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Experimentally induced frostbites

Cryotherapy and intramuscular temperature

Conference Abstracts
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The relationship between skin surface temperature measured via Non-contact Thermal Imaging and intra-muscular temperature of the Rectus Femoris muscle

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SUMMARY

Cryotherapy; the application of cold to achieve therapeutic objective, is the most commonly used technique in the acute management of musculoskeletal injuries. Despite superficial application, the deeper tissues are ordinarily the target tissues of cryotherapy. The relationship between skin surface temperature (T_{sk}) and intra muscular temperature (T_{im}) are currently poorly understood. Following clinically relevant 15 minute application of crushed ice (CI) to the Rectus Femoris muscle, T_{sk} data were collected using Non-contact thermal imaging (TI), simultaneously with T_{im} by thermistor probe. The relationship between the 2 parameter's was investigated. A strong negative quadratic relationship was established, suggesting that T_{im} decreased as T_{sk} increased. The time period following removal of the cold modality should therefore be considered an important part of cryotherapy treatment sessions to achieve full therapeutic benefit.

KEYWORDS:Intra-muscular temperature, Non-contact thermal imaging, Skin temperature, Rectus femoris.

DER ZUSAMMENHANG ZWISCHEN DER THERMOGRAPHISCH BERÜHRUNGSFREI GEMESSENEN HAUTTEMPERATUR UND DER INTRAMUSKULÄREN TEMPERATUR DES M.RECTUS FEMORIS

Kryotherapie; die Anwendung von Kälte zu therapeutischen Zwecken, ist die gebräuchlichste Maßnahme in der Erstbehandlung von muskuloskelettalen Traumen. Trotz der oberflächlichen Anwendung stellen üblicher Weise tiefliegende Gewebsschichten das Zielorgan der therepeutischen Kälteanwendung dar. Der Zusammenhang zwischen Hauttemperatur und der intramuskulären Temperatur ist zur Zeit nicht völlig klar. Deswegen wurde nach einer klinisch relevanten, 15 Minuten dauernden Anwendung von zerstoßenem Eis am M. rectus femoris die oberflächliche Hauttemperatur berührungslos mittels Infrarotthermographie und gleichzeitig die intramuskulären Temperatur mit Hilfe eines Thermistors gemessen. Der Zusammenhang zwischen diesen beiden Messparametern wurde untersucht. Es zeigte sich eine deutliche negative quadratische Korrelation, die darauf hinweist, dass sich die intramuskuläre Temperatur verringert, während die Hauttemperatur wieder ansteigt. Deshalb sollte die Zeit nach der Entfernung einer Kältepackung als wichtiger Faktor der Kryotherapie mitberücksichtigt werden, um einen maximalen Behandlungseffekt dieser Maßnahme zu erzielen

SCHLÜSSELWÖRTER: intramuskuläre Temperatur, berührungslose Thermographie, Hauttemperatur, M. rectus femoris

Thermology international 2007, 17(1): 45-50

Introduction

Cryotherapy, the application of cold to achieve therapeutic objective, is the most commonly used technique in the acute management of musculoskeletal injuries [1,2]. Cryotherapy functions in 3 possible ways: conduction, convection or evaporation. Superficial and deep tissues are influenced by conduction and convection [3]. Superficial tissues transfer temperature change to deeper tissues through conduction. Both adipose tissue and muscle tissue demonstrate poor thermal conductivity and diffusivity therefore effectively acting as insulators [4], consequently impeding transfer of cooling. The characteristic vascularity of muscle allows continuous blood flow to further dissipate the cold [3]. Deeper tissues therefore experience a smaller decrease in temperature than the skin surface.

It is evident that during application of Crushed Ice (CI), both, skin surface temperature (T_{sk}) and, up to a depth of 2 cm, intramuscular temperature (T_{im}) decreases [2,5,6,7,8]. CI is the most effective modality for reducing skin surface temperature when compared to frozen peas, commercial gel packs and cold water immersion [9], it is also reportedly most effective for reducing T_{im} at a depth of 1 cm when compared to commercial gel packs or ice packs [2]. T_{im} decreases during application of CI is well documented [2,5,6,7,8].

Following 30 minute application of CI Merrick et al. [2] suggested that; increased application time is needed to promote tissue cooling to tissue depths ≥2 cm subadipose.

However there have been case reports of ice burns following 30 minute application of commercial gel packs [10,11] and 40 minute application of frozen peas [12]. This poses that increased application time may be hazardous, highlighting the need to establish a more consistent, safe and effective treatment protocol. Previous literature has tried to identify optimum application time to achieve T_{im} decreases [2,6,7,8].

Although employing differing protocol, therefore not directly comparable, a commonality within these studies was that, temperature measurements were taken during ice application. Principles of heat conduction [4] would suggest that, transfer of cooling to deeper tissues will continue after the CI has been removed from the skin surface. Zemke et al [5] monitored T_{im} at a depth of 1cm subadipose during 15 minute application of 2 different forms of cryotherapy. Temperature was measured from the point of cold application to point when the tissues reached the lowest temperature. Reported times were longer than the 15 minute cold application, indicating that intramuscular cooling continued after the cold modality had been removed from the skin surface. Currently these are the only temperature data available, following removal of the cold modality. Although this provides evidence of intramuscular cooling at 1 cm subadipose continuing, after removal of the cold modality, these data are not reported with concurrent T_{sk} data. It therefore remains unclear what happens to T_{sk} following removal of the cold modality.

It is reported that during application of CI there is no significant relationship between T_{sk} and T_{im} [6]. T_{sk} was consequently not considered an adequate predictor of T_{im}. However, temperature data were not collected and investigated following removal of CI. Removal of the cold modality will alter the temperature gradient at the skin surface, allowing opportunity for the superficial tissues to rewarm. The duration of the cooling effect on superficial and deep tissues, and the relationship between the 2 parameters following removal of the cold modality remains unclear.

Non-contact thermal imaging (TI) is a safe non-invasive method of collecting real time T_{sk} data [13]. Previous work [9,14] highlights the effective use of TI to measure T_{sk} over a given area following the application of cryotherapy. TI is advantageous as it allows temperature data over the whole of the cooled area to be collected as opposed to a spot measurement obtained with a thermocouple.

The aim of this study was to investigate and identify the relationship between T_{sk}, as measured by TI, and T_{im} (needle thermistor probe) following clinically relevant 15 minute [15] application of CI over the quadriceps. T_{im} data were collected at a depth of 3 cm subadipose tissue to determine whether cooling to deeper tissues continues to this depth after the removal of the CI.

Method

Participants

Ethical approval for the study was granted by the Department of Exercise and Sport Science ethics committee (Manchester Metropolitan University, Manchester, England), the study protocol conformed to the World Medical Association Declaration of Helsinki (1964). Nine healthy male participants were recruited from the University staff and student body. Demographic data of the participants is shown in table 1.

Table1.
Demographic data of participants.

Male	9
Age (yrs)	27.8
Height (m)	1.8
Weight (kg)	82.9
Adipose depth (cm)	0.7

Table 2.
Exclusion criteria

- **Referred pain to lower limb from any spinal, pelvic or hip joints**
- **Pregnancy**
- **Injury to Right quadriceps muscles**
- **Psychological Problems**
- **Systemic disease**
- **Sensory Deficit**
- **Cold intolerance/hypersensitivity**
- **Skin lesions**

The data collection procedure was explained to all participants and written informed consent was obtained. Providing participants did not fulfil any of the exclusion criteria (table 2) they were accepted into the study.

All participants were required to attend 1 testing session. Two hours prior to data collection, participants were requested not to drink caffeine, undertake any physical activity or to smoke. Participants were also asked not to consume alcohol for 24 hours prior to data collection. This was to standardise TI data collection as detailed in previous studies [13,16,17]

Participant Preparation

In order to facilitate relevant TI data collection and subsequent TI data analysis, an anatomical marker system (AMS) [14] was used to define a region of interest (ROI). Thermally inert skin surface markers were used to create an anatomical frame over the quadriceps muscle bulk. The location of the markers is indicated in table 3. A mark was made on the skin surface using a permanent marker pen. This was used to indicate the point of insertion (POI) for the thermocouple needle.

A vertical measurement of the subcutaneous adipose tissue overlying the rectus femoris (RF) was made using ultrasound (AU5 EPI ultrasound machine fitted with a LA13A

Table 3.
Location of anatomical markers.

POI	50% way between ASIS and Base of Patella
Superior	1/3 way between ASIS and Base of Patella
Inferior	2/3 way between ASIS and Base of Patella
Medial	Measure circumference of thigh at level of POI. Place marker at 10% of this distance in medial direction from POI
Lateral	Measure circumference of thigh at level of POI. Place marker at 10% of this distance in lateral direction from POI

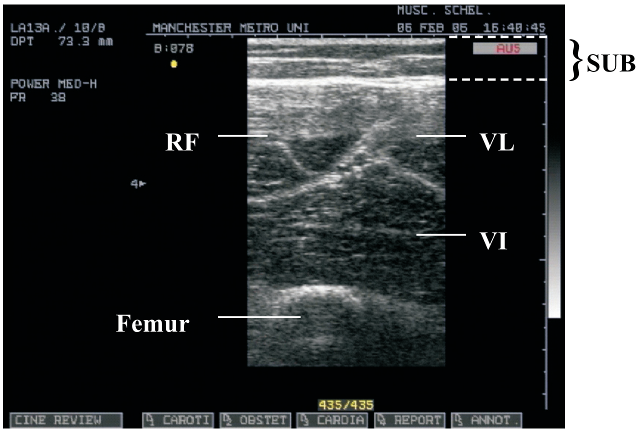

Figure 1.
Transfemoral ultrasound image at pen mark (*Rectus Femoris* (RF), *Vastus Intermedius* (VI), *Vastus Lateralis* (VL)), muscle architecture and the subcutaneous adipose tissue layer (SUB).

7.5 MHz linear probe, ESAOTE S.p.A., Genova, Italy). This measurement was made directly over the POI (figure 1).

Data collection

Data collection was carried out in an environment chamber (Manchester Metropolitan University). The ambient temperature was electronically controlled at a constant 22 °C. Following preparation, participants were seated in the environment chamber. A 15 minute acclimatisation period was allowed [13,16,1718,19,20].

A Thermovision A40M non-contact TI Camera (Flir systems, Danderyd, Sweden) was used for T_{sk} measurement. The camera was mounted on a tripod (Bilora Pro 930, Radevormwald, Germany) and interfaced with a laptop computer (Portege A100, Toshiba, Japan) running appropriate software (Thermacam Researcher Pro 2.8, Flir systems, Danderyd, Sweden).

A local anaesthetic cream was applied over the area immediately surrounding the POI. This was left on during the acclimatisation period. The area was then cleaned and a sterile 0.8 x 50 mm needle thermocouple (MKA Multipurpose needle probe, Ellab A/S, Roedovre, Denmark) interfaced, via 2.75 m of cable, with an LCD display unit (CTD-85 980259 SERIE 03, Ellab A/S, Roedovre, Denmark) was inserted at the POI. T_{im} was recorded and a baseline TI was taken. Two 0.2 kg bags of CI were then applied around the needle thermocouple within the defined anatomical frame and left in place for 15 minutes. Thermal images were taken at a rate of 1 image min^{-1} immediately following removal of the CI for a 40 minute rewarming period, T_{im} were recorded simultaneously.

Data analysis

Analysis of thermal images was performed using Therma Cam Researcher 2.8 software (Flir systems, Danderyd, Sweden). The mean temperature of the ROI, identified by the AMS, was taken from each image. The ROI was defined using the polygon tool within the computer software. As shown in Figure 3, the Anatomical Marker system is clearly visible on the thermal image. A regression analysis was performed on T_{sk} and corresponding T_{im} data, using the statistical software package SPSS (version 13 for Windows).

Results

There was a significant ($P<0.01$) difference between mean baseline T_{sk} (29.92 °C ± 0.84) and T_{im} (35.75 °C ± 0.74). No

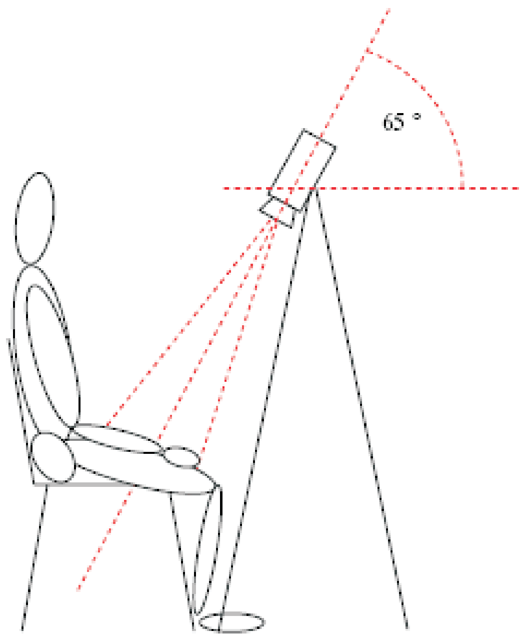

Figure 2.
Experimental setup diagram showing the thermal image camera positioned with the optical axis at approximately 90 ° to the participant thighs.

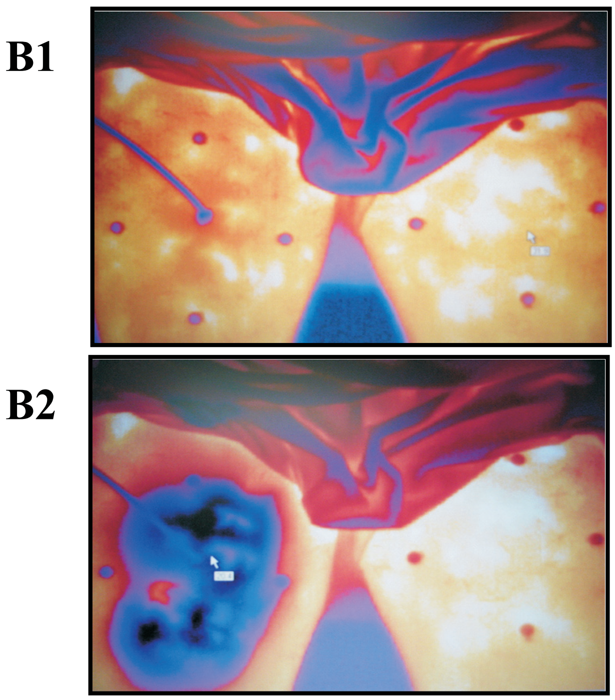

Figure 3. Thermal Image of AMS over Quadriceps Muscle Bulk. Images B1 and B2 are thermal images taken after insertion of the needle thermocouple but before and after placement and removal of CI respectively.

significant differences were found in T_{im} during the 15 minute cryotherapy application period.

Regression analysis revealed a highly significant interaction between mean change in T_{sk} (ΔT_{sk}) and mean change in T_{im} (ΔT_{im}) from baseline at the 99% confidence interval. Determination coefficient is the r^2 value (r^2 =0.979), the high value indicates a strong relationship. Regression analysis demonstrates exceptional fit of the data to a negative quadratic curve (Figure 4).

Quadratic regression of individual cases demonstrates this highly significant (P<0.01) negative relationship (r^2 =.776), is true of all participants (Figure 5) highlighting the trend for intramuscular cooling.

Significant differences (P<0.05) exist between ΔT_{sk} and ΔT_{im} up to 30 minutes into the rewarming period. This difference becomes non-significant (P=0.212) during 30-40 minutes rewarming highlighted in figure 6.

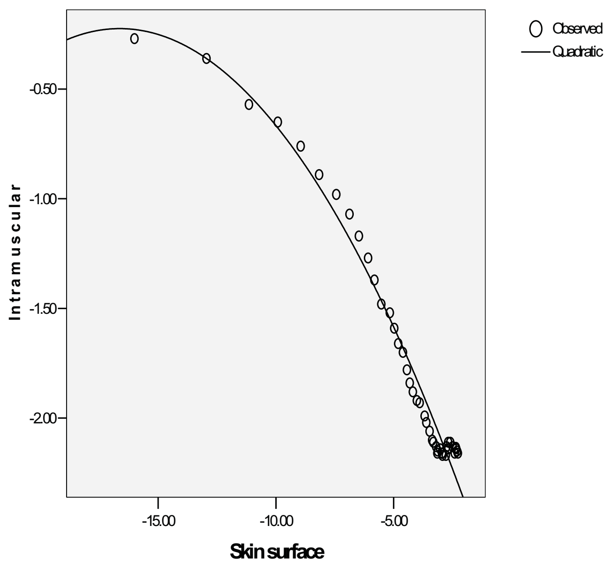

Figure 4.
Quadratic Regression of IM and Skin surface ΔT – Mean group data

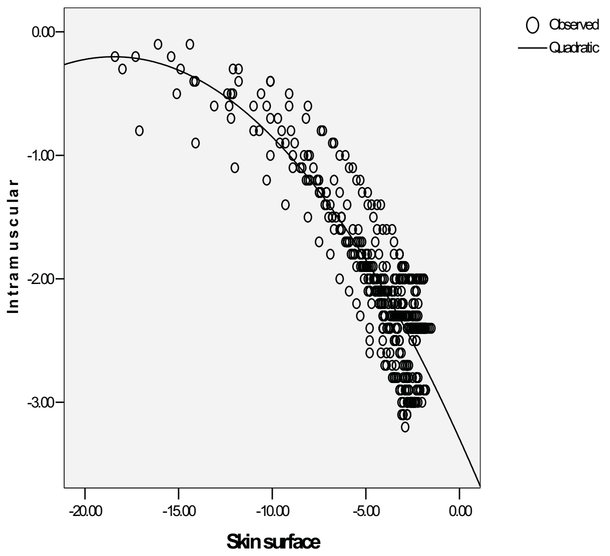

Figure 5.
Quadratic Regression of IM and Skin surface ΔT – individual cases

Discussion

Fifteen minute Crushed Ice (CI) application over the quadriceps has a clinically significant cooling effect on T_{sk} and 3cm subadipose T_{im}. Magnitude of change in temperature from baseline (ΔT), is significantly greater at skin surface than at 3cm intramuscular depth. Mean baseline T_{sk} (29.92 °C ± 0.84) and T_{im} (35.75 °C ± 0.74) are consistent with those previously reported [3].

Clinical cryotherapy is a superficial application. Initially, a gradient between T_{sk} and the modality is created. The skin is therefore unavoidably the tissue that is cooled first. This temperature change is then conducted to deeper tissues. Adipose, and muscle tissue are effective insulators, impeding cold penetration as tissue depth increases [3,4], thus creating a resultant attenuation in ΔT_{sk}. This is reflected by the trend towards a smaller ΔT_{im} demonstrated here.

The value of T_{sk} in relation to T_{im} during cryotherapy remains ambiguous. Previously T_{sk} [2] and T_{im} [2,5,8] have been reported independently, during cold application. Jutte et al [6] investigated the relationship between T_{sk} and T_{im} during cooling. Following linear re- gression analysis, no significant relationship between the two parameters was reported. As such, Jutte et al [6] did not consider T_{sk} an adequate predictor of T_{im}, during CI application.

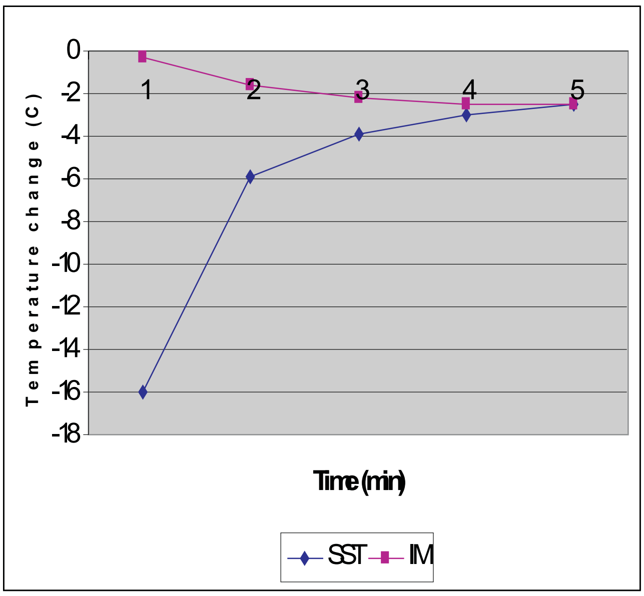

Figure 6.
Skin surface and IM ΔT over time – Mean values.

The present study investigated the relationship between the two parameters after removal of CI. In complete contrast to the findings of Jutte et al [6], the data demonstrate a very strong, highly significant negative quadratic relationship between T_{sk} and T_{im} (r^2 =0.979).

This negative relationship, essentially indicates that; following removal of the CI; as T_{sk} increases T_{im} decreases. This provides additional evidence that; superficially cooled tissues influence deep tissue cooling; as the superficial tissues draw heat from the deeper tissues.

The contrasting results of the present work and that of Jutte et al [6], may be attributed to the timing of data collection in relation to application of the CI. As previously highlighted, the relationship established here was following removal of the CI.

Zemke et al [5], previously reported a time period of 29 minutes from the point of modality application for1 cmT_{im} to reach their lowest temperature following 15 minutes CI application. This indicates that; intramuscular cooling continued 14 minutes after removal of CI.

The present data further reinforce this continuation of deep tissue cooling after removal of the CI and highlight that T_{im} , 3cm subadipose continues up to 30-40 minutes after removal of CI. This is also representative of a time delay in cooling of deeper tissues.Consequently, the 're-warming' period, should infact be con- sidered an important part of the intramuscular cooling period, during which time the intramuscular tissues at a depth of 3 cm subadipose reach their lowest temperature. Unfortunately Zemke et al [5], do not report Ts_k data, as such no direct relationship was investigated or established.

It is unclear from the data in this study whetherT_{im} decrease occurs as a result of removal of the cooling modality, or, more likely, if depth of cooling is time dependent and is coincidental that the cooling modality was removed at 15 minutes, which is possibly the time taken for the onset of intramuscular cooling to reach the 3cm depth.

