe, Japan and USA presented new results of the application of infrared imaging in breast cancer, vascular disorders and the physiology of body temperature regulation.Standards for the use of infrared imaging were also discussed.

The progress in development of modern, highly accurate and precise equipment for thermal imaging has stimulated new research in traditional applications of the technique, Based on accepted, standardised procedures and a study design of the highest methodological level, the revived use of infra red imaging may achieve better and less contradictive results in the near future than the investigations conducted in previous 25 years.

The interest of biomedical engineers in thermal imaging has contributed much to the actual reconsideration of infrared thermography in medicine.

20th Anniversary Meeting of the German Society of Thermology

20 years ago, the German Society of Thermology was founded. The Annual Meeting in Celle, was held on August 5 to remember and celebrate the 20th Anniversary.

Posters and oral presentations from members and friends of the society proved scientific endeavour and continuous interest in diagnostic and the application of therapeutic heat in Germany.

Hot jazz from the RED WINGS (featuring D.Rusch, Treasurer of the German Society of Thermology and Vice-president of the European Association of Thermology, on cornet) was the distinctive musical framework for this meeting.

The conference was originally partly intented, to celebrate the G.Bergmann Award for the second time. Unfortunately this occassion had to be postponed to 2001, because of an insuffient number of submissions.

However, the Bergmann Award is re-announced for 2001. The deadline for submissions ends by August 31, 2001. The Committee of the German Society of Thermology strongly encourages submissions from around Europe to compete for this award.

5th International Congress of Thermology 2001 in Vienna

The European Association of Thermology will host for the second time the next, 5th International Congress of Thermology. This congress has been held every three years since the first in Washington in 1989. The organisation of this meeting rotates from the AAT(=American Academy of Thermology) to the EAT (=European Association of Thermology) and then the APFT (=Asian Pacific Federation of Thermology). These three continental societies form the International College of Thermology. The presidentship of the ICT changes also every year from one member society to the next. In 2001 the presidentship of the ICD will come back to Europe (former European presidents were Prof. Dr. L.Thibault de Boesinghe, Belgium, Prof. Dr. R.Clark, U.K, and Dr. K.Ammer, Austria). In 1992 the International Congress was held in Ghent, and will be held in Vienna 2001 for the fifth time after Matsumoto in 1995 and 1998 in Ft.Lauderdale.

The Austrian Society of Thermology will organize this meeting on behalf of the EAT and hope, that the conference will be as sucessful as the European Thermology Congress held at the same place in 1997. Similar to last time, the International Conference is combined with the 14th Thermological Symposium of the Austrian Society of Thermology and the Annual Meeting of the German Society of Thermology. A distinguished panel of experts will form the Programme Committee which will bring together the leaders in the field from around the world.

Main intention of the meeting is to intensify the cooperation of all users of infrared imaging for the purpose of diagnosis, which is the detection of disease in medicine, but may cover many other fields in technical and industrial applications.

In medical thermology, other aspects than thermo-diagnosis must not be forgotten such as thermo-physiology and heat treatment, both for superficial and deep body tissues. In particular for temperature monitoring of deep body hyperthermia techniques other than infrared such as magnetic resonance imaging are used. Invited speakers will present state of art lectures for these topics.

A small exhibition of latest developments of equipment for thermal imaging and for heat treatment will be shown on site of the conference.

The conference will be organized by

e + o incentives & conventions
Kramergasse 1, 1010 Vienna; Austria
Tel: + 43 1 533 87 32, Fax: +43 1 535 99 31
E-mail: mailbox @eoinc.at URL: www.eoinc.at

which will also provide accomodation facilities.

Deadline for early registration at a reduced fee (ATS 3000.- instead 3500.- before March 7, and 4000.- after March 7) and for submission of abstracts is January 19, 2001. Registration will include admission to all scientific sessions, the book of abstracts, lunch on April 28 and 29, and coffee breaks during the whole conference. One day registration at ATS 1200.- will be available on site, but excludes meals.