As previously stated, the negative relationship demonstrated between ΔT_{sk} and ΔT_{im}, is quadratic in nature. The rate at which an object loses heat is directly proportional to it's surface area (m^2). The amount of heat an object can hold is directly proportional to it's volume (m^3). This quadratic relationship can therefore be explained by; the cooling of the surface area of the skin in relation to the dispersion in the underlying tissue volume. Analysis of data for single cases also produces a remarkable fit to the quadratic curve (r^2 =0.776), highlighting the consistency in this trend for intramuscular cooling in relation to T_{sk} re-warming.

Measures of T_{sk} have been criticised as being of limited value when observing the influence of cryotherapy on subcutaneous tissues. However this study shows there is a strong relationship between ΔT_{sk} and ΔT_{im} following 15 minute clinical cryotherapy application. As such T_{sk} can be considered a highly relevant indicator of T_{im}3cm subadipose.

Conclusions

Although this study was carried out on a small sample size, the results highlight that current clinical protocol may not be optimising the benefits of cryotherapy. The time period following removal of the cold modality during cryotherapy should infact be considered an important part of the treatment session. Further work is required to reinforce these findings. A strong relationship has been established between T_{sk} and T_{im} as measured by TI and thermistor probe, respectively.

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Correction

The article by **K Ammer** entitled **Thermology 2006 - a computer-assisted literature survey** . Thermology international 2007, 17: 5-31 appeard with a wrong version of the German abstract. The correct text is shown below. We regret this error

SUMMARY

This year, the comprehensive literature search in multiple databases yielded 3824 hits for the search terms “thermography”, “thermology”, thermometry”, “temperature measurement”, “thermotherapy”, “skin temperature” and “core temperature” Therefore, this literature survey is based only on publications listed in the medical database MEDLINE and EMBASE. After restricting the number of hits by combining the search terms with the key word “human, 844 references were obtained. Clinical trials were reported in 117 papers, all other publications were related to other temperature measurements. This literature survey has demonstrated a continuously high interest in both temperature related physiology and temperature related treatment. Hypothermia for patients in a critical state of health and hyperthermia for tumour ablation or prostatic hyperplasia were the topics most frequently published.

KEY WORDS: literature search, thermology, temperature measurement

THERMOLOGIE 2006- EINE COMPUTERGESTÜTZTE LITERATURSUCHE

Für das Jahr 2006 erbrachte eine umfassende Literatursuche in mehreren Datenbanken für die Suchbegriffe “Thermographie”, “Thermologie”, Thermometrie”, “Temperaturmessung”, “Thermotherapie”, “Hauttemperatur” und “Kerntemperatur” 3824 Treffer. Deshalb beruht diese Literatursuche nur auf Publikationen, die in die medizinische Literatur-Datenbanken MEDLINE und EMBASE aufgenommen worden waren. Nachdem die Zahl der Treffer durch die Kombination der Suchbegriffe mit dem Schlüsselwort “Mensch” eingeschränkt worden war, fanden sich 844 Zitate. Klinische Studien wurden in 117 Artikeln berichtet, alle anderen Publikationen bezogen sich auf andere Temperaturmessungen. Diese Literatursuche zeigte sowohl für die Temperatur abhängige Physiologie als auch an temperaturabhängigen Behandlungsmethoden ein anhaltend hohes Interesse. Die häufigst publizierten Themen waren die Hypothermie bei Patienten mit kritischem Gesundheitszustand und die Hyperthermie zur Tumorzerstörung und bei Hyperplasie der Prostata.

SCHLÜSSELWÖRTER: Literatursuche, Thermologie Temperaturmessung

Thermology international 2007; 17: 5-31

Thermographic Evaluation of Experimentally Induced Superficial and Deep Frostbite in Rats

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SUMMARY

Frostbite is a tissue trauma produced by exposure to freezing temperatures and even brief exposure to a severely cold and windy environment. At least 3 weeks after injury is needed to ascertain the extent and actual damage. The study was conducted to evaluate the changes in skin temperature using thermography in experimentally induced frostbite in fourteen albino rats. Frostbite was induced on one of the hind limbs under controlled laboratory setting. The severity of frostbite induced was either superficial (reversible) or deep (irreversible). Static thermograms were taken of both the hind limbs from the plantar side, immediately after exposure, 1, 4, 24, 48, 72 hours and 1 week after exposure. After one week there was clear demarcation in the exposed area in the animals with deep frostbite, which was not seen in the animals with superficial frostbite. It is concluded that thermography provides and easy and non-invasive technique for prediction of tissue viability in experimentally induced frostbite in rats

KEY WORDS: Frostbite, Superficial and Deep Frostbite, Infrared thermography, rats

DIE THERMOGRAPHISCHE BEURTEILUNG VON EXPERIMENTELL VERURSACHTEN OBERFLÄCHLICHEN UND TIEFEN FROSTBEULEN BEI RATTEN

Frostbeulen sind Gewebsschädigungen, die durch Exposition an Temperaturen unterhalb des Gefrierpunktes entstehen, wobei bereits eine kurze Exposition an eine sehr kalte oder windige Umgebung einen ausreichenden Reiz darstellen. Spätestens 3 Wochen nach der Erfrierung muss die Ausdehnung des aktuellen Gewebeschadens erhoben werden. Es wurde eine Studie durchgeführt, um an 14 Albinoratten thermographisch die Veränderungen der Hauttemperatur nach experimentell verursachten Kälteschäden zu erfassen. Erfrierungen wurden an einem der Hinterbeine unter kontrollierten Laborbedingungen provoziert. Die Ausdehnung der Kälteschäden war entweder oberflächlich (reversibel) oder tief (irreversibel). Unmittelbar nach, 1, 4, 24, 48, 72 Stunden und 1 Woche nach Kältexposition wurden statische Thermogramme von den Sohlen beider Hinterbeine angefertigt. Nach einer Woche kam es bei den Tieren mit tiefen Erfrierungen zu einer eindeutigen Demarkation des exponieten Gewebes, die bei den Tieren mit oberflächlichen Kälteschäden nicht zu finden war. Schlussfolgernd scheint die Thermographie eine einfache und nicht invasive Möglichkeit darzustellen, die Vitalität des Gewebes bei experimentell verursachten Erfrierungen bei Ratten vorauszusagen

KEY WORDS: Frostbeule, oberflächliche und tiefe Erfrierungen, Infrarot-Thermographie, Ratten

Thermology international 2007, 17(2): 51-58

Introduction

Frostbite is the severest form of cold injury. Prolonged exposure to subzero temperature or even a brief exposure to acute cold with high wind velocity produces frostbite. The severity of frostbite falls under 2 classifications: i) Superficial frostbite, which is defined as frostbite limited to the skin and subcutaneous tissue and corresponds to traditional I and II degree frostbite injury. ii) Deep frostbite which corresponds to III and IV degree frostbite, in which the injury leads to tissue necrosis, affecting muscles, blood vessel, nerve, tendons and bones.

There are two major injures associated with frostbite. The first is the physical effect of the ice crystal formation within the tissue and the second is a microvascular stasis. The resultant cessation of blood flow contributes considerably to the process of ischemic damage to tissue [1, 2]. There are three major mechanisms through which frostbite damage may develop i.e.; direct injury, hypoxia and the release of vasoactive compound and toxic byproducts of the inflammatory reactions to injury.

The treatment of frostbite is limited to amputation after 3 weeks when the line of demarcation between vital and non vital tissues is clear. The pathophysiology is such that very little can be done to salvage tissue once the freezing injury has occurred [3, 4].

One of the most difficult problems in the early management of a severely frostbitten patient is to make a prognosis. Several prognostic techniques have been used with varying results. Xenon -133 have been used for measuring the skin blood flow [5}. Technetium - 99m stannous pyrophosphate have also been used for measurement of soft tissue flow, while technetium-99m methylene di- phosphate images bone and permits bone viability [6]. Doppler ultrasound and digital plethysmography have been used from time to time for measuring peripheral blood flow. Infra-red thermography has often been used clinically as a non-invasive method for studying thermal changes resulting from alteration in skin perfusion such as in burns, vascular diseases, Raynaud's disease, skin grafts and thrombophlebitis [7 -9]. Since blood flow is acutely compromised in frostbite we wished to examine whether thermography could provide a useful alternative method for predicting tissue loss following cold injury in rats exposed to either irreversible (deep) or reversible (superficial) degrees of cold injury.

Material and Methods

The study was conducted at the Defence Institute of Physiology and Allied Sciences (DIPAS), Delhi, India. The Ethical Committee of the Institute approved of the study. The experiments were carried out in 14 albino rats (Sprague Dawley) of either sex with body weight ranging between 175-200gms, maintained on Hind-Lever diet and tap water ad-libitum. The rats were divided randomly into two groups of seven each. Superficial (reversible) frostbite was experimentally induced in one group (R) and deep (irreversible) frostbite was induced in the other group (IR). In all animals the right hind limb was exposed to cold to cause the injury and the unexposed left limb of the same animal served as its own control

Method of injury induction

The animal was placed on a wooden platform and semi-restrained with the help of a Perspex harness keeping the right hind limb freely moving. Frostbite was induced in the right hind limb by exposing the limb in the "Freezing-machine" (Fig 1). The Freezing-machine, which was designed and built at DIPAS, effectively simulates the conditions for frostbite. Compressed air is passed through coiled copper tubing, which is housed in a compartment filled with freezing mixture of ice and salt. The copper coil opens to a receptacle where the restrained animal's limb is placed. The factors determining the severity of exposure are ambient temperature, duration and wind speed. Appropriate control of these factors is helpful in obtaining different severities of frostbite. During exposure for superficial frostbite the temperature was maintained at -10 ±1°C with wind speed of 25-30 lit/min, for 15 minutes. For deep frostbite the temperature was maintained at -15 ±1°C with wind speed of 25-30 lit/min, for 30 minutes. Previous experience with the above protocol resulted in consistent production of superficial and deep frostbite [10,11].

The animals were examined by eye for loss of hair/nails, swelling, redness, blister formation, gangrene formation, functional integrity of the limb, and level of amputation if any. These observations were made before exposure, 10 minutes after exposure, 1 hour and four hours after exposure and once daily thereafter for a period of three weeks. The day of loss of nails (more than two per paw) was also recorded. At the end of the experimental period i.e. 21 days, the number of animals with loss of nails and number of nails lost per animal was noted. The swelling of the digits and paw was noted on a scale of 0, 1+, 2+, 3+ and 4+. The colour of the digits was differentiated as healthy pink/red/dark blue/ blotchy white and black according to the degree of severity.

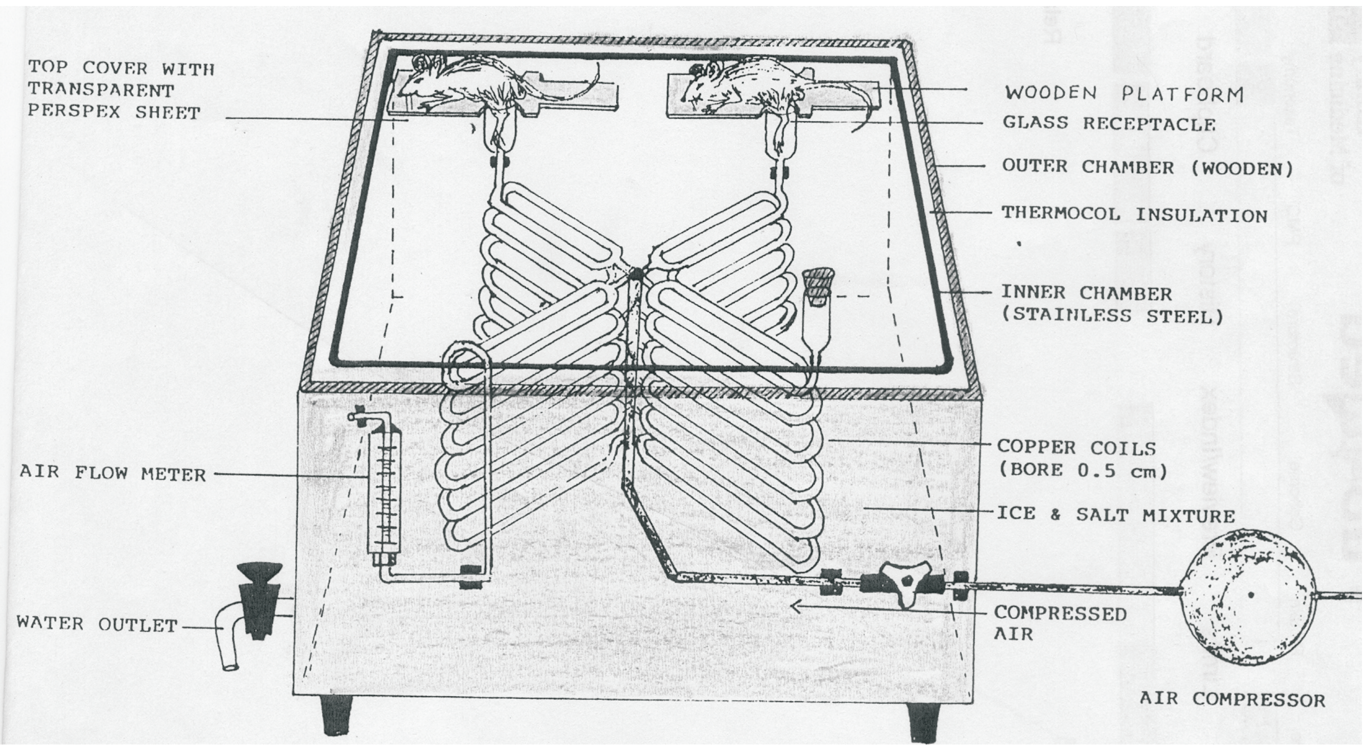


Figure 1
Schematic diagram of the freezing machines

The functional integrity of the limb was assessed for each animal on a daily basis with reference to whether the animal was using the limb for locomotion (L) or merely dragging (D) it. The level of amputation i.e. terminal phalanges, middle phalanges, proximal phalanges, metatarsals or ankle was also noted after 21 days after exposure.

IR Thermography

The IR-systems IRTIS-200 (Russia) with Software Package IRTIS v3.4 was employed to record the thermographic changes in the cold exposed paw of the animals (12).

Thermograms were taken of the plantar surface of the foot, before and after placing the animals in the freezing machine. Thermograms of both the injured (right) and uninjured (left) paws were recorded immediately after exposure (10 min) and 1, 4, 24, 48, 72 hours and 1 week after exposure. The thermograms were taken against an ice background to improve visual contrast. The distance between the camera and the hind paws of the animal was maintained at 30- 40cm, in order to minimize distortion and loss of accuracy. Thermograms were taken at an ambient temperature maintained at about 20°C in a draft free environment. Before imaging a minimum equi.ibration period of 10 minutes was observed (13). Each thermo- gram was analyzed with the help of the software for the following: Temperature at the tip of terminal phalanges (point 1), base of the proximal phalanges (point 2), midpoint of the paw (point 3) and mid point over the tarsal regions (point 4) was recorded (Fig 2). These points are representative of the temperature of the entire injured area. The temperatures of the individual points were summed up and the mean temperature was also determined.

Data Analysis

Each animal was its own control by comparison of the injured right foot to the uninjured left foot. Student T-test, Keul's test and ANOVA were employed for the recorded temperature data. p<0.01 was used as level of significance. The data was correlated with the progressive changes observed in the physical examination

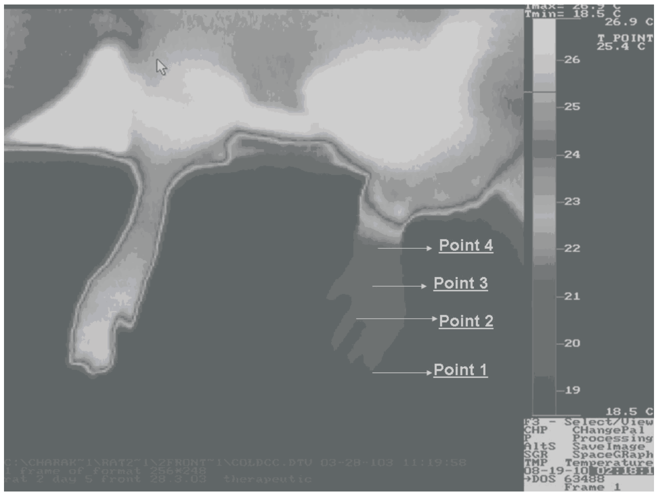


Figure 2:
Infrared thermogram Temperature showing sites of temperature measurements (Tip of terminal phalanges (Point 1), base of the proximal phalanges (Point 2), midpoint of the paw (Point 3) and midpoint over tarsal region (Point 4).

Results

To give a general impression of the effect that the two different degrees of cold injury have on the rats used in this study a photographic and thermographic presentation of the hind limbs after one week of exposure in a rat exposed to a deep cold injury and in a rat exposed to a superficial cold injury are shown in Figure 3.

Visual Observations

The results of the visual observation are presented in Table 1 and can be summarized as follows:-

(a) In the R group the loss of nails occurred on Day 5 and 3 animals lost their nails (>2) at the end of 21 days. The maximum nails lost in one animal were 3. In the IR group the loss of nails occurred on Day 3 and 7 animals lost their nails (>2) at the end of 21 days. The maximum nails lost in one animal were 5.

Table 1
Physical And Functional Changes In Animals With Frostbite

Group	Amputation	Condition of Nails		Inflammation					Functional Integrity of limb		
		Day of fall of nails	No of animals with nail loss >2 on day 21	Max no of nails lost per animal	Swelling on day 3	Swelling on day5	Swelling on day 7	Color of tissues on day 7	Day 5	Day 15	Day28
Reversible 'R'	Nil	5	3	3	+++	+	-	Pink	L	L	L
Irreversible 'IR'	6/7 (86%)	3	7	5	+++	+++	Onset of gangrene	Bluish black	D	D	L (after amputation)

(b) On day 3 the swelling in the R group and IR group was 3+ and but in the IR group the swelling subsided by day 7 at which time the gangrene is observed. In the R group the swelling subsided after day 3 and the injured tissue started to develop a healthy pink hue.

(c) The colour of the exposed paw changed from healthy pink to red and reverts to pink during healing. In the IR group all animals developed blotchy white colour, which progresses to black at the onset of gangrene by Day 7 and this ultimately led to amputation.

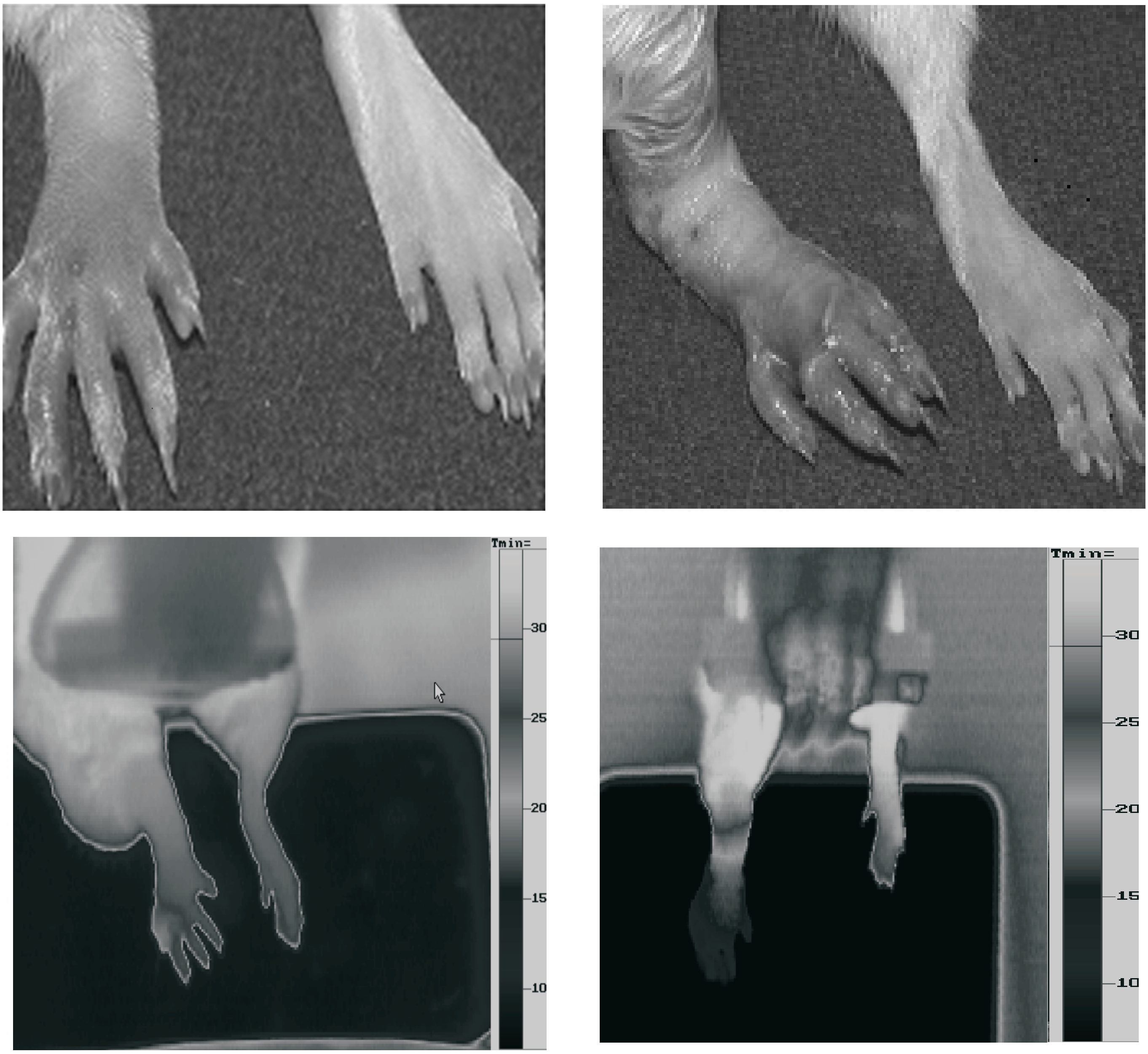
(d) With regard to functional integrity of the limb, in the R group all animals started using the injured limb for locomotion by Day 5 whereas in IR group the animals dragged the injured limb for 21 days. These animals only started to use the limb after healing of the amputated stump i.e. around 28 days.