All Registration forms must be sent to the organizing secretariat e **+o incentives & conventions,** which will also provide information on the conference and facilities for registration on their web- site in due course.

Submitted papers related to the topics of the conference are preferred, however, other free papers outside of the main theme are welcomed.

All submitted papers must be organised as follows: background, aim of the study, methods, results, conclusion. Please use the abstract form printed on page 166 of this issue. A simultaneous submission on disk in common word processing format is strongly suggested. Submissions by e-mail to:
"KAmmer1950@aol.com" are welcomed.

All submissions must be sent **not later than January 19, 2001** to the conference President

Kurt Ammer, MD, Ph.D

Ludwig Boltzmann Research Institute for Physical Diagnostics, Hanuschkrankenhaus,

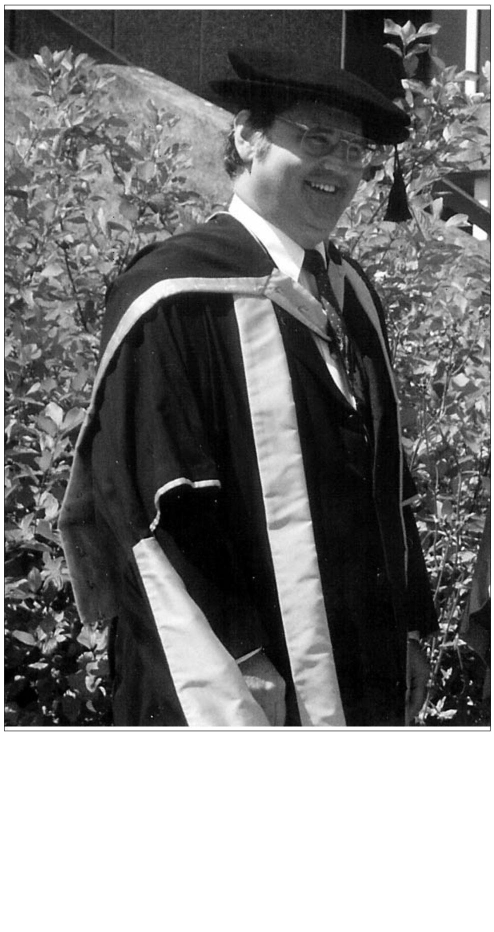
Heinrich Collinstr. 30, A-1140 Vienna,Austria

The organizing Committee definitely expects an interesting, stimulating and exciting conference in the lovely Viennese springtime of 2001.

Congratulations

Congratulations to the editor Dr Kurt Ammer MD on receiving the degree of Doctor of Philosophy in July 2000. Dr Ammer was granted the degree by the University of Glamorgan in The U.K. for his thesis of scientific publications entitled "*Thermological Studies in Rehabilitation and Rheumatology Using Computerised Infrared Imaging*". Dr Ammer is the first European physician to receive this higher degree given for infrared imaging in medicine from the School of Computing at Glamorgan.

The University School of Computing has a medical imaging research group, which includes infrared thermal imaging as one of its main fields of interest. A new laboratory for thermal imaging is being created, for new projects concerned with standards, normal reference images and effects of stress loading on the human body. Some centres have already indicated a willingness to collaborate in the normal thermogram project, and it is hoped that this study will begin next year. More details can be found on the web pages, http//www.glam.ac.uk under the school of computing, or linked to Prof. Bryan Jones and Prof. Francis Ring.