(e) No amputations occurred in the R group. In the IR group 3 animals had amputations up to the level of the metatarsophalangeal joints and in 3 other animals up to the level of the tarsometatarsal joints.

IR Thermography

Intra group spatio temporal trends

R Group (Table 2): When the normal paw and frozen paw temperature profile was compared in animals subjected to reversible injury there was statistically significant difference in temperature of all the points when recordings were done immediately after the exposure and also after 72 hrs. Difference in recordings of point 2 and point 3 between



Superficial Frostbite **Deep Frostbite**

Figure 3
Photographic and thermographic presentation of rat hind limbs after one week of exposure

the normal and exposed paw were statistically different throughout the experiment. Overall significance of the change in temperature in all the points in the time frame observed was statistically significant (p<0.01). The pattern of change in temperature in point 1 and point 2 were similar and no statistically significant difference was seen. The difference in pattern of change in temperature was significantly different in between the points 1 and point 3 (p<0.01), point 2 and point 3(p<0.05), point 3 and 4 (p<0.05), point 2 and point 4 (p<0.01) and in between point 1 and point 4 (p<0.001).

IR group (Table 3): The comparison of all the four points in the frozen and normal paw in IR group shows a statistically significant difference in all the four points in immediate recordings, 4hr recordings and 1 week recordings. Overall significance of the change in temperature in all the points in the time frame observed was highly statistically significant p<0.001). The pattern of change in temperature in point 2 v/s point 3, point 3 v/s point 4 and point 2 v/s point 4 were similar and no statistically significant difference was seen. The difference in pattern of change in temperature was significantly different in between the points 1 and point 3 (p<0.01), point 1 and point 2(p<0.01) and in between point 1 and point 4 (p<0.001).

The time course of change in mean skin temperature (mean of the four measuring points) are presented in Figure 4. The temperature profile in the animals with superficial and deep frostbite show a different pattern. Immediately after

Table 2
Statistical Comparison Between Frozen and Normal Paws For Various Time Intervals In Rats with Reversible Injury

R GRP	PT1	PT2	PT3	PT4	Significances							
	Frozen (A)	Normal (B)	Frozen (C)	Normal (D)	Frozen (E)	Normal (F)	Frozen (G)	Normal (H)	A vs B	C vs D	E vs F	G vs H
IMM	17.6±0.1	22.9±0.4	13.5±1.3	24.2±0.4	12.2±1.1	25.5±0.3	11.4±0.7	25.5±0.3	p<0.01	p<0.001	p<0.001	p<0.001
1 Hrs	24.5±0.4	24.9±0.4	25.0±0.3	26.0±0.3	26.2±0.2	26.1±0.5	26.1±0.5	26.2±0.2	NS	p<0.01	NS	NS
4 Hrs	20.4±0.8	23.2±0.4	22.1±0.4	24.5±0.3	23.0±0.6	25.0±0.5	23.7±0.4	25.4±0.7	p<0.05	p<0.01	p<0.05	NS
24 Hrs	23.4±0.3	23.8±0.2	24.5±0.2	25.9±0.3	22.6±0.7	26.2±0.5	24.6±0.8	27.0±0.4	NS	p<0.05	p<0.001	p<0.001
48 Hrs	23.2±0.5	24.3±0.4	24.2±0.4	25.4±0.3	25.4±0.5	27.3±0.3	26.1±0.4	27.0±0.6	NS	NS	p<0.05	NS
72 Hrs	22.9±0.3	24.3±0.3	23.7±0.3	26.1±0.2	21.8±0.5	27.2± 0.3	25.8± 0.6	28.0± 0.4	p<0.01	p<0.01	p<0.05	p<0-05
1 Week	23.1±0.3	25.6±0.5	23.9±0.5	25.3±0.4	24.5±0.5	27.5±0.7	26.5±0.7	28.3±0.4	p<0.01	NS	p<0.05	NS

PT1 = Tip of terminal phalanges , PT2 = base of the proximal phalanges, PT3 = midpoint of the paw. PT5 = mid point over the tarsal regions. IMM = immediatly, RGRP= reversible group. Values are mean ± SEM

Table 3: Statistical Comparison of Skin Temperature Between Frozen and Normal Paws For Various Time Intervals In Rats with Irreversible Injury

IR GRP	PT1	PT2	PT3	PT4	Significances							
	Frozen (A)	Normal (B)	Frozen (C)	Normal (D)	Frozen (E)	Normal (F)	Frozen (G)	Normal (H)	A vs B	C vs D	E vs F	G vs H
IMM	4.3±0.4	13.8±0.6	3.6±0.3	14.8±0.5	3.7±0.4	15.2±0.3	3.6± 0.4	15.3±0.3	p<0.001	p<0.001	p<0.001	p<0.001
1 Hrs	16.9±0.2	16.8±0.2	18.3±0.3	18.0±0.4	18.8±0.3	18.6±0.4	19.2±0.4	18.8±0.3	NS	NS	NS	NS
4 Hrs	17.0±0.1	16.6±0.1	18.8±0.2	18.0±0.1	19.4±0.3	18.5±0.1	20.2±0.4	18.7±0.1	p<0.01	p<0.01	p<0.01	p<0.01
24 Hrs	17.6±0.9	16.6±0.4	19.5±0.7	18.8±0.4	19.3±0.5	19.0±0.6	20.5±0.5	19.8±0.5	NS	NS	NS	NS
48 Hrs	18.6±05	18.4±0.4	20.5±0.6	19.4±0.5	20.7±0.5	19.8±0.5	21.6±0.4	20.3±0.4	NS	NS	NS	NS
72 Hrs	16.6±0.3	16.8±0.2	17.9±0.4	18.8±0.4	19.5±0.8	19.6±0.4	19.8±0.5	19.8±0.5	NS	NS	NS	NS
1 Week	17.1±0.2	18.0±0.2	18.7±0.2	20.5±0.3	19.1±0.3	20.7±0.2	20.0±0.4	21.1±0.3	p<0.05	p<ß.01	p<0.001	p<0.05

PT1 = Tip of terminal phalanges , PT2 = base of the proximal phalanges, PT3 = midpoint of the paw. PT5 = mid point over the tarsal regions. IMM = immediatly, IRGRP= irreversible group. Values are mean ± SEM exposure both groups showed a drop in skin temperature in all the four points. But the drop of skin surface temperature was less in case of superficial type of frostbite ($p<0.001$). By the 1st hour there was a large increase in the mean temperature in both types of injuries. After 24 hours the difference in mean temperature of superficial and deep frostbite was significant ($P<0.001$). The mean temperature of the superficial frostbite notably returned to pre-exposure values after 72 hours. While the mean temperature in case of deep frostbite became progressively colder and there was no rise in temperature, even after one week. (Figure 4)

Line of demarcation

The line of demarcation for the IR appeared after 48 hours and progressed noticeably by one week. This was not discernible in the R group though there was a faint appearance after 48 hours but disappeared by the end of one week when the paw had healed.

Discussion

In these experiments two types of severity of cold injury were produced, deep and superficial frostbite. It has been previously reported that there is a cessation of blood flow in profound cold injury and resuscitation of blood flow in superficial cold injury [14, 15, 16]. The rat model that has been used in this study has the advantage that the vascular anatomy is similar to that in human extremities [17-21]. A point to note especially during exposure is the ambient room temperature. Gangrenous tissue, having no blood flow, will tend to have a temperature similar to the environmental temperature. If the room temperature and the body temperature are close to each other then the temperature recordings of the gangrenous tissue will be very similar to the viable normal paw and may give a false positive indicator of healing. Hence it is recommended that the room temperature should be maintained at 20 ºC to eliminate this error. In this study we adopted another simple procedure to obtain clearer thermograms, by keeping a slab of ice behind the paw to be thermographed. This gave excellent temperature contrast and resulted in very good quality and sharp thermograms. We have not come across this technique in any other infra red thermography studies.

The surface thermographic temperature is a composite temperature of deep temperature and skin temperature [22, 23]. In this study progressive monitoring of the frostbite showed that there is a sharp decline in temperature immediately after exposure. The fall was greater in the deep (irreversible) injury group. Thereafter the temperature in the injured limb rose, probably because of rebound increase in perfusion and the onset of inflammation in both the groups. A change in the temperature of the normal limb was also seen to occur in a similar pattern as that of the injured limb but the changes were quantitatively smaller than in the injured limb. This indicates the presence of a sympathetic response from the animal to cold exposure. This rises the question as to whether the uninjured limb in the experimental animal should be used as an unexposed control. The exposed area in both groups was warm during the first 24 hours after injury, reasonably due to inflammation, edema formation, vasodilatation and increased permeability and sympathetic tone. The temperature trends

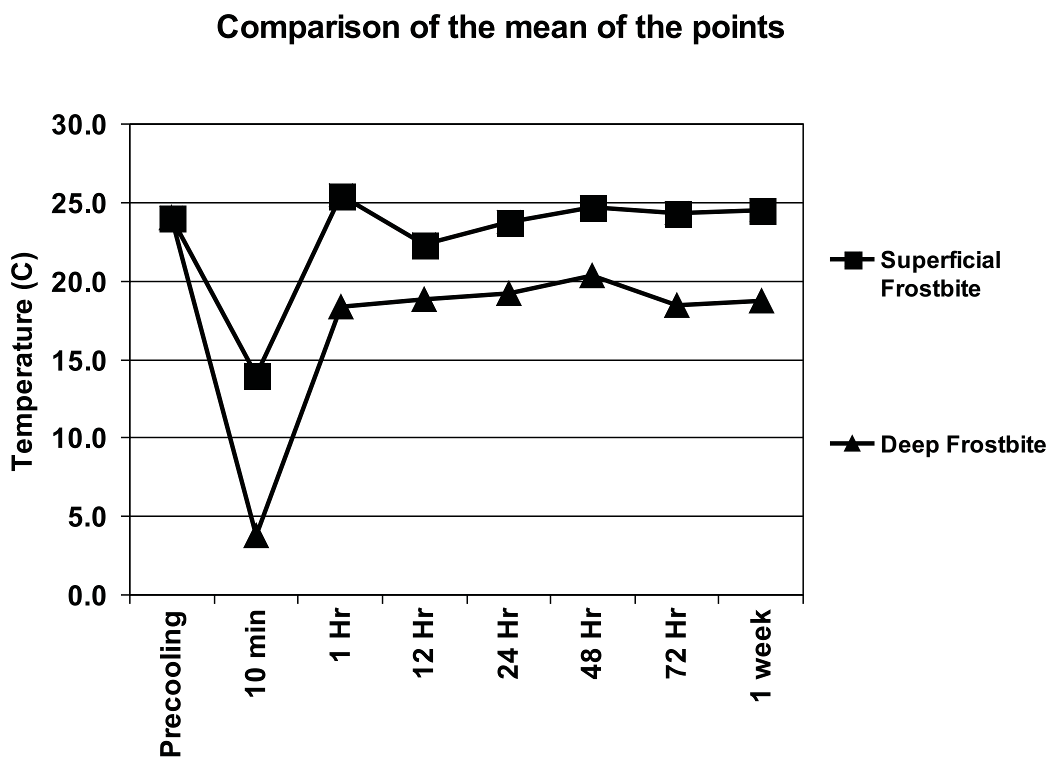


Fig.ure 4
Time course of changes in mean skin temperatures of exposed rat paws in rats subjected to superficial (open symbols) and deep (closed symbols).

for the one week recordings were similar to those found in other studies [24].

Another interesting finding of this study is that in the R group the digits and the distal metatarsal area of the paw function as one thermal unit and the mid metatarsal and tarsal appear as distinct thermal units. This also indicates that the temperature difference is mainly because of vascular compromise and less because of actual freezing. The vascular pattern in the paws of the rat is very similar to that of the humans (21) in that up to the mid-metatarsal region there is an arch pattern of vessels and regional vasospasm is compensated by opening up of other vascular channels. From the heads of the metatarsal to the tips of the digits the supply is through single digital arteries and any spasm of these vessels will reflect as uniform change in temperature through out the region. This is shown in our study in the R group where no statistically significant difference in temperatures of point 1&2 was seen. In the IR group the digits function as a distinct thermal unit thereby indicating that in spite of recovering some vascular function the tissue damage due to freezing and ischemia remains evident in the thermograms . The damage to the tissues makes the digits behave independently of recovering vascularity (I cannot fully follow this last sentence - please rewrite it more clearly. This also reiterates the importance of preventing freezing injury rather than trying to treat after the damage to the issues has occurred [3,4].

By 48 hours the expected defence mechanism against cold seems to be completely broken down in the deep freezing injury group hence the thermographic pattern is more defined with an ill-defined line of demarcation. The return of the temperatures values in the R group towards the healthy paw temperatures indicates healing and in the IR group the temperature trends indicate the presence of gangrene since the tissue temperature approaches ambient temperature. It is also interesting to note that the temperature values at 4 hr already indicates whether or not the tissue will survive. the possibility of gangrene or healing in the future. The demarcation line progressively becomes prominent by the end of one week for deep injury, while in case if superficial injury the line never assumes prominence and eventually fades by the end of the first week. Results of this study differ from previous findings [22, 23] as we observed that the cold area was defined only after one week for deep injury. However from the temperature values at 4 hrs after the injury there is a definite indication of deep injury as indicated by the statistically significant difference between the normal and exposed paw.

Only a few experimental investigations on frostbite have made use of thermography. Hamlet et al [22] claimed that it was possible to define the area of demarcation in rabbit feet using infra red thermography just after 24 hrs of cold exposure. Subsequent studies in experimentally induced frostbite of the rabbit ear showed that the affected area was very warm up to 48 hours after onset of frostbite, and the demarcation line appeared only after three weeks [23,25]. In earlier studies the severity of cold injury had not been taken into consideration. In our study we found the line of demarcation to be evident after one week in the animals with deep frostbite, whereas no such line appears in the superficial injury group. In previous studies ethylene glycol-alcohol or liquid nitrogen was used to produce deep necrotizing lesions. We feel that the cooling method used in this study more closely simulates the conditions in which frostbite occurs in humans at high altitude cold areas, where low temperatures, wind-chill contributes to cold injury formation.

Conclusion

Frostbite and its treatment is a clinical challenge and there is no clear means to reduce the tissue damage in the acute phase of frostbite. Presently the level of amputation is based on clinical inference, which is a protracted method. It would be useful to find reliable methods that could earlier ascertain the line of demarcation between viable and non-viable tissues than just by physical investigation. Thermography is therefore a simple, benign, and non-invasive examination modality by which frostbite injuries can be monitored thermographically to determine the line of demarcation between viable and non-viable tissues. Further investigations with this method and collateral studies of histo-pathology are required to ascertain whether or not this technique could have use in clinical practice.

Acknowledgments

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PRE-CONFERENCE ACTIVITIES

Thursday, June 7, 2007 — **Memorial Coliseum**

(Thursday schedule is for auxiliary groups only.)

9 a.m.-4 p.m. AUBURN-GLAMORGAN WORKSHOP — **Coliseum, Rm. 1081**

9.00am- 9.30	Historical Introduction	F.Ring
9.30-10.15	IR Detectors and cameras	R.Thomas
10.15- 10.30	Questions/discussion/coffee	
10.30- 11.00	Quality Assurance in Thermography	P.Plassmann
11.00- 12.00	Principles of thermal physiology	K.Ammer
30 minute lunch break		
12.30- 13.00	Film, Hot and cold "Living Body"	F.Ring
13.00- 13.30	Standard protocols for thermography	F.Ring
13.30- 14.15	Causes of human temp. increase & decrease	K.Ammer
15 minute break		
14.30- 15.00	Provocation tests	F.Ring
15.00- 15.30	Image processing principles	P.Plassmann
15.30- 16.00	Educational resources	K.Ammer

4 p.m. CHIROPRACTOR SOCIETY MEETING — **Coliseum, Rm. 1082**

4-6 p.m. AMERICAN ACADEMY OF THERMOLOGY BOARD MEETING, Blair Suite, AU Hotel & Conference Center

INTERNATIONAL AND AMERICAN ACADEMY OF THERMOLOGY MEETING

*Asterisk denotes student presentations)

Friday, June 8, 2007 — College of Veterinary Medicine

7:45-9 a.m. Transportation from AU Hotel to College of Veterinary Medicine (CVM)

8-9 a.m. **REGISTRATION/CHECK-IN** — **Overton/Goodwin Center**

Continental Breakfast

8 a.m.-5 p.m. Exhibitors and Posters — **Overton/Goodwin Center**

9 a.m.-12:20 p.m. WORKER'S COMPENSATION
Chairs: Woody McDaniel, Tim Conwell

9-10 a.m. Tim Conwell: *Current Colorado Division of Worker's Compensation Guidelines for CRPS and Reimbursement for Diagnostic Testing*

10-10:20 a.m. Florin: *Thermographic Monitoring of Physiological Changes in Patients with Chronic Regional Pain Syndrome (CRPS)*

10:20-10:40 a.m. Haber: *The Use of Thermographic Movies as Real Time Monitoring*

10:40-11 a.m. **BREAK**

11-11:20 a.m. Moon & McDaniel: *A Proposed Standard for the Evaluation of Lumbral/Sacral Radiculopathy in the General Population using Digital Infrared Imaging*

11:20-11:40 a.m. Conwell: *Current Pathophysiological Concepts in Complex Regional Pain Syndrome*

11:40-12:20 p.m. Worker's Compensation Panel Discussion

12:30-1:30 p.m. **LUNCH** (provided)

TUTORIAL

1:30-2:30 p.m Mercer: *Dynamic Infrared Imaging and Blood Flow*

2:30-3:10 p.m. **BREAST SESSION**
Chair: Phil Hoekstra

2:30-2:50 p.m. Hobbins: *Evaluation of Breast Health—35 years Experience with Monitoring Blood Flow*

2:50-3:10 p.m. Crawford (Saputo): *Beyond Mammography*

3:10-3:30 p.m. Hoekstra: *Autonomic Pattern Recognition Applied to Thermal Imaging for Large-Scale Breast Cancer Detection*

3:30- 3:50 p.m. **BREAK**

3:50-5:10 p.m. **CLINICAL TRACT**
Chair: Kurt Ammer

3:50-4:10 p.m. Ring: *Pandemic? Thermography Screening for Fever Screening of Airport Passengers*

4:10-4:30 p.m. Harding: *Sniffing Out Raynaud's Syndrome*

4:30- 4:50 p.m. Ammer: *Influence of Imaging and Object Conditions on Temperature Readings from Medical Infrared Images*

4:50-5:10 p.m. Lyon &Orlove: *A Brief History of 25 years (or more) of Infrared Imaging Radiometers*

Poster: Foster*: *Deviations in Normal Dermatome Patterns: A Collection of Three Studies*

Poster: Kyung-Sub Lee: *The Effects of Acupuncture in Patients with Cold Hypersensitivity Using the Cold Stress Test*

5:10-5:30 p.m. Transportation from CVM to AU Hotel

5:30-7 p.m. **CONFERENCE SOCIAL** Blair Suite, AU Hotel

Saturday, June 9, 2007 — College of Veterinary Medicine

8:15-9 a.m. Transportation from AU Hotel to CVM

8:30-9 a.m. **REGISTRATION/CHECK-IN** **Overton/Goodwin Center**
Continental Breakfast

8:30 a.m.-5 p.m. **Exhibitors and Posters** **Overton/Goodwin Center**

9:00-10 a.m. **EQUIPMENT/STANDARDS**
Chair: Francis Ring

9-9:20 a.m. Vardasca*: *Thermal Symmetry on Extremities of Normal Subjects*

9:20-9:40 a.m. Fisher*: *Equilibration Period Following Exposure to Hot or Cold Conditions when Using Infrared Thermography*

9:40-10 a.m. Plassmann: *Performance Testing of Thermal Imaging Systems in Medicine*

10-10:20 a.m. **BREAK**

10:20-11:00 a.m. **VETERINARY MEDICINE**
Chair: TBA

10:20-10:40 a.m. Ryan: *Ocular Thermal Imaging as a Measure of Febrile Responses in Foals to Endotoxin Challenge Testing*

10:40-11 a.m. Rashmir-Raven: *Early Detection of Hyperelastosis Cutis/Herda Lesions in Horse Using Digital Infrared Thermography*

Poster- Nienaber*: *Thermal Windows in Seals and Sea Lions: Non-Invasive Indicators of Health?*

11:30-12:30 p.m. **LUNCH** (provided)

12:30-1:30 p.m. **PHYSICAL THERAPY/ATHLETIC TRAINING**
Chair: David Pascoe

12:30-12:50 p.m. Demmick: *Use of IR Thermography in Determining Spatial Heat Distribution of Varying Ultrasound Treatment Techniques*

12:50-1:10 p.m. MacNunn*: *Cryogenics Changes in Differing Ice Treatments*

1:10-1:30 p.m. Daisy*: *A Thermographic Comparison of Cold Therapy Devices on Surface Skin Temperature*

Poster- Hoyt: *Relationship between Digital Infrared Thermal Imaging Determined Knee Temperatures and Knee Pain in Distance Runners during a 3-Month Cross Country Season*

Poster- St Onge: *Tissue Compression at the Ischial Tuberosity and the Middle Posterior Thigh: Impact on Nerve Function, Blood Flow, and Tissue Oxygenation*

1:30-3:10 p.m. **BRAZILIAN THERMOGRAPHIC SOCIETY**
Chair: Dr. R.K. Vyas

1:30- 1:50 p.m. Brioschi: *Application of a New Radiological IR Imaging Technique. MRI with IR 3D Fusion and 3D Stereoscopic Printing*

1:50-2:10 p.m. Brioschi: *High Sensitive IR Images Report. New System of Musculoskeletal Injuries Description*

:10-2:30 p.m. Brioschi: *Infrared Expertise: From Diagnosis to Treatments. Infrared Imaging of Far-Infrared Radiation in Different Types of Applications.*

2:30-2:50 p.m. **BREAK**

2:50- 3:10 p.m. Brioschi: *Surgical Infrared Imaging Applications: Directions for the Future*

TUTORIAL

3:10- 4 p.m. Govindan: *Role of Mast Cells in Chronic Regional Pain Syndromes*

4-5 p.m. **SPECIAL INTEREST GROUPS (SIGs)**

*Time will be provided for those interested in meeting as infrared specialty groups.
(Neuromuscular, Veterinary, Clinical, Breast, Physical Therapy/Athletic Training, Physiology, Workers Comp, etc.)

5-5:30 p.m. Transportation from CVM to AU Hotel

6:30-9:30 p.m. **BANQUET** AU Hotel & Conference Center Ballroom

OUTLINE OF THE AUBURN-GLAMORGAN WORKSHOP

HISTORICAL INTRODUCTION

Francis Ring

The historical link between changes from the normal process of thermoregulation and disease is well documented. Even so it was the development of the thermometer that ultimately replaced the medical art of detecting fever by touching the patient. Galileo's simple thermoscope indicated the temperature of the water, but as an open system it was influenced by atmospheric pressure. Once this was realised and the tube was sealed, the glass thermometer became the standard instrument for measuring temperature to the present day. In medicine, a dramatic change in approach to temperature measurement of sick patients followed the thesis of a German physician Dr Carl Wunderlich. He systematically recorded the temperature of his patients at regular times throughout the day, and charted their progress. His main work sets out some forty different statements about the value of temperature measurement in medicine, the proof of fever by elevated temperatures, indication of worsening or improvement, and ultimately the decrease of temperature leading to death and post-mortem cooling. For 200 years, temperature charts have been a familiar record of hospitalised patients throughout the world. Of special, significance was his concept of the maximum or clinical thermometer, optimised to a narrow temperature range for clinical indication of fever.

The original mercury thermometers are now replaced by coloured fluid, for safety reasons. Electrical sensors, particularly thermocouples have been used in contact temperature sensors. Thermistors are not generally as rapid in response, but well suited to continuous monitoring have their place, especially in intensive care medicine.

Radiometric temperature detection of the naturally emitting infrared radiation has been a more recent development. In clinical medicine, simple radiometers are now used for aural temperature, and in some countries are replacing glass contact thermometers, mainly because they are considered to a lower risk for infection. The current interest in mass fever screening in airports etc. is based on thermal imaging, but verified by clinical thermometry to relate to core temperature.

Infrared thermal imaging systems have reached a significantly higher level of performance since 2000. Focal plane array detectors with high spatial and thermal resolution are available, at a relatively lower cost than in previous years. Criteria for their use in medical imaging have been described, and optimal conditions for a physiological recording of temperature should be a part of any thermal imaging routine. Most modern cameras claim to be fully in service within 10-15 minutes from start-up. This may not be valid for all cameras, and some will require much longer before they reach full radiometric specification. Furthermore the time to reach this required stability can change over time. It is therefore important that the user of each camera system is fully aware of the minimum time required before any images of the patient are made. Image capture requires as much standardisation as possible to ensure the ultimate repeatability of the images. Software can be used to help in the precise location of the target and of the regions of interest used for measurement. Improved resolution, stability and accuracy of temperature measurement are significant technical advances. However, critical technique and understanding of thermal physiology are also necessary to obtain clinical benefits from thermal imaging. The new interest in fever screening raises important challenges for the future.

IR DETECTORS AND CAMERAS

Rod Thomas

The use of Infrared Technology has developed significantly in recent years from the very cumbersome, sometimes unreliable, often liquid nitrogen cooled and extremely expensive infrared cameras prevalent in the later part of the twentieth century. Infrared detector technology has developed to an extent where repeatability, reliability and accuracy are now synonymous with modern systems.

Currently there is a proliferation of Infrared Cameras available worldwide representing a number of differing applications and challenges in choosing the appropriate camera . Examples of applications are wide and include predictive machine condition monitoring , which directly impacts on the efficiency of British Industry to the use of infrared thermography to improve efficacy during laser therapy on human tissue.

Optimum IR camera specification is an important consideration especially when adopting quantitative thermography. Examples of key specifications are discussed.

Higher specification infrared cameras are emerging and able to satisfy the requirements of medical practice. These systems have high levels of thermal and spatial resolution ideal for diagnostic purposes. There currently remain one or two challenges regarding spatial uniformity and geometric distortion but these are already subject to experimentation and testing There are a growing number of medical examples of such work in Europe most notably at the University of Glamorgan in the UK.

An important aspect of any infrared programme is training (Snell, 2005). The success often pivots on training and that it is recognised, relevant and most importantly imparts the necessary skills for qualitative and quantitative thermography

QUALITY ASSURANCE IN THERMOGRAPHY

Peter Plassmann

Standardisation is important for reliable use of infrared thermal imaging in medicine. Infrared camera systems are now of higher performance with improved reliability, which can lead the operator to assume that the system is continually giving optimal performance. This, however, is not the case.

We propose a series of simple experiments based on inexpensive and easy to acquire materials, which a thermographer can use under normal clinical conditions to monitor the performance of thermal imaging equipment in order to maintain confidence in the measurements made. The 5 tests proposed here are not intended to replace those performed by manufacturers or calibration laboratories, but can provide valuable information on both short and long-term camera performance. The proposed tests identify: a) offset drift after switching on, b) long-term offset drift, c) offset variation over the observed temperature range, d) image non-uniformity and e) the thermal 'flooding' effect.

Measurement results based on the above experiments will be presented which demonstrate that cameras may drift over several degrees centigrade in less than 2 hours after switching on. We will also show that imaging equipment can produce a varying amount of measurement error (up to 1.5 degrees centigrade), which depends on the temperature range observed. Results also show that equipment may be prone to non-linear errors (in the region of 1 degrees C), which are caused by deficiencies of the optical system and will manifest themselves if the equipment is not calibrated regularly.

Although the proposed tests will identify errors if present, due to the simplicity of the materials used, the tests are only of limited use for the quantification of these errors. We therefore present experimental results obtained using a new 3-point calibration blackbody source currently under development by the UK's National Physical Laboratory (NPL) specifically for use in medicine. The source exploits the stability of the melting/freezing point of certain chemicals which makes it extremely stable and when in use does not require a power source, cables or electronic stabilisation circuits. This source, once commercially available, will provide a highly reliable and practical tool not only for the quality control of thermal imaging equipment but by virtue of its inherent precision it will also enable cross-calibration for multi-centre trials.

PRINCIPLES OF THERMAL PHYSIOLOGY

Kurt Ammer

Thermal physiology describes all body functions related to thermal energy given to or removed from a living body. The most important physiological system in this context is temperature regulation, which keeps the temperature of the inside of the body on a constant level. This is achieved by changing the temperature in the outside of the body varying the superficial blood flow and heat production or activation of additional cooling mechanisms such as evaporation of sweat on the skin surface. The human body uses sympathetic nerve fibres for information spread related to temperature regulation. However, temperature regulation is only one function of the autonomic nerve system. Its main function is the non-voluntary control of smooth muscle fibres.

Strong interactions exist between temperature regulation and the cardiovascular system, also with fluid and energy control Heat generated by contraction of striated muscle fibres is the most important internal heat source of the body. Understanding the mechanisms of heat exchange of the body with the environment is essential for correct interpretation of temperature patterns on the body's surface. Any disturbance of the heat balance of the body is followed by temperature regulation, which keeps the deep body temperature close to the set point. Exhausting the regulation capacity of the system leads to a new set-point i. e. either increase (hyperthermia) or decrease (hypothermia) of the core temperature. The mean skin temperature and the core temperature jointly determine the regulation process. Skin temperature is the result of the heat storage of the body and the thermal environment. The law of physics for heat transfer provides the means of predicting the mean skin temperature under defined conditions.

Various mechanisms unrelated to temperature regulation may affect the diameter of superficial skin vessels, resulting in different levels of skin temperature. Temperatures on the surface can only be correctly interpreted if the condition of the thermal environment is known. It is not true to assume that the surface temperature is synonymous with perfusion or that blood flow is exactly the same as surface temperature. However, very specific responses of vessel control do occur in certain thermal conditions.

Temperature regulation under working conditions is of practical importance to man, especially for research into safety procedures in extreme temperature conditions. The balance between protection against either heat or cold and gross endogenous heat production can be a very difficult challenge. In such a situation interactions of temperature regulation with the cardiovascular system and fluid balance become significant.

Many physiological functions are related with the thermal phenomenon, but not all are the result of temperature regulation. Basic knowledge of thermal physiology is necessary for the correct interpretation of human body temperature measurements.

STANDARD PROTOCOLS FOR THERMOGRAPHY

Francis .Ring

Despite the availability of infrared thermal imaging for medical investigation for 50 years, there is a notable lack of reference data for normal subjects. Human body temperature is known to be self regulating (homeothermic) and to remain within narrow range of temperatures in a healthy subject. Inflammation, reduced blood perfusion and a number of defined clinical conditions can affect skin temperature to a significant degree. Nevertheless, to use thermal imaging to study body surface temperature, strict protocols must be followed; to obtain the thermal sensitivity required for measuring the changes in the limited thermal range. Thermal imaging equipment has increased thermal and spatial resolution, now attainable at lower cost than in the past. Even with the improved technical performance, there are a number of pitfalls to be avoided in order to obtain reproducible and reliable thermal data from medical thermography.

Eight stages for potential errors or artefacts have been identified.

1.Patient information and preparation for examination.

2. IR Camera systems and calibration.

3. Patient positioning & Image Capture.

4. Thermal image analysis.

5. Image storage.

6. Elec-tronic image exchange (radiometric)

7. Image presentation.

8. Information on protocols and learning resources.

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

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

Standard distances are also advised, since resolution (thermal and spatial) are usually decreased as scanning distance increases. Image analysis must also be standardized. Regionsof interest are frequently chosen on subjective parameters,which have been shown to be irreproducible even by the same investigator on the same image with repeated analysis. A protocol for defined regions of interest based on anatomical limits is the only sure way to minimize inter operator variation.

Finally, reporting the images requires al relevant data on the temperature range and level of the camera setting, the location of regions of interest and their data, and the conditions under which the ex amination was carried out. Failure in any of these parameters can lead to sizable errors, and misinterpretation of the findings.

Examples will be given of false results in thermal imaging from failure of the investigator to understand the essential factors for the patient examination. Inadequate camera settings, or unproven stability after starting the camera have been found to significantly alter the final image. Errors resulting from subjective sizing and placement of regions of interest also show significant variations, all of which can be avoided. The importance of standardized reporting is evident when comparisons over time are required.

In medical-legal issues, each image must be clearly identified, and shown to be taken under comparable conditions. No less a standard is required for normal clinical work with this technique. Knowledge of the normal patterns, and causes of hyperthermia or hypothermia are also important to both the technician and the physician using this technique.

CAUSES OF HUMAN TEMPERATURE INCREASE & DECREASE

Kurt .Ammer

Thermal imaging is a technique capable to map the temperature distribution on the human skin. In healthy subjects skin temperature is highly symmetrically distributed related to a symmetry axis situated in the median plane of the human body. In the extremities, higher temperatures are normally seen at the proximal end of the limb than on the tips of fingers or toes. Any disturbance of these normal temperature pattern may be detected either as hyperthermic or hypothermic area.

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

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

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

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

Hypothermic skin changes may be caused by decreased blood flow, loss of muscle contraction, sympathetic hyperactivity induced by partial nerve lesion, lymphedema or artefacts due to the environment. Typical findings from patients with obstructive angiopathy . Raynaud`s phenomenon, motor deficit due plexus paresis, poliomyelitis, herpes zoster, radiculopathy, peroneal palsy and decreased range of motion induced by arthritis or arthodesis will be presented . The thermographic changes of common nerve entrapment syndromes such as carpal tunnel syndrome, thoracic outlet syndrome and ulnar nerve entrapment will be discussed. Cases of reflex dystrophy, thermal images from patients suffering from lymphedema and some artefacts causing hyperthermic changes of the skin temperature will close this lecture.

PROVOCATION TESTS

Francis Ring

Infrared thermal imaging of the human body skin surface is normally carried out after a standard period of acclimatisation in a temperature-controlled room. A number of normal temperature patterns have been identified. Clinical abnormalities in temperature can be identified. Once the normal pattern is established. Dynamic reactions to provocation tests can be useful when there is a possibility of loss of thermal symmetry between the two sides of the body. The effects of some work related injuries on skin temperature may also be made more obvious following such tests.

In general, provocation or stress testing the skin can be made by using either *Chemical, thermal or mechanica challenges*.

1.*Chemical* and pharmacological skin tests are used in dermatology.[1] These may be applied allergens, or inflammatory mediators such as prostaglandins, 5HT etc. Nicotinic acid compounds in sufficient dose are known to provide local and transient areas of inflammation on the skin under normal conditions. In certain circumstances, this reaction may be inhibited or enhanced, depending on local blood perfusion to the skin and the status of the sympathetic nervous system.

2.*Therma*l tests have been used primarily to quantify the finger and toe temperatures in Raynaud's Phenomenon.[2] Immersion of the hands in a water bath at 20^{0}C or colder for a fixed period e.g.1 minute, provides a useful clinical test of recovery which is related to the local perfusion and the sympathetic response. Normal subjects may produce reactive hyperaemia in the fingers, or should recover baseline temperatures quite quickly (<10 mins) A vasospastic reaction is marked by delayed recovery in one or more fingers. Exposure to Ultraviolet radiation may also be used to generate local inflammation, and has been used to test solar barrier creams on the skin in-vivo.[3]

3.*Mechanical* tests may be based on muscular work, by performing controlled exercises and observing the muscular heat so generated. This may be absent in some cases of pain syndrome or where permanent damage to the nervous or vascular system has occurred. In vibration white finger VWF, which is work related, cold fingers and hands may occur as a result of local damage to the peripheral micro-vascular and nervous systems. Controlled contact with a suitable vibrating surface is one means of provoking a reaction in these patients. Rapid re-warming of the fingers is normal, but delayed localised recovery of skin temperature can be found in fingers affected by VWF.

Examples of the above techniques demonstrate that thermal imaging has a valuable role in assessing the response to provocation tests on the skin. Under standard conditions the tests can be quantitative, thus providing the means for clinical trials of pharmaceutical compounds, and evoking abnormal responses in certain injuries which affect the vascular and local sympathetic nervous systems.

IMAGE PROCESSING PRINCIPLES

Peter Plassmann

Over recent years practitioners of medical thermography have recognised the need for introducing standards into the various processes of image acquisition, analysis and data exchange. Commercially available thermal imaging software, however, is generally designed with industrial applications in mind and as such often more a hindrance than a help in achieving this goal.

A set of 24 standard "masks"is proposed which can be superimposed onto live thermal camera images in order to aid the precise positioning of subjects in pre-defined standard views. Embedded in the description of each mask are codes and descriptions which simplify searching and indexing of acquired images in data bases.

Images captured in such a way have a number of advantages: they can be readily compared with other images and lend themselves to semi-automated analysis such as a cold-stress-test. Morphing techniques can be used to create an average image of body region of interest and such average images me be used for reference and comparison with images recently captured.

Examples of standardised image capture and semi-automated analysis produced by the CTHERM software package are presented. The author has developed data file conversion tools so that images captured and analysis data produced by CTHERM can imported into the ImageThermabase package (and vice versa). Copnversion tools for AGEMA CATS-Images and images recorded with the software package IRIS from NEC-Thermotracers are also evailable. It is planned to incorporate conversion tools for further packages, to enable and simplify consultation and data exchange within the medical thermology community.

EDUCATIONAL RESOURCES

Kurt Ammer

Knowledge of thermal imaging is necessary Rehabilitation medicine (in Austria part of the postgraduate training for Physical Medicine and Rehabilitation), Human Physiology, Occupational Medicine and optional in Rheumatology, Dermatology, Orthopaedics, Neurology, Neurosurgery. In 1993, the European Association of Thermology (EAT) organized in cooperation with the Austrian Society of Thermology a course on medical thermography with lecturers from around Europe, Francis Ring and myself conducted a three days course on thermal imaging in Sao Paolo in 1999, which triggered the foundation of a Brazilian Society of thermology. The University of Glamorgan offers since 2001 a regular training course on medical thermal imaging. Thermology Societies all around the world provide training and certification for technicians and physicians (for example the AAT), organize meetings and conferences and publish journals.

The International College of Thermology was founded in 1987 and links the three continental associations, namely the American Academy of Thermology, European Association of Thermology, and Asian-Pacific Association of Thermology. The president and the International Congress of Thermology used to change for a one year period from Asia to Europe, from Europe to America and from America to Asia. The cycle of international Thermology-Conferences started 1989 in Georgetown, Washington DC, went then to Ghent, Belgium, Matsomoto, Japan, Ft.Lauderdale, Florida, Vienna, Austria and Seoul, South Korea and is now 2007 in Auburn. The EAT started with European Congresses in 1974 in Amsterdam and had the last European Conference last year in Zakopane, Poland. National conferences on thermology were regularly organized in Japan, Korea, USA, Austria, Germany, Hungary, Poland, United Kingdom.

Scientific journals related to temperature are manifold, but only some were dedicated to medical thermology. Acta thermographica and Thermology had ceased publication years ago, Biomedical Thermology publishes now only in Japanese, the German ThermoMed has problems to appear regularly. Thermology international is at the moment the only journal which publishes 4issues/ year with thermological papers in medicine and biology. A number of books are related to thermal imaging in medicine, the latest is a spin off of the chapter on infrared imaging in the handbook of biomedical engineering.

ABSTRACTS OF THE INTERNATIONAL AND AMERICAN ACADEMY OF THERMOLOGY MEETING

CURRENT PATHOPHYSIOLOGICAL CONCEPTS IN COMPLEX REGIONAL PAIN SYNDROME

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Current concepts regarding the role of the autonomic nervous system and its relationship to nociceptive C-fiber afferents in CRPS I are reviewed. In the normal milieu, sympathetic efferents and sensory afferents are not conjoined. Current investigation suggests that the functional and perhaps structural interaction between the sensory afferent and sympathetic efferent fibers in both the periphery and possibly centrally play a significant role in CRPS I. A review of the literature that elucidates this current understanding will be presented along with putative IR signature images.

THERMOGRAPHIC MONITORING OF PHYSIOLOGICAL CHANGES IN PATIENTS WITH CHRONIC REGIONAL PAIN SYNDROME (CRPS)

Robert E. Florin, M.D. and Constance Haber, D.C.

Sponsored by PhotoMed Technologies, Inc.

Thermal imaging of skin temperature is used to study regional abnormalities in blood flow associated with the autonomic abnormalities seen in patients with neuropathic pain.

We will illustrate the utility of thermal imaging in CRPS patients as a diagnostic adjunct, to monitor thermal changes during therapy, and to provide objective measures of physiological changes following therapy.

Twelve chronic CRPS patients were studied using thermography during therapy with modulated visible light applied to the skin at sites remote from the affected parts. Regional skin temperatures of distal extremities were recorded from infrared thermal images during each session of therapy. Changes in temperature were used as a measure of changes in regional perfusion during and following light therapy.

The average maximum change in skin temperature of the monitored extremities in CRPS patients was 4.3^{0}C relative to the pre-treatment temperature. In normal subjects, the average maximum change was only 1.3^{0}C. All 12 CRPS patients changed 2.0^{0}C or more at least twice during the course of light therapy sessions. In the same period, 75% reported much improvement in their pain intensity, lasting a month in seven cases and up to a year in four cases.

THE USE OF THERMOGRAPHIC MOVIES AS REAL-TIME MONITORING

Constance Haber, D.C. and Robert E. Florin, M.D.

Sponsored by PhotoMed Technologies, Inc.

Breakthrough technology permitting automated computer management of thermal movies during therapeutic intervention has revolutionized the modern thermal imaging laboratory.

The tasks which required extended physician involvement in order to produce scientifically valid data have been able to be markedly reduced and in many instances eliminated with specific computer programming. Documents required tovalidate thermal equilibration, laboratory conditions, quantification of response to therapeutic intervention, daily chart notes, outcomes assessments and billing can be produced before the patient reaches the front desk. The laboratory can now operate in a more efficient and cost effective manner. Instead of the physician having to spend hours drawing circles, creating tables and working after hours to produce necessary data and reports the required data is produced effortlessly and almost instantly. The factors which made comparison of data between patient visits difficult have been eliminated.

Patient compliance to treatment recommendations and insurance reimbursement are markedly improved when thermal images document improvement with the therapeutic intervention chosen by the physician while creating valid and irrefutable data.

Rather than enter the controversial arena of establishing a medical diagnosis based on thermal imaging, gathering and presenting real-time scientific data of the patient's physiological response to treatment has added a new arena to the thermal imaging laboratory.

We have chosen to report on data that has been collected and analyzed from twelve (12) chronic CRPS patients commencing October 2005, whose condition had previously been recalcitrant to management. The graphic physiological demonstrations have added a much needed and easily understood acceptance of the treatment offered.

Thermography provides an objective measure of physiological changes in the regional perfusion of affected limbs in CRPS patients during light therapy. Thermography is useful as a confirmatory diagnostic test of changes in skin temperature and blood flow in patients with CRPS treated with light and is characteristic of the sympathetic abnormalities seen in CRPS. During therapy, it provides a means of monitoring the effectiveness of the applied light and allows for termination of therapy in the event of excessive warming of the region. Outcomes assessment is facilitated by providing objective measures of the degree and patterns of thermal changes that correlate with beneficial reductions in pain.