Veranstaltungen (MEETINGS)

21.-28. September 2000

3rd Congress of the Polish Society of Medical Thermology in Djerba, Tunisia plus

Certification Course
"Practical application of thermal imaging in medical diagnostics"

Information:
Prof.Dr.A.Jung

Pediatric and Nephrology Clinic,
Central Clinical Hospital, Military University, School of Medicine. Szaserow 128 str
00-909 Warsaw-60, PL

Tel/fax +48 22 6817236

2001

26.-27. January 2001

7thInternational Conference on Infrared Imaging in Tampa, Florida

Clinical & Industrial Sections

Fee: 195 US $ per person pre-registered
275 US $ after November 1, 2000

Payable to: Ashwin Systems International Inc.
P.O. 1014m Dunedin, FL 34697 USA
Phone: +1 727 785 5844

Information:
G.J. Rockley
Director of Operations
Teletherm Infrared

E-mail: infrared@gte.net
Internet: http://home1.gte.net/infrared/7thinter.htm

14. March 2001

Meeting of the UK Thermographic Association at the University of Glamorgan, Pontypridd.

*Information:*Mr. Collin Pearson
The Building Services Research and Information Association, Old Bracknell Lane West, Bracknell, Berkshire,
RG12 7AH;England
Tel +44 1344 426511Fax +44 1344 487575
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16 – 20. April 2001

XXVIII conference SPIE Aerosense Infrared Technology and Applications in Orlando

Conference Chairs:
Andres E. Rozlosnik, SI Termografia Infrarroja (Argentina);
Ralph B. Dinwiddie, Oak Ridge National Lab.

Topics: Applications of Infrared in:

Automotive Industry, Power Generation and Distribution, Manufacturing and Processing Industries, Aerospace Applications, Infrastructure, Environmental & Resource Monitoring; Research & Development; NDT & Material Evaluation; Night Vision; Maintenance Management;Miscellaneous

Panel Discussion and Invited Papers are expected in the following important fields:

Infrared cameras calibration ISO 9000 Industrial requirements Blackbodies NIST Traceability .Law Enforcement and Fire Rescue

Topical Workshops

Related Tutorial Short Courses

Joint sessions are being planned in which attendance in this conference will be combined with two other important conferences of the AeroSense symposium:

Joint Session with Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XII (OR34):

Research and Development Applications

Although initially developed by the military, infrared imaging systems have a wide range of applications in the civilian and industrial communities. This joint session focuses on new technologies, developments, or approaches to existing methods that advance the field or lead to new application areas. Suggested topic areas include, but are not limited to, micro- scopy, enhanced spatial or time resolution, spectral analysis, fiber bundle applications, medical applications, and image interpretation.

Abstracts Due Date: 18.September 2000

Abstract Due Date for On-Site Proceedings: 4 September 2000
*Manuscript Due Date:*19 March 2001

Manuscript Due Date for On-Site Proceedings: 22 January 2001

Information:
Internet: http://spie.org/web/meetings/calls(or01/

28.-30. April 2001

5thInternational Congress of Medical Thermology combined with the 14th Thermological Symposium of the Ludwig Boltzmann Research Institute for Physical Diagnostics and the Austrian Society of Thermology and the Annual Meeting of the German Society of Thermology

Venue: SAS Radisson Palais Hotel, Vienna

Main Theme: Thermology- the science of heat

Topics: Thermo-Physiology,
Body temperature measurement by infra red and other techniques
Diagnostic infrared imaging
Thermo-Therapy
Monitoring (maintenance) by thermometry

Deadline for abstracts: January 19, 2001

Scientific Programme Committee:

DDr.K.Ammer (president)	(Austria)
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Prof.Dr.I.Benkö	(Hungary)
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Information:
OA.DDr.Kurt Ammer
Ludwig Boltzmann Research Institute for Physical Diagnostics, Hanuschkrankenhaus, Heinrich Collinstr. 30; A-1140 Wien

Tel: +43 1 914 97 01; Fax: +43 1 914 92 64
E-mail: KAmmer1950@aol.com

13.-15. June 2001

12th International Conference on Thermal Engineering and Thermogrammetry(THERMO) in the OSSKI Center (Törley Palace), Budapest XXII (Budafok) Anna u.5.