A PROPOSED STANDARD FOR THE EVALUATION OF LUMBAR/SACRAL RADICULOPATHY IN THE GENERAL POPULATION USING DIGITAL INFRARED IMAGING.

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A study was conducted on a worker's compensation patient population to ascertain the viability of utilizing Digital Infrared Imaging (DII) to diagnose lumbar/sacral radiculopathy. The purpose of this exercise was to evaluate an imaging protocol that was developed in-house and based on dermatonal mapping of regions of the low back and lower extremities. This protocol was developed due to the lack of established protocols in the literature.

Patients were selected for the study between October 2005 and May 2006 only if they presented with pain complaints in the low back region and the insurance carrier approved reimbursement for the test. Radiation of the pain into the lower extremities was not a requirement for patient inclusion. The "proof" of the appropriateness of DII for this pain complaint was the correlation of the infrared findings with other anatomical and/or physiological studies. In ninety-three percent (93%) of the patients who tested positive with DII, the findings correlated with other tests.

Conclusion: The protocol developed for evaluation of radiculopathy has high correlation with other, more expensive, testing procedures such as MRI, CT Myleogram, Bone Scan, NVC and EMG. The sharing of evaluation protocols developed by users of DII systems will promote more standardized testing, overall correlation of diagnostics, improved patient outcomes, and the acceptance of DII testing by insurers.

DYNAMIC THERMOGRAPHY

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Infrared thermography or infrared thermal imaging is based on analysis of skin surface temperatures as a reflection of normal or abnormal human physiology using specialized IR-cameras. In a fraction of a second, a large area of the human body can be imaged to an accuracy of less than 0.1°C. In general, skin surface temperature is proportional to local blood flow. However, it is difficult to obtain adequate information on the dynamics of perfusion physiology with static thermographic images. With dynamic infrared thermography it is possible to better evaluate skin perfusion (1). The technique of dynamic infrared thermography (DIRT) is based on the relationship between dermal perfusion and the rate of change of skin surface temperature following the application of a transient local thermal challenges (2,3,4). Rapid physiological changes can be readily registered with the new generation of infrared cameras. The information can be easily analysed using infrared camera that employ, for example, fire-wire technology. This new development allows real time analysis of images (i.e. image sequencing rather than just still pictures). Having access to this technology provides an enormous advantage in the use of IR-thermography. This is especially important since being able to follow dynamic changes in skin temperature opens up a whole new field of possibilities for this technique. For example, it is very usual to use provocation tests (responses to heating and cooling) in both research and clinical situations. Examples of the use of Dynamic Thermography will be presented in both research and routine clinical situations

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EVALUATION OF BREAST HEALTH-35 YEARS EXPERIENCE WITH MONITORING BLOOD FLOW

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Physiology of the breast by infrared imaging of the breast is a skin organ which is unique in that its function and growth which is best monitored by its blood flow.

The Symposium on Biomechanical Engineering of the skin in 1983 determined that thermography was an accurate measure, if not the most accurate! Dr. Atisumi, Professor of Cardiac Surgery and first heart transplant, stated likewise and devised a formula for blood flow. Since 1972, all conditions of the breast have been studied with thermograms from Harvard to John Hopkins and University of Southern California to Austria, England, France, Italy, Japan, Korea, and Asia.

The breast presents changes in blood flow in 1.0 growth, 2) injury, 3) pregnancy, 4) endocinre manipulation, 5) mastopathy, 6) infection, 7) neoplasia, and 8) ingestion of drugs.

Thermography is the greates help in endocrine management of 1) PMS, 2) monioting birth control, 3) monitoring fibrocystic consition, 4) early detection of in angiogenesis in neoplasia, 5) most accurate prognosis of survival, 6) effects of chemotherapy, and7) early diagnosis of inflammatory carcinoma.

Thermography provides major physiological information to be interwoven with ultrasound, x-ray, and MRI with gadolinium contrast. Thermography is the most important exam on declaring the health and function of the breast. This is an important medical observation.

BEYOND MAMMOGRAPHY

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The most devastating loss of life from breast cancer occurs between the ages of 30 to 50. Fortunately, women today have more options available to them to help in the detection of breast cancer than in the past decades. Unfortunately, education and awareness of these options and their effectiveness in detecting breast cancer at different stages on life are woefully deficient.

This presentation explores the latest finding on the effectiveness and shortcomings of various detection methods used by the mainstream medical community, including mammography, clinical breast exams, ultrasound, and to a lesser extent, magnetic resonance imaging (MRI's) and PET scans. This presentation will also explore the highly advanced but much maligned detection tool for breast cancer- breast thermography. Breast thermography, which involves using a heat sensing scanner to detect variations in the temperature of breast tissue, has been around since the 19060's. However, early infrared scanners were not very sensitive and were insufficiently tested before being put into clinical practice, resulting in misdiagnosed cases. Modern day breast thermography boasts vastly improved technology and more extensive scientific clinical research. In fact, reference data from major peer review journals and research on more than 300,000 women who have been tested using this technology. Combined with successes in detecting breast cancer with greater accuracy that other methods, the technology is slowly gaining ground among more progressive practicioners. This "Beyond Mammography" review concludes that breast thermography needs to be embraced more widely by the medical community and awareness by women. Not only has it demonstrated a higher degree of success in identifying women with breast cancer under the age of 55 in comparison to other technologies, but is also an effective adjunt to clinical breast exams and mammography for women over 55. Finally, it provides a non-invasive and safe detection method, and if introduced at age 25, provides a benchmark that future scans can be compared with for greater detection accuracy.

AUTOMATIC PATTERN RECOGNITION APPLIED TO THERMAL IMAGING FOR LARGE-SCALE BREAST CANCER DETECTION

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Malignant breast tumors have characteristic thermal signatures that comport to Hippocrates' cardinal sign of Calor and were empirically recognized since the earliest electronic images. Basic science has revealed the underlying physiologic mechanisms for these thermal signatures and a quantitative and objective method has been developed to improve the reliability of thermal imaging as a diagnostic modality for detection. Intelligent Computation (IC) is now applied to extend the diagnostic parameters, increase reliability and enable large-scale application. Particularly we are applying IC to evaluate the variability of true-positive and false-positive cues by using specialized proprietary neural network (Dynamic Perception) architecture for the analysis of 2000 patients pre-screened for breast malignancies. Moreover, we are applying the technique to a sample data set of 2000 patients screened for breast malignancy with good infrared features but unreliable response to the infrared analysis due to imperfect techniques by the human operators. Finally, the same architecture is being evaluated in ongoing research on breast cancer screening in a hospital environment. Preliminary results are presented and discussed also in relationship with other more classical techniques.

PANDEMIC? THERMOGRAPHY FOR FEVER SCREENING OF AIRPORT PASSENGERS

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The SARS outbreak in S.E.Asia in 2002/3 prompted several local health authorities to assemble a number of thermal imaging systems for installation at airport terminals. Not all the cameras used were of proven radiometric standards, and the manner in which they were employed was highly variable. On the premise that facial temperatures in excess of 38^{0}C were classified as fever, a number of subjects were sent for clinical examination before being cleared for travel. The International Standards Organisation ISO has appointed a working group to prepare a new version of the SPRING documents for International use, defining a screening thermograph. IEC TC/SC62D – ISO/TC121/SC3, *Clinical thermometers, writing group on thermography for human temperature screening.* This group has now met on four occasions since December 2005, and has a document that is moving into its final stages later in 2007. The outcomes of the ISO committee, the definitions involved, and the preliminary results from febrile and non febrile subjects will be presented. Some practical work is being undertaken on fever detection in children in Warsaw where the author has access to some of the latest thermal imaging technology in a paediatric clinic. The aim is to investigate the relationship between facial, auxiliary and aural temperatures in normal and febrile children between 1 year and 16 years of age. To date some 95 children have been examined. Results to date indicate that the inner canthi of the eye are reliable targets for temperature measurement, and when this area is over 38^{o}C, other thermometric measurements confirm the presence of fever. It is anticipated that the standard and advice documents arising from this work, may well lead to a further standard for clinical thermography.

SNIFFING OUT RAYNAUD'S PHENOMENON

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

INFLUENCE OF IMAGING AND OBJECT CONDITIONS ON TEMPERATURE READINGS FROM MEDICAL INFRARED IMAGES

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Several circumstances influence the accuracy and precision of temperature readings from thermal images: the object imaged, the camera systems, standards, imager calibration and image analysis affects both accuracy and precision, but object position, image capture, information protocols and resources have only an impact on the repeatability of measurements. The Medical Imaging Research Group at the University of Glamorgan investigated the influence of imaging and object conditions on temperature readings from thermal images.

Ring & Dicks showed differences of older and newer thermal imagers in spatial and temperature resolution and Plassman et al. reported a set of 5 tests to control for equipment related measurement errors.

In 2001, the Glamorgan protocol established a series of standardized positions of the body for image capture. Repeatability was proven for most of these body positions. The Glamorgan protocol created also a complete standard for the definition of regions of interest in thermal images based on anatomical limits. Both variations in body position during image recording and variations of shape and size of measurement areas affect the precision of temperature measurements.

The reproducibility of temperature measurement from thermal images was shown. The biggest variation of temperature readings can be detected when the same body region is imaged from a different angle of view. The measurement error may be as much as 1 degree C. A similar, but minor error occurs in slight variations of body position or different size or shape of measurement areas. However, variation of the room temperature in repeated image recordings have a higher impact on the temperature readings than variation in the size of measurement areas

The results indicated that following strictly standard procedures for camera calibration, image capture, subject preparing, body positioning and image analysis reduces errors and increases both accuracy and precisions of temperature measurements.

A BRIEF HISTORY OF 25 YEARS (OR MORE) OF INFRARED IMAGING RADIOMETERS

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FLIR Systems, Inc. - Infrared Training Center

Modern thermal imaging radiometers are infrared systems usually endowed with some means of making surface temperature measurements of objects, as well as providing an image. These devices have evolved considerably over the past few decades, and are continuing to do so at an accelerating rate. Changes are not confined to merely camera size and user interface, but also include critical parameters, such as sensitivity, accuracy, dynamic range, spectral response, capture rates, storage media, and numerous other features, options, and accessories

Familiarity with this changing technology is much more than an academic topic. A misunderstanding or false assumption concerning system differences, could lead to misinterpretation of data, inaccurate temperature measurements, or disappointing, ambiguous results.

Marketing demands have had considerable influence in the design and operation of these systems. In the past, many thermographers were scientists, engineers and researchers. Today, however, the majorities of people using these instruments work in the industrial sector and are involved in highly technical skilled Documents required tovalidate thermal equilibration, laboratory conditions, quantification of response to therapeutic interven the status of these devices from a “scientific instrument,” to an “essential tool.” Manufacturers have recognized this trend and responded accordingly, as seen in their product designs.

This paper explores the history of commercial infrared imaging systems and accessories. Emphasis is placed on, but not confined to, real time systems with video output, capable of temperature measurements.

DEVIATIONS IN NORMAL DERMATOME PATTERNS: A COLLECTION OF THREE CASE STUDIES.

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As somatic skeletal nerves are directly associated with their respective dermatomes, neuromuscular dysfunction in areas can be positively linked to impingements or damage to specific spinal nerves. However, due to the neural divergence and convergence that occurs within the paravertebral and collateral ganglia, there is a dilution in direct specificity concerning sympathetic outflow. Traditional diagnostic techniques are sometimes inadequate in the diagnosis of neural impingements and/or disruptions in sympathetic outflow to specific dermatomes. Infrared imaging provides a noninvasive means of visualizing and qualifying these types of circulatory, neuromuscular, and/or thermoregulatory aberrations. **Purpose**: The purpose of this collection of case studies is to demonstrate infrared images of select cases displaying neural or vascular impingements and/or interruptions in sympathetic outflow to specific dermatomes. **Methods**: Infrared images obtained from a CTI Thermal Imaging Camera are presented with accompanying subject information. **Results**: Follow up details are provided on subjects for whom the displayed problem has been resolved. **Conclusions:** Infrared imaging provides a fast, noninvasive method for visualizing neural or vascular impingements and disruptions in sympathetic outflow to specific dermatomes; and may prove beneficial in determining cause/effect relationships.

THE EFFECTS OF ACUPUNCTURE ON THE PATIENTS WITH COLD HYPERSENSITIVITY USING COLD STRESS TEST.

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Purpose: The number of patients with cold hypersensitivity would like to be treated with Oriental Medicine. However, there has not been any studies on the effect of acupuncture treatments on the patients with cold hypersensitivity. Therefore, we examined the effect of treatment at different acupuncture points and also compared the results of the first and the second Cold Stress Test(CST).

Method: In this study, 8 patients with cold hypersensitivity on hands participated. In order to avoid the bias, we excluded the patients with skin diseases, spinal nerve disease of cervical spine, or external wounds.

We measured the patients' body temperature using Digital Infrared Thermal Imaging(D.I.T.I.). Then, we performed CST at 6 thermographic observation using D.I.T.I.. First, the test was taken after 15 minutes of resting. The second test was taken immediately after the first; to differ, the patients' hands were placed in the water at 20 degree Celsius for a minute before taking the second test. For the third, the patients were to wait 10 minutes after the second test. The fourth test was taken a week after the third; this time, the patients were to rest for 15 minutes before the test. Following the fourth immediately, their hands were again soaked in the water at 20 degree Celsius for a minute and then took the fifth test. After the fifth CST, the patients received acupuncture treatment. The sixth test was taken 10 minutes after the fifth.

We divided the patients into two different groups for the acupuncture therapy, which the patients received after taking the fifth CST. For one group, we performed the acupuncture therapy on the distal points. For the other group, the therapy was done on the proximal points. Then we compared the first and the second CST recovery rate results.

Results: The recovery rate of the patients with the acupuncture therapy on the distal points was a little higher than the one without the therapy; however, the difference is not statistically significant. On the other hand, the recovery rate of the patients with the treatment on the proximal points was much higher than the one without it.

Conclusions: Acupuncture treatment may be one of the effective therapy methods on cold hypersensitivity; according to this study, the treatment on the proximal acupuncture points would be more useful on the patients with cold hypersensitivity.

THERMAL SYMMETRY ON EXTERMITIES OF NORMAL SUBJECTS

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Infrared thermal imaging is being utilized increasingly in the study of neurological and musculoskeletal disorders providing data on the symmetry of skin peripheral temperature. Skin temperature measurements were carried out on 26 healthy subjects' thermograms. Temperature measurements were obtained using a computer interfaced application developed in past projects of this research unit, CTHERM, this thermographic instrument with the capability of obtaining average temperatures and standard deviation values in corresponding areas of interest on both sides of the body. In the healthy control subjects the overall temperature difference was maximum value 0.19º C on total body view and 0.16 º C on regional views. This study has confirmed with quantitative data from CTHERM software, the thermal symmetry in normal subjects, which can be used to assess thermal changes in specific pathologic states. This work has also compared the usage of total body view (table 1) with the regional views (table 2). No other studies have been carried out with the current generation of higher resolution cameras. There is not a substantial difference on thermograms taken by current generation high resolution thermal cameras on usage of total body views or regional views.

EQUILIBRATION PERIOD FOLLOWING EXPOSURE TO HOT OR COLD CONDITIONS WHEN USING INFRARED THERMOGRAPHY.

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Introduction: Infrared Thermal Imaging (ITI) is capable of detecting skin temperature up to 1.5 cm deep with a sensitivity of 0.01°C. Ensuring proper equilibration before thermal imaging takes place is imperative to facilitate ITI's reliability and validity when assessing temperature and thermal patterns related to cutaneous blood flow. The use of ITI requires following precise protocols that have been set by the International Academy of Clinical Thermology (IAOCT). A minimum of 15 min is the current amount of time suggested by the IAOCT. To date, there is very little data available showing 15 min is sufficient time for equilibration to take place.

Purpose: To determine the equilibration time required after exposure to a hot (31.7 °C) or cold (18.9°C) environment.

Methods: Thermal images of the anterior and posterior views for 17 subjects were taken during two separate trials; a hot trial on day 1 and a cold trial on day 2. Upon arrival to the thermal lab, a 60 min equilibration period in a climate controlled room at optimal ambient temperature (24.2 °C) was used to determine a control skin temperature. Subjects wore minimal attire in order to expose maximal skin surface to room temperature. Subjects then stood in the thermal chamber for a 20 min exposure period to the hot or cold trial. Images were taken of the anterior and posterior views at optimal ambient room temperature immediately after exiting the thermal chamber, and at 15, 30, 45, and 60 min. Views were subdivided into periphery and trunk segments; mean, min, max, and standard deviations were determined for each segment. Temperature differences between control, immediate, 15, 30, 45, and 60 min time periods were compared using repeated measures ANOVA ($p < 0.05$).

Results: During the hot trial mean trunk temperature increased 1.03 °C and remained significantly different from control until the 30 min time period. The mean periphery temperature increased 1.37 °C and remained significantly different during the entire 60 min time period. During the cold trial the mean trunk temperature decreased 1.1 °C and remained significantly different until the 15 min time period. The mean periphery temperature decreased 1.7 °C and remained significantly different until the 30 min time period.

Conclusion: Results from this study indicate that exposure to hot or cold conditions (31.7 °C and 18.9 °C) may require a longer equilibration period than the recommended 15 min for skin temperature to stabilize to room temperature when using ITI.

PERFORMANCE TESTING OF THERMAL IMAGING SYSTEMS IN MEDICINE

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Consistent and regular condition and performance monitoring is important for the reliable use of infrared thermal imaging in medicine. Infrared camera systems nowadays offer increasingly higher capabilities and improved reliability, which can lead the operator to assume that the system is continually providing optimum performance. This, however, is not the case.

We propose a series of simple experiments based on inexpensive and easy to acquire materials, which a thermographer can use under normal clinical conditions to monitor the performance of thermal imaging equipment in order to maintain confidence in the measurements made. The 7 tests proposed are not intended to replace those undertaken by manufacturers or calibration laboratories, but can provide valuable information on both short and long-term camera performance. The proposed tests identify: a) offset drift after switching on, b) long-term offset drift, c) offset variation over the observed temperature range, d) image non-uniformity, e) the thermal 'flooding' effect, f) thermal resolution and g) spatial resolution.

Measurement results based on the above experiments will be presented which demonstrate that cameras may drift over several degrees centigrade in less than 2 hours after switching on. We will also show that imaging equipment can produce a varying amount of measurement error (up to 1.5 degrees centigrade), which depends on the temperature range observed. Results also show that equipment may be prone to non-linear errors (in the region of 1 degrees C), which are caused by deficiencies of the optical system and will manifest themselves if the equipment is not calibrated regularly.

OCULAR THERMAL IMAGING AS A MEASURE OF FEBRILE RESPONSES IN FOALS TO AN ENDOTOXIN CHALLENGE TEST

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The objective of this study was to evaluate febrile responses in weaned foals on a diet, with or without probiotic supplementation, using ocular thermography as a non-invasive and rapid means of body temperature acquisition following an endotoxin challenge test. Twenty two Quarter Horse and Thoroughbred foals (4-5 months) were weaned, individually stalled and given a feed supplement (CP 16%) alone (CON, n = 11) or top-dressed with a commercial probiotic preparation (Fastrack Microbial Pack, Conklin Inc.) at 28.4 g/head/d (PB, n = 11) for 30 d, with free access to hay and water. On d 30, a subpopulation of six foals per treatment group had indwelling catheters placed in the left jugular vein and iButton® data loggers configured to record body temperature at 10 min intervals placed under the tail-head. On d 31, foals were infused via catheter with lipopolysaccharides (LPS; *E. coli* 055.B5; 30 ng/kg BW). Infrared ocular thermal images and digital rectal temperatures were obtained at -0.5, 0, 0.5, 1, 1.5, 2, 4, 6, 12, 24 h as were blood samples for cortisol RIA and cytokine macrophage analysis (data not shown). Within 1 h of infusion all foals showed stress-induced clinical symptoms (dry cough, recumbency, mild diarrhea). Correlative analysis was performed between maximum ocular eye, rectal and data logger temperatures. No significant effect of probiotic treatment was observed for body temperature. Rectal temperatures (°C) peaked at 1.5 h in both groups (CON, 38.8 ± 0.22; PB, 38.7 ± 0.15) and returned to baseline 24 h post infusion. Both infrared ocular and data logger temperatures (°C) were positively correlated ($p<0.001$) with digital rectal temperatures ($r = 0.48$ and 0.56, respectively). These data suggest that ocular thermography may be an effective, alternative and non-invasive method of assessing body temperature of horses.

[Supported by MAFES and Conklin Inc., Shakopee, MN]

EARLY DETECTION OF HYPERELASTOSIS CUTIS/HERDA LESIONS IN HORSES USING DIGITAL INFRARED THERMOGRAPHY

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Hyperelastosis cutis (HC) is an autosomal recessive skin disease of economic significance in Quarter Horses. Affected animals do not generally develop lesions until one to two years of age. There is currently no test for carrier animals. The objective of this study was to determine whether digital infrared thermal imaging could be used to detect HC carrier foals. Studies using digital infrared thermal imaging (DITI) of mature affected horses detected cooler areas of skin ($P = 0.01$) associated with developing HC lesions compared with normal animals. Based on these findings, four HC-affected and two carrier foals were compared using DITI with aged-matched normal foals (n = 5). Digital rectal temperature and thermal images of the skin surface were recorded at two to three-week intervals using a ThermaCam® S60 camera (Flir Systems, Boston, MA) and location of thermal lesions were documented. Data analysis is based on five imaging sessions. Affected animals demonstrated a greater ($P < 0.05$) range of skin temperatures when compared to carriers and control animals, while carrier skin temperatures also differed ($P < 0.05$) compared with controls. There was a strong correlation between rectal and skin temperatures in normal ($r = 0.94$) foals but poor correlations existed in affected ($r = 0.38$) or carrier ($r = 0.47$) foals. One affected foal developed a thermal lesion one week prior to developing a visible skin lesion. Measurements were repeated in these animals as yearlings and the thermal image patterns remained consistent with observations made as foals. In addition, histology confirmed the presence of HC lesions as detected by thermal imaging. Electron microscopy demonstrated irregular tangled arrangement of collagen bundles in HC lesions compared to normal skin. These observations indicate that DITI may be a useful, non-invasive means of early detection of HC carrier foals.