Conference Organizer:

Branch of Thermal Enineering and Thermogrammetry

Hungarian Society of Thermology at MATE

European Association of Thermology

International Centerfor Heat and Mass Transfer

Deadline for abstracts: 15.10.2000

Information
Dr.Irme BENKÖ, Technical University of Budapest (BME), Department of Energy
(DoE) H-1111 Budapest, Müegyetem rkp. 7.
D.208., Hungary,
office phone. +361-463-2183.
BME Fax: +361-463-1110,
DoE Phonelfax: +361-463-3273 or -463-3272.

E-rnail:benko@eta.enrg.bme.hu
or mate@mtesz.hu

19.-21.June 2001

8th International Symposium on Temperature and Thermal Measurements in Industry and Science (TEMPMEKO 2001) in Berlin, Germany

Organized by Physikalisch-Technische Bundesanstalt (PTB) und VDI-VDE-Gesellschaft mess- und Automatisierungstechnik (GMA)

Topics: Instrumentation and Methods
Fundamental Aspects and Standards
Traceability and Dissemination
Sensors
Applications in Thermometry and Humidity

Deadlines:

Submission of abstracts 30.9.2000
Notification of acceptance: 10.12.2000
Submission of full papers: 1.4.2001

Information: VDI/VDE-GMA
Tempmeko 2001
Graf-Recke-Straße 84
D-40239 Düsseldorf
Phone:+49-2116214-215 Fax:+49-2116214-161

E-mail:tempmeko@vdi.de
Internet: http://www.vdi.de(gma/tempmeko.htm

22.-24. June 2001

American Academy of Thermology
Annual Conference, Auburn University, Alabama, U.S.A

Topics for presentation or poster session:

The conference planning committee will make the final assignment of abstracts to conference sections based on topic area and abstract submissions.

Thermal Physiology, Pharmacological, Neurology/Neuroscience, Vascular, Orthopedics, Breast, Forensics, Technical/Equipment, Applied Thermography, Veterinary Medicine, Clinical Medicine/Surgery, Pain, other Pathologies (RSD, diabetes, wound healing, etc.)

Deadline for Submission of Abstract:
February 1, 2001

Registration Fee (US dollars) :
* After April 1, 2001 add $25

Members $250
Non-Members $300
Residents, Nurses, Technicians $150

Teaching Courses and **thermography certifications** will be available at the conference.

For more Information, Abstract Forms, or Abstract Submission Contact:

Ms. Pam Helmke,
Conference Coordinator
College of Veterinary Medicine, 05 Greene Hall,
Auburn University, AL U.S.A 36849-5528 ;
Phone (334) 844- 3699; (800) 483-8633
Fax (334) 844-3697;
Email chambpj@vetmed.auburn.edu

David Pascoe,
Scientific Director;Dept. of Health & Human Performance; 2050 Memorial Coliseum
Auburn University, AL U.S.A 36849,
Phone (334) 844-1479;
Fax: (334) 844-4025; Email pascodd@auburn.edu

5th International Congress of Thermology

organized by the European Association of Thermology
Österreichische Gesellschaft für Thermologie
Ludwig Boltzmann Forschungsstelle für Physikalische Diagnostik

Radisson SAS Palais Hotel

Vienna / Austria - April 28-30, 2001

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Title of abstract____

Return this form not later than January 19, 2001 to
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Ludwig Boltzmann Forschungsstelle für Physikalische Diagnostik im Hanuschkrankenhaus
Heinrich Collinstr. 30
A-1140 Wien, Austria
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This journal is a combined publication of the Ludwig Boltzmann Research Institute for Physical Diagnostics and the Austrian Society of Thermology. It serves as the official publication organ of the European Association of Thermology (EAT), the American Academy of Thermology, the German Society of Thermology, the UK Thermography Association (Thermology Group) and the Austrian Society of Thermology. An advisory board is drawn from a panel of international experts in the field. The publications are peer-reviewed.

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Hernalser Hauptstr.209/14
A-1170 Wien
Österreich

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