[Supported by American Quarter Horse Foundation]

TISSUE COMPRESSION AT THE ISCHIAL TUBEROSITY AND THE MIDDLE POSTERIOR THIGH: IMPACT ON NERVE FUNCTION, BLOOD FLOW, AND TISSUE OXYGENATION

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Paresthesia of the lower limb is a common condition associated with extended sitting. Although these sensations are typically produced by spontaneous action potential propagation originating from ischemic regions of affected axons, total limb blood flow and tissue oxygenation may also contribute to the condition. The purpose of this investigation was to evaluate the effects of controlled tissue compression on nerve function, blood flow, and tissue oxygenation. Counter balanced compression intensity (30, 90, 150, and 210 mmHg) produced by a purpose-built plunger was applied to either the ischial tuberosity or the middle posterior thigh of four participants lying prone. Nerve function, blood flow, and tissue oxygenation were evaluated by the soleus' response to repeated 50% H-maximum Hoffman reflex stimuli, thermography, and near infrared spectroscopy (NIRS) measures, respectively. Each measure was recorded each minute throughout compression and the ensuing 10-minute post-compression period. Nerve function was altered for the 150 and 210 mmHg middle posterior thigh condition as evidenced by an increase in the soleus Hoffman reflex amplitude. This response did not occur at the ischial tuberosity location or during the other compression intensities. Thermography comparisons between the baseline condition and the uncompressed lower limb showed no change, indicating that blood flow within the compressed limb was not altered. NIRS demonstrated that tissue oxygenation did not change for any condition. However, the areas immediately proximal and distal to the compression surface showed a marginal total hemoglobin reduction. This change likely occurred due to tissue deformation produced by the compression since both oxyhemoglobin and deoxyhemoglobin showed equivalent reductions. Paresthesia sensations may be attributed to altered nerve function and not noticeable differences (as assessed by thermography and NIRS) in total lower limb blood flow or oxygenation.

THERMAL WINDOWS IN SEALS AND SEA LIONS: NON-INVASIVE INDICATORS OF HEALTH?

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Alaskan harbor seals and Steller sea lions have adapted to the extreme weather conditions of their aquatic and terrestrial habitats through the use of blubber, which is not only a remarkable energy source but also an efficient insulation system that provides security from their harsh surroundings. Despite their shared habitat, the anatomy and life history traits of the two groups differ such that energy resources and thermoregulation may take variable precedence with different body sites and physiological states. Nine harbor seals (8F, 1M) and two female Steller sea lions at the Alaska SeaLife Center in Seward, AK, are the focal subjects of the validation of the use of infrared thermography as a diagnostic tool. Data are collected from each individual up to bi-weekly with a FLIR P25 camera, coupled with a non-invasive assessment of blubber depth via a SonoSite 180Vet portable imaging ultrasound from up to 10 body sites. Preliminary studies suggest that thermal windows vary between the two species as well as among individuals, between seasons and with body condition (i.e., blubber depth). Establishment of a thermal window baseline may allow for future diagnostic applications in both long-term captive and free-ranging pinnipeds, such as identification of inflammatory processes, disease, or nutritional stress.

USE OF IR THERMOGRAPHY IN DETERMINING SPATIAL HEAT DISTRIBUTION OF VARYING ULTRASOUND TREATMENT TECHNIQUES

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Background and Purpose: In physical therapy, short wave heat is used as a possibility to achieve deep heat in patient treatment. One of the modalities used is ultrasound, where the ultrasound transducer is moved in order to avoid the non-uniformity of the ultrasound beam. The purpose of this research paper is to see if infrared thermography can be used to determine if different techniques have different characteristics in spatial heat distribution.

Methods : The experiments were performed on the cross section of a fresh pig cadaver hind leg, reflecting a location a physiotherapist may encounter in clinical situations. The experiments were carried out with an ultrasound frequency of 2MHz, an intensity of 1W/cm^2 and three different techniques, i.e. an 8cm/sec circle technique, a 3cm/sec circle technique and a 3cm/sec linear technique. The temperature increase patterns were thermally imaged at 30 sec. intervals with an insonation period of 5 minutes. In the computerized comparison, every temperature data point from the reference image was "subtracted" from the thermal image after the respective intervals.

Results: The circle techniques show that the heat distribution is concentrated around the middle of the circle. In the 8cm/sec circle technique the heat distribution is found in the superficial tissue layers, while for the 3cm/sec circle technique the heat is also found in the deeper tissue layers. The linear 3cm/technique shows heat at the turning points of the movement.

Conclusions: The different techniques are not interchangeable. A faster circular movement and a slow longitudinal movement of the transducer influence the heat penetration depth. The three techniques have different heating characteristics.

CRYOGENICS CHANGES IN DIFFERING ICE TREATMENTS

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The purpose of this study is to look at the differences between a fifteen minute ice bag treatment and a fifteen minute ice towel treatment. If they differ which treatment would be more beneficial to rehabilitation of injuries? Three factors were compared in this study: 1) Coverage area of the treatment 2) time for surface temperature to return to normal 3) Average change in surface temperature. Seven college students were tested in two trails on separate days (4 m, 3 f, age 22.2 ± 1.8). A baseline themographic image was taken of both the anterior and posterior torso. The area of the deltoid, scapula and pectoralis were used as the treatment area. From baseline images an average surface temperature was determined for the treatment area. A fifteen minute ice treatment was administered using either a standard plastic ice bag or a cotton ice towel. Immediately following the treatment, an image was taken to determine the maximum and average decline in temperature. Images were then taken in thirty minute intervals until the average temperature returned to within one degree Celsius of the baseline. The results showed the ice towel covered a space 30% larger than the plastic bag, and that the towel effectively doubled the treatment time. On average the towel was 6°c cooler than the bag. Cooler temperatures allows for a better guarantee that the vessels are being constricted and reducing swelling. The larger coverage insures that both the injured and surrounding areas can be treated. Finally, doubling the amount of time it takes for the surface temperature to return to normal means that the treatment is still working long after the ice is removed. Taking these factors into consideration it is important to look to ice towels as a viable substitute for the standard ice bag.

A THERMOGRAPHIC COMPARISON OF COLD THERAPY DEVICES ON SURFACE SKIN TEMPERATURE

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Purpose: This study compared the practical effects of two medical cold therapy devices, ProThermal (Pro) and Game Ready (GR), to a conventional ice treatment (CI) on surface skin temperature using infrared thermal imaging. **Methods**: Six male subjects (ages M=23.2 years) were randomly assigned to each cold modality for a treatment period on three separate days. Following 15 minute room equilibration (EQ), each modality was applied to the anterior upper right leg (treatment site; indicated by the superior 1/3 of the tibia) for a twenty minute cold treatment period. Using infrared thermography, skin temperatures were imaged at the treatment site at four different time periods: Pre-treatment (PT), after EQ; Post- cessation of the treatment period; Post15- fifteen minutes post treatment; Post30- thirty minute post treatment. Area skin temperatures of the treatment site were measured for each image and the mean values were collected using Computerized Thermal Imaging software. **Results**: Repeated ANOVA's were employed to determine statistical differences between treatments ($p = 0.05$). No statistical differences were identified after equilibration during PT conditions. All three modalities resulted in significantly colder skin temperatures from PT to Post. However, Pro achieved significantly higher Post skin temperatures than CI and GR (Pro 17.7 ± 2.06; CT 10.6 ± 2.53; GR 11.71 ± 2.53). The warmer temperatures demonstrated by Pro at Post treatment resulted in skin temperatures statistically insignificant from Post15 to Post30, compared to PT. Consequently, Pro displayed significantly higher skin temperature than GR and CI at Post15, and with CI only at Post30. There were no significant differences between GR and CI at any time period, thus showing a similar beneficial lowering of skin temperature during the Post treatment periods. **Conclusion**: Our data suggests that a CI treatment along with the medical cold therapy devices GR and Pro are capable of significantly lowering skin temperature after a twenty minute cold therapy treatment. However, only CI and GR were cooler and were able to maintain a lowered skin temperature for 30 minutes, following a cold treatment.

RELATIONSHIP BETWEEN DIGITAL INFRARED THERMAL IMAGING DETERMINED KNEE TEMPERATURES AND KNEE PAIN IN DISTANCE RUNNERS DURING A 3-MONTH CROSS-COUNTRY SEASON

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Introduction: Attempts have been made to identify or predict tissue injury in animals and humans using digital infrared thermographic imaging (DITI). Limited data are available describing normal DITI profiles of human limb joints, although progress has been made towards establishing a normal DITI profile of the knee of distance runners. **Purpose**: To develop case studies describing the relationship between DITI-determined knee temperature and knee pain in two collegiate distance runners. METHODS: Two males, out of 26 male and female athletes, reporting unilateral knee pain ≥ 4 on the Nirschl Phase Pain Scale (NPPS) on multiple assessments during a 3-month cross-country season were selected for analysis (subject 1: 23% of visits; subject 2: 43%). NPPS ratings ≥ 4 are defined as causing and an athlete to alter performance. At each assessment, subjects rated knee pain bilaterally with the NPPS and Visual Analog Scale (VAS). Anterior (A), posterior (P), lateral (L), and medial (M) DITI were recorded for each knee. For each view, temperature points within a standard observation area were analyzed to determine mean, maximum, minimum, and range using Therma CAM Researcher Professional software (Flir Systems, Wilsonville, OR). DITI data were correlated with NPPS and VAS pain ratings using Pearson's *r*. RESULTS: Correlations between knee pain, determined using NPPS or VAS, and DITI-determined knee temperature were consistently low and not significant. R values between knee temperatures and NPPS for A, P, L and M views ranged from 0.05 to 0.52; for VAS and DITI, r values ranged from 0.00 to 0.48. The only statistically significant correlation ($p < 0.01$) was between NPPS and anterior maximum temperature ($r = 0.52$). CONCLUSIONS: In the two case studies, there was a lack of a strong and consistent relationship between DITI-determined knee temperatures for various views and subject reported knee pain during a cross-country season.

APPLICATION OF A NEW RADIOLOGICAL IR IMAGING TECHNIQUE. MRI WITH IR 3D FUSION AND 3D STEREOSCOPIC PRINTING

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MRI fusion and 3D IR imaging: We are developing a new IR imaging technique which consists of fusing magnetic resonance imaging (MRI) (1.3 Tesla Magnetom MR Systems, Siemens) and thermal infrared (IR) imagery to generate a diagnostic 3D image in real-time. The authors used high resolution IR images (0.02° C) produced by sensitive QWIP FPA IR detectors acquired through a high sensitive camera (ThermaCam SC3000, FLIR Systems, Sweden). In order to build an Image Fusion Scheme, it was necessary to standardize the MRI image acquiring process by filming the whole body 360° upstanding under automatic rotatory motion. The best incidences acquired through real time 14-bit digital output connector for fast image caption and recording were chosen. A sophisticated and dedicated software (ThermaCam Researcher 2001, FLIR Systems) was used in the evaluation of high resolution images in continuous color pallet. After acquiring the images, a 3D reconstruction with graphics computer systems was performed. Contrast-enhanced MRI for breast cancer assessment has been increasingly used. This modality of imaging provides 3D functional information, via pharmacokinetic analysis of the interaction between the contrast agent and tumor vascularity. MRI is an important breast imaging modality: it can be applied to women of all ages including patients with surgical/radiotherapy scarring, in contrast to X-ray mammography , which has limited use in younger women, HRT users and for postoperative assessment. IR imaging was frequently used in the past to detect changes in skin surface temperature associated with breast cancer. A 1-2° C elevation in skin surface temperature can usually be observed at the tumor periphery. Such effect suggests that there is a local change in temperature that might be due to the hypervascularity resulting from tumor-associated angiogenesis. Pathological changes (such as calcifications and fine spiculations) are more difficult to be assessed through MRI. Therefore, there is clinical and diagnostic application of this technique that fuses high-resolution functional data acquired from IR imaging with the structural data acquired from MRI imaging. Using breast imaging fusion software, the clinician is able to analyze areas of interest seen in X-ray mammogram with the aid of MRI and IR 3D imaging acquisition. Application of this research technique include improving MRI diagnostic capability that can be applied towards breast cancer angiogenesis, intracranial diseases and peripheral vascular occlusion diseases.

3D anaglyphic stereoscopic IR imaging: The authors describe how to use the 3D anaglyphic method in order to produce stereoscopic IR imaging prints for anatomical and physiological teaching and report preparation by using professional photographic and computer software. Similar to any other method of producing stereoscopic images, the anaglyphic procedure is based on the superimposition of two slightly different images of the object to be seen in a 3D fashion. One image is generated with the camera angled from the left side and the other image from the right angle. Both pictures are obtained through a single camera, or by using two cameras affixed to each other. After the images are processed by applying different complementary color dyes, they are scanned and superimposed to each other with the aid of professional imaging-manipulation software and printed out. Glasses with colored lenses, normally one red and one blue, are employed to allow stereoscopic vision. Stereoscopic 3D IR anaglyphic prints can be reproduced using photographic and personal computer equipment; so the prints can be easily reproduced without significant cost and are of particular help to disclose the 3D character of IR imaging.

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HIGH SENSITIVE IR IMAGES REPORT. NEW SYSTEM OF MUSCULOSKELETAL INJURIES DESCRIPTION

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IR imaging has an important role in worker's compensation and insurance reimbursement. It is necessary though that the report is official as a traditional radiological report. We developed a new evaluating system to describe IR signaling of 3D vascular territories (callled "angiosomes") (Govidan, 2005), in order to better assess musculoskeletal pain diseases using high sensitive IR imaging equipment The aim of this study is to compare the IR imaging skills of physicians in training with those of experienced IR radiologists. Also we evaluate the impact of a training program using a new evaluating system applied to real patients.

Method: In an academic setting, 32 physicians (neurology, orthopedic and occupational medicine residents) evaluated patients using a high sensitive device (Thermacam SC3000 FLIR Systems, Sweden). The thermal camera produced high resolution and high sensitivity images (0.02 °C) through a QWIP FPA IR detector. It can detect IR radiation in the 7.5-13 μm range. These parameters of sensitivity are necessary for detailed medical observation and quantification of heat flow.

A Volunteer control group comprised of 333 patients with musculosk eletal pain injuries whose IR signs were identified after completing a clinical questionnaire. IR signs (IR imaging Area Interpretation Criteria (Brioschi, 2002): region of interest, intensity, size, shape, distribution, delimitation and margins) were determined beforehand by an independent skilled IR imaginologist and were validated by ultrasonography (US) and a skilled pain physician. All patients were seen pre and post-interventional by the same physician in a course of one week.

Results: Exams were normal in all participants from the volunteer control group. The sensitivity and specificity of the US were 79 and 100% respectively, while the IR imaging was 100% and

100%. The total accuracy was 89% for US and 100% for IR imaging. When US was compared with IR imaging findings, it showed a positive correlation of 89%. In 11.2% of the cases the IR imaging was abnormal while the US result was normal; these were non specific injuries without anatomic correlation. The experts were the most skillful, achieving 100% recognition of IR signs and making correct diagnoses in 100% of cases. The residents identified 80% of the thermal signs and made correct diagnosis in 70% of cases in the first month. After one week of training sessions of the new system, the mean percentage for correct diagnosis was 98% [an increase of 28% ($p<0.05$)].

Conclusion: The level of diagnostic skills in this relatively small group of physicians in training was indeed high and was improved by a short period of training with this new IR training course for musculoskeletal pain diagnosis. Actually the system is a tool available in the internet for continuous training and supporting to the affiliated physicians.

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INFRARED EXPERTISE: FROM DIAGNOSIS TO TREATMENTS. INFRARED IMAGING OF FAR-INFRARED RADIATION IN DIFFERENT TYPES OF APPLICATIONS.

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Infrared radiation is subdivided in an arbitrary pattern into three categories: near- (0.8–1.5 ìm), middle- (1.5–5.6 ìm), and far-infrared radiation (5.6–1000 ìm). Only little is known about the biological effects of infrared (IR) radiation, although human skin is increasingly been exposed to IR from several natural as well as artificial sources. IR, similar to ultraviolet (UV) radiation, is likely to exert biological effects on human skin. IR radiation has increasingly been used for cosmetic and wellness purposes. Apart from this, IR radiation is used as a therapeutic approach in the treatment of several entities such as autoimmune, inflammatory and malignant diseases and also wound healing disorders. Electromagnetic energy in the form of far-infrared rays (FIR) is now under extensive investigation as local, regional, and whole-body treatment. Recently, much attention has been paid to its activities concerning health and food preservation. Accumulated evidence indicates that FIR is biologically active. FIR has been reported to inhibit tumor growth in mice and has been applied as a therapeutic approach of bedsores in clinical settings. However, there are few reports of scientific analysis of biological activities of FIR radiation, with most of these being related to the hyperthermic effect of FIR. The biological effects of FIR on whole organisms remain poorly understood. Herein we report different applications of continuous exposure to FIR and its evaluation through IR imaging with high sensitivity sensors.

Methods: A randomized, controlled trial was approved by the hospital ethics committee and conducted at the Center of Pain, Division of Neurology and Neurosurgery at University of Sao Paulo from January to December 2006. 110 subjects aged 27 to 66 years old were evaluated. All subjects provided written informed consent for their participation in the study. Skin blood flow and temperature of individuals were measured using a FIR camera (ThermaCam A40M, FLIR Systems) in a room with constant temperature (T = 20° C) and constant relative humidity of 50%.

Skin blood flow, edema, inflammation and pain from study group (n = 80) was compared to control group (n = 30); study group was composed of different conditions (pos-poliomyelitis syndrome, lumbar pain, neuropathic pain, cellulite, carpal tunnel syndrome, fibromyalgia, obesity, leg varices, tendinopathies, toe inflammation).

Garment ceramic-impregnated by aluminum, silica and magnesium (95% polyurethane and nylon; 5% ceramic) that absorb ambient FIR (3 to 15 micrometers wavelength) from the environment and body was utilized for this study. The garment reflects a thermal energy intensity of 12.6 to 71.5 kcal/m² per hour to the underlying tissues. These products, known as "INVEL® garments," were approved in 2005 by the National Health Surveillance Agency in Brazil. Different garments were used: short drawers, shirts, gloves, cards, multi belts, plush, and elastic bandages. Also an emulsion prepared with the ceramic-impregnated powder was tested.

Results: Measured skin blood flow, edema, inflammation and pain change significantly after FIR radiation application via the ceramic-impregnated garments. Secondary improvement occurred through vasodilatation and improved circulation. Skin temperature increase ranged from 0.6 to 1.5° C. Average measured decrease in medium body circumference was 1.8 cm.

Conclusions: These results suggest a biological effect of increased exchange of body fluids, due to decrease in size of water clusters, without a significant increase in the temperature of the body tissues. The results suggest that the FIR increase the lymphatic drainage in the first steps of the inflammatory process. Nitric oxide (NO), constitutively produced by endothelial NO synthase (*e*NOS), plays an important role in vascular biology including regulation of vascular tone and blood pressure, as well as the regulation of angiogenesis. These findings suggest that FIR therapy also up-regulate the expression of arterial *e*NOS increasing circulation as demonstrated by IR imaging.

The potential effect of FIR radiation in the improvement of circulation is suggested by our studies. This study suggests that FIR radiation has the potential to increase skin blood flow to the tissues. FIR rays show different photobiological properties. We used FIR with wavelengths ranging from 3 to 15 ìm in these studies, whereas lasers deliver a specific coherent beam (helium-neon at 632 nm and argon at 488 nm). Although it is thought that further studies of FIR are required, the biostimulatory effects of FIR radiation might be similar to those of low energy lasers or near-IR rays. FIR can be combined with radiation, chemotherapy and biological therapy in an effort to increase their effectiveness. These findings suggest that whole-body FIR radiation at room temperature could be a promising way of photochemical therapy. Further analysis of the molecular 'IR response' and the photophysical and photochemical reactions induced by IR should provide valuable information on the role of IR on cellular functions with its impact on aging, tumor inhibition and stress resistance. These studies may also disclose novel therapeutic applications of IR radiation in clinical settings. In addition, it was very practical to evaluate the biological effects of IR by IR imaging in vivo studies. Moreover, these results should allow the development of IR photochemical therapy magnifying the spectrum of knowledge and research for IR beyond diagnosis.

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SURGICAL INFRARED IMAGING APPLICATIONS: DIRECTIONS FOR THE FUTURE.

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The 20th century brought with it the bundle of the wars. From 1914 to 1945, in only thirty-one years, mankind witnessed the largest scientific revolution ever seen. Men achieved, in those years, what had not been accomplished in nineteen centuries. At the same time that it caused an enormous destruction in the world, the two great world wars brought scientific and technological progress. The most recent example is the use of infrared (IR) thermal images by the Coalition Air Forces, utilized against the Iraq attacks of high precision as intelligent weapons guided by the heat. Thanks to the high resolution and sensitivity IR vision technology, today it is possible to visualize the coronary arteries flow during revascularization surgery of the myocardium, observed through a monitor in a totally non-invasive way. This increases the surgical success rate and the quality of life offered to the patient. Surgical IR applications are being more extensively studied by our group in the last 5 years.

Thermocoronary angiography: Brazil has one the highest rates of death by heart disease in the world (34 %). One third of these cases are caused by coronary artery disease which is the main reason of sudden death, infarction, angina and cardiac pathology. In coronary occlusions, the most common approach is the revascularization procedure by using either an arterial or venous graft. Inadequate anastomosis leads to reintervention surgery or even death by infarction either during or after surgery. Intraoperative coronary angiography has always been favoured by cardiac surgeons. The arterial coronary net lies in the heart surface (epicardium). Right after the surgical clamp is released during coronary anastomosis, the warmth of the blood pattern can be observed flowing to the 4th order arterial branch. Because of its benefits, it is likely to become the gold standard in safe cardiac revascularization surgery. Thermal coronary angiography (TCA) is a useful method for intraoperative control of graft patency. It detects heat differences between tissues, provides easy-to-interpret angiographic images and even measures quantitatively the graft flow. Thermal imaging provides decisive coronary angiographies, and detects the perfusion area and flow of the implanted graft. It allows real-time detection of technical failures, reveals unexpected occluding plaques or any kind of flow-restricting lesions, and gives the chance of refinement of the anastomosis during the arrest period. Thermal imaging technique is a safe, non-invasive and feasible method to document the quality of the myocardial revascularization intraoperatively.

Sympathectomy IR imaging studies: Endoscopic sympathetic block (ESB) is used as a treatment of excessive palmar sweating and sympathetic dysfunction. IR imaging study of palmar and facial skin temperature can be performed pre-, intra- and post-operative during thoracic sympathectomy. IR imaging studies offer descriptive information about the autonomic innervation of the upper thoracic sympathetic trunk.

IR evaluation of organ transplantation: IR imaging use in surgery has increased, especially in the evaluation of the organ and tissue microcirculation. Unlike skin surface, the surface of internal organs are not wrapped up in a thermal insulator. According to Newton's third law, they get cold when exposed to a cold environment. Their surface temperature is determined basically by the flow of the blood perfusion. For this reason, an organ's viability can be evaluated by continuous registration of thermal images. When there is an arterial net in a certain organ, its anatomical pattern is clearly observed through thermal images. Due to the increasing need for liver donors, transplantation from non-heart-beating donors (NHBD) has increased. As there are not detailed studies of reperfusion injury of these livers so far, an IR imaging evaluation of liver ischemia reperfusion immediately after NHBD organ explantation could be extremely useful. It has been applied in kidney, liver, lung and intestines transplants, in the postoperative evaluation to check for venous thrombosis, acute rejection and immunosuppressive drugs toxicity.

IR Direct Calorimetry: The authors developed a method of IR thermographic calorimetry (ITC) to estimate the protein intake requirement. Digital radiometric images were taken with a FLIR SC3000 infrared camera (FLIR Systems, Sweden), and the thermal data associated with heat loss theories were used to calculate mean body surface temperature, heat losses, and total energy expenditure caused by radiation, convection, evaporation and conduction. The personal parameters included age, weight, and height. In order to determine an ideal protein requirement, caloric needs were calculated based on their resting metabolic rate using ITC and sophisticated software. In comparison with other calorimetric method, interpretation with ITC is more accurate because it is taken when metabolic pathways other than oxidation predominate or when there are clinical conditions that affect carbon dioxide exhalation from the lungs. ITC is an accurate, noninvasive, and easy method for measurement of heat loss and energy expenditure in surgical patients, and therefore it may be an useful clinical and research tool especially to estimate the adequate protein intake.

Conclusion: With the development of faster computers and more powerful programs in data processing and complex imaging, we realized that IR imaging should be regarded as a functional and dynamic diagnostic tool and not as a conventional anatomical and static imaging exam.

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ROLE OF MAST CELLS IN CHRONIC REGIONAL PAIN SYNDROMES.

Srini Govindan

American Academy of Thermology

Chronic Regional Pain Syndromes can be spontaneous or induced eg., migraine by triggers or for CRPS as a complication of surgery (or) trauma.

The majority of migraine and CRPS patients do not show maximum obtainable temperature differences at room temperature/ static measurement, in the region of interest or between ipsi-lateral and contralateral sides. The temperature differences may vary based on regional/angiosome territory and mast cell properties and can be imaged at room temperature following vasomotor challenge using thermal (or) nonthermal factors. Central and regional vasomotor control may require/respond to specific vasomotor stress requirements eg., for facial/ trigeminal(hyperoxia, hypercarbia, positive pressure and / or drug) and for extremity cold or warm temperature challenges/ regional or whole body cooling and warming.

Mast cells are critical players in inflammatory diseases. These cells are located perivascularly, in close association with neurons. Neuropeptides such as CGRP, hemokinin A, neurotensin (NT), Pituitary adenylate cyclase activating peptide (PACAP) and substance P (SP) activate mast cells leading to secretion of vaso-active, proinflammatory and neurosensitizing mediators, thereby contributing to migraine and CRPS pathogenesis.

Chronic Pain Syndromes, migraine and CRPS/ RSD both have the following similarities:

Is associated with allodynia and hyperpathia, show regional perfusion abnormalities, have neuropeptide changes, e.g., CGRP, have tissue hypoxia/ A-V O^2 difference, AVAs are involves in altering flow independent of metabolism, functional anatomy correlates with angiosomes and physiological anatomy correlates with activation of perivascularly located mast cells and its vaso-active mediators.

Use of thermal and non thermal stress to study vasomotor capacitance allows thermologists to monitor and provide a non invasive method with increased sensitivity and specificity to be applied clinically in chronic pain.

Clinical Temperature Measurement & Thermography
Cardiff International Arena, UK, 2nd May 2007

Abstracts

THE TEMPERATURE OF THE HEALTHY AND INJURED HUMAN BRAIN

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Introduction Knowledge of human brain temperature is limited. Theoretical models of human brain temperature in health predict small differences only, between brain and body temperature. In animals and primates, incoming arterial blood temperature exerts a major influence on the thermal environment of the brain with fluctuations in aortic blood temperature, due to feeding sleeping and arousal, having parallel changes in brain temperature over time. When the brain is damaged e.g. by severe head injury, studies have shown that average brain temperature exceeds body temperature by approximately 1°C and in some cases by as much as 2°C. If brain temperature is measured in critically ill patients, and there are suggestions that this would be an advance in monitoring and management of clinical benefit, how should this 'new' information be interpreted and what, if any, is the significance of brain-body temperature dissociation (positive or negative)?

New developments in non-invasive techniques for absolute brain temperature measurement have been developed using nuclear magnetic resonance-based techniques (NMR) in spectroscopy (MRS) and imaging (MRSI). Using the proton ^1H chemical shift of water referenced to the brain metabolite N-acetylaspartate (NAA) our group have acquired absolute brain temperature in a number of single voxels, to show the temperature distribution within a region of interest. Now, with invasive and non-invasive techniques available for use in man, and alongside other imaging techniques and clinical measurements, it is possible to study human thermoregulation in the brain-damaged patient, the goal being to understand the physiological and pathological responses to a rise in temperature.

The aim of this short review is to discuss the techniques of brain temperature measurement in man, the potential disadvantages of using body temperature 'surrogates' of brain temperature and the controversies surrounding, and the implications of, variability in the brain-body temperature gradient in the damaged brain.

DEVELOPMENT AND VALIDATION OF MICROWAVE RADIOMETRY FOR NON-INVASIVE INTERNAL THERMOMETRY AND ITS POTENTIAL MEDICAL APPLICATIONS

A P Levick 1 D V Land 2, J W Hand 3

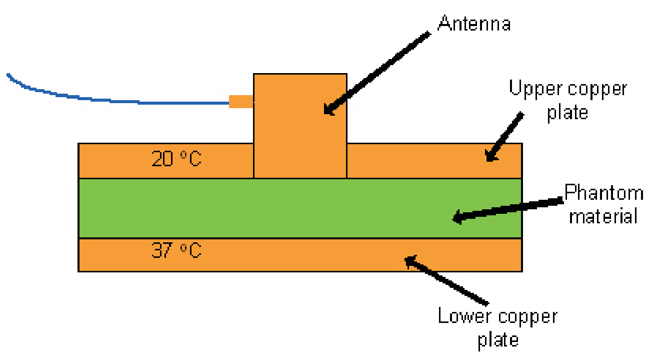
1 Thermal Metrology, National Physical Laboratory
2 Department of Physics and Astronomy, University of Glasgow)
3 Division of Clinical Sciences, Imperial College, Hammersmith Hospital

Microwave radiometry offers a non-invasive method of measuring the *sub-surface* temperature of a wide range of lossy dielectric materials such as foods and human tissue. It measures the temperature dependent intensity of natural Planckian thermal radiation emitted by a material over a band of frequencies in the microwave region. In the microwave region of 1 GHz to 4 GHz, the materials of interest are partially transparent to electromagnetic radiation, allowing the radiometer to measure temperature within the material over a depth of several centimetres. This technique has been developed by several research groups over the last 25 years and applied to a variety of medical and food processing applications. One particular application that has gained considerable interest recently is hypothermic neuroprotection therapy in neonatal babies with hypoxic-ischaemic encephalopathy. Hypoxia-ischaemia affects 2 per 1000 babies, and approximately 1000 babies per annum in the UK could benefit from neuroprotection therapy for which microwave radiometry may provide a non-invasive control technique.

At the National Physical Laboratory (NPL), we have quantified the performance of microwave radiometry by carrying out measurements with two test targets:

(1) An isothermal target that allowed the uncertainties to be measured for microwave radiometers operating as basic thermometers. The noise, flicker and drift levels were determined using the Allan variance statistical method for two radiometers of very different design developed at Glasgow University and Hammersmith Hospital respectively.

(2) A linear temperature gradient phantom target allowed microwave radiometry assessed for its ability to measure sub-surface temperatures. The figure below is a schematic diagram of a linear temperature gradient target comprising a volume of "phantom tissue material" with known dielectric properties sandwiched between two copper plates at different temperatures. The plates are temperature controlled by water circulation using closed-circuit water baths. A nominally linear temperature gradient is thus established across the phantom material. The microwave radiometer antenna is coupled to the upper and central surface of the phantom material volume. The target simulates the superficial layers of a baby's brain in which the upper face of the sample represents the skin surface and the lower surface corresponds to the brain core.



MRI THERMOMETRY FIXED-POINT VALIDATION TARGET

Rob Simpson, Andrew Levick

National Physical Laboratory, Teddington, Middlesex, UK,

Magnetic Resonance Imaging (MRI) thermometry provides a unique means of mapping internal temperature and is performed using a number of methods including T1 relaxation, molecular diffusion and proton resonance frequency shift. Such a map can provide useful information for many thermal therapies such as laser, RF, ultrasound and hypo/hyperthermia, enabling close treatment control and analysis. All of the methods however suffer from drift causing significant uncertainty in the absolute temperature.

The National Physical Laboratory (NPL) has conceived and developed a novel fixed-point validation target for MRI thermometry. This fixed-point target provides a stable reference source of accurately known temperature for validating and calibrating MRI thermometry. The prototype consists of an ethylene carbonate fixed-point cell with a phantom material cavity located at its centre. The fixed-point cell provides a stable (within ± 0.01 °C), repeatable (within ± 0.03 °C) near body temperature source for nominally 3 hours. This paper describes the design, testing and validation of the system including some provisional results from field trials.

DEVELOPMENT AND LABORATORY TRIAL EXPLORING USE OF INFRARED ENDOSCOPY DURING ENERGISED SURGICAL PROCEDURES

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Objective: A novel infrared endoscope has been developed to monitor thermal spread and collateral damage in real time during energized laparoscopic surgery.

System and Method: The infrared endoscopic system consisted of an endoscope measuring 10 mm in diameter and 30 cm in length. The endoscope is directly coupled to an advanced Cedip mid-infrared (3-5 μm) thermal camera, which has a focal plane array of 320 by 240 pixels, and a thermal sensitivity of 0.02°C.

The system was evaluated in a standard laparoscopic surgery trainer with the aim of detecting thermal spread during laparoscopic energised dissections. Cutting and coagulation procedures were conducted on pig stomach using HF electrosurgery, AutoSonix scalpel and LigaSure vessel sealing system. Digital and thermographic videos were taken for advanced thermal analysis and image processing.

Results: During the energized cutting and coagulation experiments, thermographic measurement showed that the average thermal spread was 4.2 mm above 45°C with the LigaSure, and the exposed instrument surface at the tip developed a temperature of approximately 100°C. The LigaSure Atlas 10 mm laparoscopic device exhibited a superior performance with only 2.3 mm thermal spread and with a maximal temperature on the jaws well within tolerable limit 35°C. The AutoSonix dissection device caused a bigger thermal spread of 5.3 mm. During HF electrocoagulation temperatures reaching 275°C were observed.

Conclusions: The study has confirmed that infrared laparoscopy is able to monitor thermal profiles in tissues during energised dissections in real-time. It thus has the potential to increase the safety of laparoscopic dissections when used as an adjunct to white light laparoscopy.

IMAGE PROCESSING TECHNIQUES FOR THERMAL INFRARED IMAGING - AN OVERVIEW

Gerald Schaefer

School of Engineering and Applied Science

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Reduced costs and improved camera technology are among the factors that led to an increased interest of thermal infrared imaging in medicine in recent years. Thermograms are captured in an automated way and stored in digital form. While in other medical fields various digital image processing techniques are commonly used to assist clinicians, in medical infrared imaging this is often not the case and diagnosis is hence dependent solely on the expertise of the clinician involved when viewing the thermogram(s) on screen.

The aim of this contribution is to provide an overview of image processing methods that have or can be applied to thermograms and covers techniques such as image thresholding, segmentation, tracking, registration, and feature extraction.

THE CHALLENGE FOR THERMOGRAPHY IN FEVER SCREENING OF AIRPORT PASSENGERS

Francis J Ring,

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The SARS outbreak in S.E. Asia in 2002/3 prompted several local health authorities to assemble a number of thermal imaging systems for installation at airport terminals. Not all the cameras used were of proven radiometric standards, and the manner in which they were employed was highly variable. Some were ceiling mounted to view a cohort of passengers up to 30 in number. On the premise that facial temperatures in excess of 38^{0}C were classified as fever, a number of subjects were sent for clinical examination before being cleared for travel. In a few weeks some 30million travellers were claimed to have been screened in China in 8 weeks, from which approx.9,000 had raised temperatures, 38 were SARS suspects and 21 were ultimately diagnosed.

The technique and the equipment were employed in a manner that would at best give a minimal chance of success. Following a more critical employment of the technique in Singapore, the SPRING Standardisation Dpt. published two guidance documents (TR15 2004) to improve the specification and method of employment in future epidemics.

The International Standards Organisation ISO has appointed a working group to prepare a new version of the SPRING documents for International use, defining a screening thermograph. IEC TC/SC62D – ISO/TC121/SC3, *Clinical thermometers, writing group on thermography for human temperature screening*. This group has now met on four occasions since December 2005, and has a document that is moving into its final stages later in 2007.

There are a number of problems in this area; not least the lack of high quality peer reviewed studies on temperature screening for fever, and the more demanding technical specification of the imaging devices to discriminate between hot subjects and those with genuine fever.

Some practical work is being undertaken on fever detection in children in Warsaw where the author has access to some of the latest thermal imaging technology in a paediatric clinic. The aim is to investigate the relationship between facial, axillary and aural temperatures in normal and febrile children between 1 year and 16 years of age. To date some 95 children have been examined. Results to date indicate that the inner canthi of the eye are reliable targets for temperature measurement, and when this area is over 38^{o}C, other thermometric measurements confirm the presence of fever.

The outcomes of the ISO committee, the definitions involved, and the preliminary results from febrile and non febrile subjects will be presented. It is anticipated that the standard and advice documents arising from this work, may well lead to a further standard for clinical thermography.

The need for standardised image capture, using an imaging system with good stability and calibration standards are highlighted in the screening application. The same conditions, with suitable quality assurance checks apply in clinical thermography, with improved reproducibility. This in turn, can improve the acceptability of the technique as a non invasive and objective measure of skin temperature in health and disease. The screening thermograph to meet the new standard is to be considered a medical device. If a Clinical standard follows, it will also be based on a medical device, which will be a change of practice from the current situation where many thermal imaging devices used in medicine are primarily built for industrial applications

FACIAL THERMOGRAPHY IS A SENSITIVE AND SPECIFIC METHOD FOR ASSESSING FOOD CHALLENGE OUTCOME

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Rationale: Oral challenge is the gold standard for diagnosing food allergy but outcome requires interpretation by observers, which may cause error when symptoms are mild and/or subjective. Facial thermography was evaluated as a novel, objective and sensitive indicator of challenge outcome.

Methods :Eighteen children with egg allergy underwent oral egg challenge. Facial temperatures were measured using thermography at baseline and 10min intervals throughout. The difference between mean and baseline temperature (ÄT), maximum ÄT during challenge ($ÄT_{max}$), maximum ÄT during first 20min ($ÄT_{max20}$) and area under curve of ÄT against time (ÄTAUC) were calculated for predefined nasal, oral and forehead areas, and related to challenge outcome.

Results: There were 9 positive and 9 negative challenges. Nasal ÄTAUC and $ÄT_{max}$ were respectively 8.1 and 3.3 fold greater in positive compared to negative challenges ($p<0.05$). In all positive challenges, nasal temperatures showed an early transient rise at 20min, preceding onset of objective symptoms (median 67min). There was a sustained temperature increase from 60min, reduced by antihistamines. A rise in nasal temperature of 0.8°C in the first 20min predicted challenge outcome with 88% sensitivity (PPV 100%) and 100% specificity (NPV 89%) p<0.05.Subjective symptoms predicted outcome with sensitivity 11% and specificity 67%.

Conclusions: In the subjects studied, facial thermography consistently highlighted the early onset of significant nasal inflammation during positive compared to negative oral food challenges, evident before objective symptoms occurred. Subjective symptoms did not predict food challenge outcome. Therefore, thermography may offer a sensitive and specific method for determining food challenge outcome, providing new insight into food reaction pathophysiology.

MULTI FIXED-POINT THERMAL IMAGE CALIBRATION SYSTEM

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Clinicians practicing medical thermography utilise thermal imagers as a means of patient diagnosis and monitoring. This work involves the analysis of thermal images, including the periodic intercomparison of assessment images of the same patient and of like patients both in-centre and cross-centre (nationally and internationally). When image intercomparisons require an absolute comparison of measured temperature it is critical that the thermal imager is providing a traceable calibrated temperature. This is usually achieved through regular accredited imager calibration. If not, the comparison will be open to significant measurement risk and uncertainty.

The NPL has developed a multiple fixed-point blackbody system for the in field-of-view calibration of thermal images. The system consists of three fixed-point sources gallium-zinc (25.3 °C), gallium (29.8 °C) and ethylene carbonate (35.9 °C) with repeatability of 0.1 °C. This paper describes the design, testing and validation of the system including provisional results from clinical field trials.

EVALUATION OF TEMPERATURE CHANGES IN HANDS AFTER COLD CHALLENGE

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Immersion of hands in water of 20°C is a well accepted cold challenge test for the thermographic diagnosis of Raynaud's phenomenon. However, a standard for evaluation of temperature changes is not yet established. Francis Ring has proposed a Thermal Index by combining the temperature gradients from the dorsum to the fingers prior and past the cold challenge. Others determined the gradient of single fingers or used the slope of the rewarming curve.

The results of Ring's Thermal Index were compared with the determination of the temperature gradients of single fingers in hands of 26 subjects after cold challenge. The cold stress testtool of the software package C-Therm was used for the calculation of the Thermal-Index. Temperature gradients for single fingers were determined in the following way: Spot temperatures were measured on the tip and over the mid of metacarpal bone of each finger. Gradients were calculated by subtracting the metacarpal temperature from the temperature of the finger tip. The mean value of the temperature gradients of all fingers of the right and the left hand were calculated. The difference of the mean temperature gradient prior and 10 or 20 minutes past cold challenge were compared with the findings of the Thermal Index for the same periods.

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

Using a threshold of –4.0 for a diagnostic thermal index, significantly more cases with Raynaud's phenomenon were identified with the thermal gradients than with the C-Therm derived Thermal Index

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

MONITORING TUMOUR DYNAMICS IN XENOGRAFTS VIA THERMOGRAPHY

C Song[1,2], L Campbell[2], V Appleyard[2], K Murray[2], T G Frank[2], B Spruce[2], A. Thompson[2], A Cuschieri[2], W Sibbett[1] PA Campbell[3]

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[2]Department of Surgery & Molecular Oncology, University of Dundee, Scotland
[3] Division of Electronic Engineering and Physics, University of Dundee, Dundee DD1 4HN

We tested the hypothesis that thermal imaging might represent a useful adjunct technique in monitoring the presence and dynamic spatial extent of [breast] tumours occurring near to the skin. We also considered the response of tumours to antiangiogenic drugs in animals and in cancer patients. Here we exploit the inherent non-contact and non-invasive advantages of thermography, together with its thermometric accuracy (on presumed thermodynamic 'black bodies') to detect minute skin surface temperature changes. Usually a 1-2ºC increase in skin surface temperature is observed at the tumour periphery, and it has been proposed that this change is due to the hypervascularity and increased blood flow resulting from the tumour-associated angiogenesis. In our study, human tumour xenografts were established in immunocomprised nude mice with MDA-MB-231 mammary carcinoma cells injected. Thermographic investigation was performed continually to detect and monitor tumour growth. It was found that, unlike human breast cancer, no tumour-associated skin temperature increase was observed, but a constant and highly significant decrease 1-2.5ºC was noted, which was independent of tumour size. The explanation for this effect may be due to the exponential tumour growth in mice, and the tumour was just subcutaneous, unlike in human breast which is deeply embedded, convection cooling to the environment may play a major role. Interestingly, smaller secondary tumours, which were unable to be seen by the naked eye, were clearly evident by thermal imaging. Our study indicates that thermographic imaging may have considerable potential in monitoring human tumour xenografts and their response to antiangiogenic drugs.

A THERMOGRAPHIC INVESTIGATION OF PATELLOFEMORAL PROBLEMS

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Introduction: There is some evidence of circulatory disruption in patellofemoral pain syndrome (and . Ben-Eliyahu (1992) suggests vascular disruption at the knee leads to local hypothermia which may be observed through non-contact digital infrared thermography. Few clinical studies have investigated this phenomenon.

Methods: Thirty six patients were recruited from Bolton PCT, Bolton Hospitals NHS Trust and University of Central Lancashire Injury clinic. Modified Functional Index Questionnaire (MFIQ) scores were taken from patients as a clinical measure of their patello-femoral pain. Based on previous research (Selfe 2003), patients were subjectively categorised into 'normal' and 'cold' groups. A thermal washout technique, using a cryo/cuff was developed specifically for this project , to provide a thermal challenge to the symptomatic knee.

Result: Thirteen male and twenty three female patients, age 29.5±11.6 years volunteered. Room temperature was 23.7±1.8 ºC. Twenty four patients were categorised as 'normal', twelve as 'cold'. Modified Functional Index Questionnaire (MFIQ) scores were; 27.5±16.2 for the 'normal' group and 35±22.9 for the 'cold' group (non-significant, p=.264). There was no significant difference (p=.598) between the 2 groups for body fat %; 'normal' group demonstrating 18.3±5.2%, and 'cold' group 17±5.5%. The 'normal' group demonstrated a significantly (p=0.048) higher patella skin-fold measurement; 8.3±2.5mm, versus 'cold' group; 6.2±3.2mm. Ambient room temperature was not significantly different (p=.080) between the 2 groups. Baseline skin surface temperature (T_{sk}), was significantly (p=.046) higher in the 'normal' group than that of the 'cold' group, with temperatures of; 29.6±1.6ºC and 28.5±1.4ºC respectively. This remained true following the 20 minute re-warming period; there was a significant (p=.046) difference between the 2 groups; 'normal' 27.2±1.7ºC and 'cold'; 26.0±1.2ºC.

Discussion: MFIQ scores showed similar differences between groups to those found in a previous study , with the 'normal' group demonstrating a mean score of 33 and the 'cold' group a mean score of 40. Elevated MFIQ scores may be a useful clinical indicator when used in combination with other measures, suggesting the patient has a cold related problem. Body fat % was not significantly different between the two groups, which, may be indicative that; the significantly lower patella skin-fold demonstrated by the 'cold' group (6.2±3.2mm), may be a contributing factor to the symptoms experienced by the 'cold' group; patella skin-fold below 6.2mm may be a characteristic of this subgroup of patients and may serve as a useful clinical measure in identifying these patients. The 'normal' group demonstrated significantly higher T_{sk} compared to the 'cold' group, both at baseline and at the end of the re-warming period, highlighting T_{sk} as another distinctive characteristic of this patient group.

Conclusion: These data support the evidence base that a 'cold' subgroup of patello-femoral pain sufferers exists, and begins to define a clinical profile characteristic to this 'cold' sub-group. These data also confirm the usefulness of a thermal washout technique and thermal imaging in a clinical environment in helping to define this clinical subgroup through developing a combination of useful subjective clinical indicators and objective clinical markers.

THERMOGRAPHIC IMAGING FOR AMPUTATION LEVEL VIABILITY ASSESSMENT: JUST A PRETTY PICTURE OR A QUANTITATIVE TOOL?

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We have previously described the use of skin oxygen saturation (SO_2) measurements to predict healing viability in lower limb amputations for critical limb ischaemia.[1] The technique involves determining the *degree of tissue hypoxia (DTH)*[1] which is defined as the percentage of SO_2 values along the leg with a value of less than 10%. It was found that if the DTH was less than 15% or the mean SO_2 at two specified sites along the line of a proposed below knee amputation (BKA) was 30% or greater, healing at the BKA level was successful. The technique, using the above criteria and in combination with thermographic imaging[2], has been applied to routine clinical practice in the University Hospital of North Durham since 1999. The results of an initial audit of these techniques was published in 2002[3] and demonstrated a 94% healing rate of BKAs was being achieved at a BKA to above knee amputation (AKA) ratio of 9:2. The quantitative assessment of DTH is the primary criterion that is used to recommend amputation level, and to date temperature gradients in the thermographic image have only been used as a qualitative guide.

During a recent survey of 33 amputations carried out in the 3 year period 2004-2006, not only was the predictive power of DTH re-assessed, but also temperature gradients were measured retrospectively along the limb from the thermographic images. 9 patients were omitted from the audit: 3 died before the operation, 1 had a flexion contracture, and 5 that were recommended a BKA received an AKA on clinical grounds.

Of the 24 patients that lay within the inclusion criteria 2 were predicted for, and underwent, a AKAs, 2 were predicted for and underwent BKAs but needed to be revised to an AKA because of apparent stump ischaemia. The remaining 20 patients were recommended and underwent BKAs that successfully healed.

Analysis of the thermographic images revealed that the difference in the temperature gradients between the AKA and BKA groups over the first 5cm distally was significant (T test, p=0.03) and also that there was a significant difference (p=0.005) in absolute temperatures 5cm distal to the tibial tuberosity between the two groups. However, despite these significant differences, the overlap between the BKA and AKA groups was too great to be able to formulate a predictive tool from the results.

Further scrutiny of the records of the patients whose BKAs were revised showed that in one case the amputation was carried out 2 months after the assessment. However, anecdotally in the second case (amputation 1 week after assessment) the temperature along the limb was the lowest of the entire cohort.

In conclusion, as in the 2002 audit, skin SO_2 remains a robust predictor of healing viability in the critically ischaemic limb. However, it is intended to carry out a larger retrospective analysis of thermographic images to investigate whether there is a critical limb temperature below which a BKA is not viable. This could play a role in improving even further the accuracy of the assessment.

(1) Harrison DK, McCollum PT, Newton DJ, Hickman P and Jain AS; Amputation level assessment using lightguide spectrophotometry; Prosthetics and Orthotics International 1995; 19:139-147

(2) Spence VA, Walker WF, Troup IM, Murdoch G; Amputation of the ischaemic limb: Selection of the optimum site by thermography 1981; Angiology; 32:155-169

(3) Hanson JM, Harrison DK, Hawthorn IE; Tissue spectrophotometry and thermographic imaging applied to routine clinical prediction of amputation level viability; In "Functional Monitoring and Drug Tissue Interaction"; SPIE Proc. Series 2002; 4623:187-194

COMPARING THE EFFECTS OF DIFFERENT THERMAL REGULATION TESTS (COOL AIR STIMULUS VS. COLD WATER STRESS TEST) ON INFRARED IMAGING OF THE FEMALE BREAST

Reinhold Berz, Helmut Sauer
German Association of Thermography and Regulation Medicine

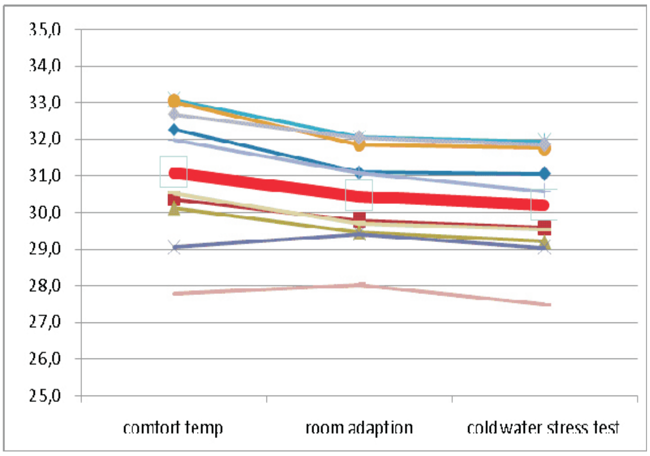
There are different approaches to applying stimulus response tests for thermographic examinations, especially regarding infrared breast imaging, in order to get additional diagnostic or prognostic value.

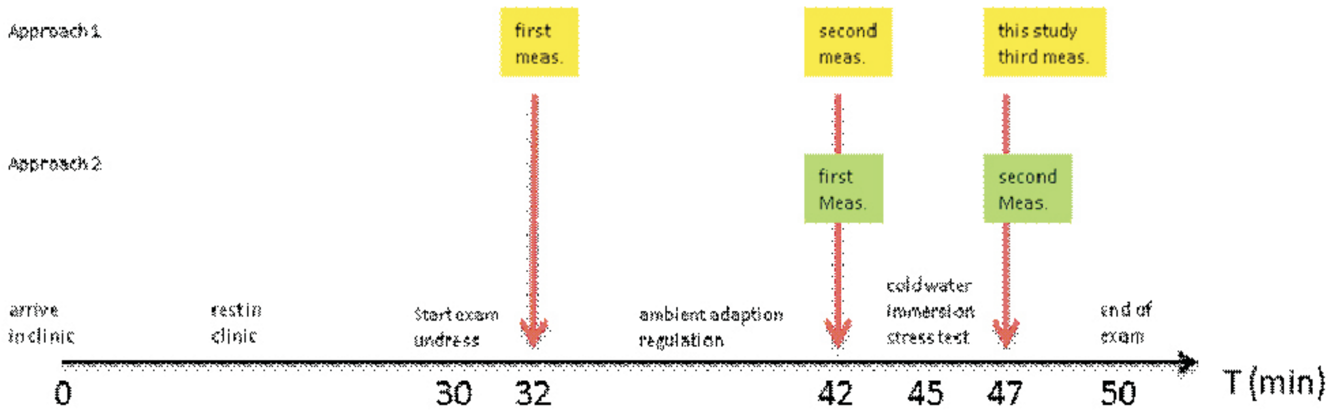
One method (approach 1) is to expose women after undressing to an ambient temperature of 20 °C to 22 °C. The measurement is applied directly after undressing, recording the "comfort temperature". After this the un- dressed subject will adapt to the ambient temperature by a centralization regulation to keep a thermal steady state in the body's core. About 10 minutes after the first measurement, when the subjects have performed this regulation and present a decrease in skin temperature, the second measurement is recorded.

Another method (approach 2) is to wait 15 minutes or longer after undressing before the first measurement is done. After this a cold water immersion stress test is applied (45 to 60 seconds of putting the hands and half of the forearms into either ice water or ice cooled water of less than 10 °C). After this cold water immersion test the second measurement is recorded.

A group of 10 women were examined by MammoVision (infrared breast imaging including regulation tests). Both approaches (1 and 2) were combined and applied in a timeline as displayed in the figure. The infrared measurements have been recorded by a highly precise cooled (-196 °C) infrared scanning camera device (Jenoptik VarioScan High Resolution). Using the MammoVision system it was ensured that exactly the same regions of interest were compared. The statistical evaluation was performed including average, mean, maximum and minimum as well as first and third quartile of the overall temperature of every breast.

Eight of the ten women showed a clear decrease in the median temperature over the breast of 0.9 °C within approach 1 between comfort temperature and adaptation to the room temperature. After the cold water stress test there was only a slight additional decrease (0.2 °C). Two subjects demonstrated paradoxical regulations. One of them showed extremely cold breast temperatures, the other subject was using drugs influencing the blood pressure.





The preliminary results of this explorative study suggest that the additional effect of the cold water stress test usually applied in approach 2 is low and that the contribution of the cold water stress test to additional diagnostic value is limited. Taking into account that the cold water stress test is perceived to be more invasive than just adapting to the room temperature most women would prefer approach 1 as a mild regulation stimulus to be applied.

Further research has to be conducted to establish a scientific based protocol of infrared regulation examinations in order to compare the results worldwide.

Meetings

21st April 2007

Tampa, Florida

Neuromuscular Thermography Update

Location: Embassy Suites, 3705 Spectrum Blvd, Tampa, Florida 33612

Organization: American Academy of Thermology and Tampa General Hospital Rehabilitation Center,
In association with University of South Florida CME office.

Topics::Thermography: History, Guidelines, Physiology, Autonomic Testing., . MRI/EMG Correlation, Animal Model for Pain Research, Recent Developments in Drug Testingm "RSD Look Alikes and Unusual Syndromes", Sports Injury.

Programme Committee:
Bernie Batas, M.D, Gerald S. Goldberg, M.D
Srini Govindan, M.D, Robert Schwartz, M.D

Programme Chairmen:
Robert Schwartz MD, Gerald S. Goldberg, M.D.

Programme coordinator:
Srini Govindan MD

USF CME Coordinator
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Phone: 813-974-6237 FAX: 813-974-3217

2nd-3rd May. 2006

IPEM & UKTA Meeting, Cardiff International Arena

Clinical Temperature Measurement and Thermography

2 May 2007

09:00 -09:55 Coffee and registration

09:55 -10:00 Introduction - Dr Diane C Crawford, University Hospital of Wales

10:00 -10:20 The temperature of the healthy and injured human brain - Charmaine Childs, Salford Royal Hospitals NHS Trust

10:20 -10:40 Development and validation of microwave radiometry for non-invasive internal thermography and its potential medical applications - Andrew Levick, National Physical Laboratory

10:40 -11:00 MRI thermography fixed-point validation target - Rob Simpson, National Physical Laboratory

11:00 -11:20 Development and laboratory trial exploring use of infrared endoscopy during energized surgical procedures - Chengli Song, University of Dundee

11:20 -11:40 Coffee & exhibition

11:40 -12:00 Image processing techniques for thermal infrared imaging – an overview -G.Schaefer

12:00 -12:20 The challenge for thermography in fever screening of airport passengers -F Ring, University of Glamorgan

12:20 -12:40 Facial thermography is a sensitive and specific method for assessing food challenge outcome - Jasdip Mangat, Addenbrooke's Hospital, Cambridge

12:40 -13:00 Multi fixed-point thermal image calibration system- Rob Simpson, National Physical Laboratory

13:00 -14:00 Lunch & exhibition

14:00 -14:20 Evaluation of temperature changes in hands after cold challenge K Ammer, Institute for Physical Medicine& Rehabilitation, Hanuschkrankenhaus; Vienna; Austria

14:20 -14:40 Monitoring tumour dynamics in xenografts via thermography - Chengli Song, University of Dundee

14:40 -15:00 Comparing the effects of different thermal regulation tests on breast images- R. Berz, German Association of Thermography & Regulation Medicine

15:00 -15:20 A thermographic investigation of patellofemoral problems - James Selfe, University of Central Lancashire

15:20 -15:40 Thermographic imaging for amputation level viability assessment: just a pretty picture or a quantitative tool? - D. Harrison

15:40 - 16:00 Discussion and Close

DISCUSSION WORKSHOP

This will take place on **Thursday 3 May** at Cardiff Medicentre near the University Hospital of Wales from approximately 9.30 am till 12.30 pm finishing with lunch

Discussion will focus on the following topics:

Standardisation issues for temperature devices and thermal images, New challenges in clinical temperature measurement Thermal mapping on a small-scale (cellular)

26th -30th May, 2007

OPTIMESS 2007

3rd Workshop on Optical Measurement Techniques for Structures and Systems

Faculty Club, Leuven - Belgium

CONFERENCE SECRETARIAT:
Jenny D'haes, Secretary, Dept. of Mechanical Engineering, Vrije Universiteit Brussel, Belgium

Tel: ++32.(0)2.629.28.06, Fax: ++32.(0)2.629.28.65
E-mail: info@optimess.org
web site:www.optimess.org

6th June 2007

AUBURN-GLAMORGAN WORKSHOP

9.00am- 9.30 Historical Introduction . F. Ring

9.30-10.15 IR Detectors and cameras R.Thomas

10.15- 10.30 Questions/discussion/coffee

10.30- 11.00 Quality Assurance in Thermography P.Plassmann

11.00- 12.00 Principles of thermal physiology K.Ammer

30 minute lunch break

12.30- 13.00 Film, Hot and cold "Living Body" F.Ring

13.00- 13.30 Standard protocols for thermography F.Ring

13.30- 14.15 Causes of human temp. increase & decrease K.Ammer

15 minute break

14.30- 15.00 Provocation tests F.Ring

15.00- 15.30 Image processing principles P.Plassmann

15.30- 16.00 Educational resources K.Ammer

7th-9th June 2007

33rd AAT Congress and 7th International Congress of Thermology in Auburn, Alabama, USA

Friday, June 8, 2007

9 a.m.-12:20 p.m. Worker's Compensation

1:30-2:30 p.m. Tutorial- J. Mercer: Dynamic Infrared Imaging and Blood Flow

2:30-3:10 p.m. Breast Session

3:50-5:10 p.m. Clinical Tract

5:30-7 p.m. Conference Social

Saturday, June 9, 2007

9:00-10 a.m. Equipment/Standards
10:20-11:00 a.m. Veterinary Mediine

12:30-1:30 p.m. Physical Therapy/Athletic Training

1:30-3:10 p.m. Brazilian Thermographic Society

3:10- 4 p.m. Tutorial - S. Govindan:
Role of Mast Cells in Chronic Regional Pain Syndromes

4-5 p.m. Special Interest Groups (SIGs)

6:30-9:30 p.m. Banquet

Information: Prof Dr. David Pascoe
Auburn University

Email: pascodd@auburn.edu

15th-16th June 2007

7. Gemeinsamer Kongreß -der Deutschen Gesellschaft für Thermographie und Regulationsmedizin e.V.
-der Gesellschaft für Ozon- und Sauerstoff- Anwendungen in Medizin und Technik e.V.
-der Internationalen Ärztegesellschaft für funktionelle Proteomik e.V. (CEIA)

im Hotel Dolce, Bad Nauheim

Freitag, den 15. Juni 2007

Schwerpunkt „Rheuma"

Vorsitz : Ronald Dehmlow

15.00 Uhr Begrüßung der Teilnehmer

15.05-15.30 Uhr Herr Sauer
Grundlegendes zur Diagnostik rheumatischer Erkrankungen

15.30-16.00Uhr Herr Herbosch
Ozontherapie bei chronisch-entzündlichen Darmerkrankungen. Verlaufskontrolle mittels CEIA-Profil

16.00-16.30 Uhr Herr Schöbe
Ozontherapie bei rheumatischen Erkrankungen

16.30-17.00 Uhr Pause

17.30-17.50 Uhr Frau Fischer
CEIA Diagnostik und Therapie bei rheumatischen Erkrankungen

17.50-18.15 Uhr Herr Vetter
Regulationsthermographie nach ROST bei rheumatischen Erkrankungen

18.15-18.30 Uhr Diskussion

19.00 Uhr Sektempfang

20.00 Uhr Gemeinsames Abendessen
Gemütliches Beisammensein

Samstag, den 16.Juni 2007

Schwerpunkt Krebsgeschehen"
Vorsitz: Sabine Fischer

9.00-9.25 Uhr Sabine Fischer
Cancerosen und Praecanzerosen im CEIA Profil

9.25-9.50 Uhr Karin Kaeten
Thermographische Befunde beim Mamma-Carcinom

9.50-10.15 Uhr Peter Rothdach
Interessante Fälle aus 10 jähriger Bild-Thermographie-Praxis

10.15-10.45 Uhr Pause

10.45-11.10 Uhr Herr Heinicke
Carzinom Psychosomatik und Diagnostik mittels CEIA-Profil

11.10-11.35 Uhr Ronald Dehmlow
Chancen und Grenzen vonThermographie, CEIA-Profil und Ozon-Therapien

11.35-12.00 Uhr Jost Reeh
Thermographie in der Isselschen Krebsklinik

12.00 Uhr Mitgliederversammlung der Deutschen Gesellschaft für Thermographie und Regulationsmedizin e.V. (falls beschlussfähig)

12.00-14.30 Uhr Pause

14.30-15.30 Uhr Kurse

2 ½ Std Kurs Frau Dr. Fischer: Einführung in das CEIA-Profil
1 Std Kurs Herr Dr. Sauer: Aktive Fiebertherapie
1 Std. Kurs Herr Motyka: Demo Thermogeräte
1 Std.Kurs Frau Sacher: Neue Konzepte desKrebsgeschehens nach Dr. Kremer
1 Std.Kurs Herr Julian Berz: MammoVision und ReguVision Möglichkeiten und neue Funktionen von Exam 5

Vorsitz: Reinhold Berz

15.30-15.50 Uhr Dieter Blaschke
Der VATh als Partner der DGTR. Wie kann der wechselseitige Nutzen noch erhöht werden?

15.60-16.10 Uhr Dietmar Henning
Zertifizierungen in der Thermographie, Ideen für die Medizin und Veterinärmedizin

16.10-16.30 Armgard von der Wense
Zertifizierte veterinärthermographische Ausbildung der DGTR: Erfahrungen aus 3 Kurszyklen

16.30-17.00 Uhr Pause

17.00-17.20 Uhr Helmut Sauer
Mistel- und Wärmeregulation / Thermographie

17.20-17.40 Uhr Reinhold Berz
Infrarot Regulations Imaging (IRI) als essentieller Baustein einer Präventivmedizin (am Beispiel Brustkrebs-Prävention)

18.00 Uhr Mitgliederversammlung der Deutschen Gesellschaft für Thermographie und Regulationsmedizin e.V.

23rd -24th June, 2007

European Conference on Veterinary Infrared Thermography

Conference room Opel Zoo, Kronberg near Frankfurt, Germany

Recently the interest in Infrared Thermography of horses and other animals has been growing steadily. Applications are in the field of veterinary medicine, and physiotherapists and also amongst horse owners and trainers. Since 2004 the German Society of Thermography and Regulation Medicine (DGTR, founded in 1954) has established a forum of Veterinary Thermography. Since this time a number of new members from the veterinary field have joined the Society.

There is a lot of knowledge about Infrared Imaging and Thermography of horses worldwide. Two of the leading experts, Dr. med. vet. Dietrich Graf von Schweinitz BSc DVM MRCVS from the UK and Jean Koek from Australia will be the main speakers at of the conference.

The conference will host up to 60 participants from Germany and other European countries. The official language of the conference language is English.

The organization of this conference is managed by the MIRA, the Medical InfraRed Academy (part of the InfraMedic AG).

Saturday, June 23rd, 2007

09:00 Opening, Coffee and more

09:30 Official regards, introduction into the conference program

10:00 Infrared Imaging (IRI) as a diag-nostic tool in human and veterinary medicine - short history

10:30 Physics and technical basics of Infrared Imaging - strength and limits of the method

11:00 Coffee break

11:30 Homoiothermia and temperature gradients - heat flow, heat loss and influence of the hair coat

12:00 Infrared Thermography of horses - international experience and recent developments state of the art

13:00 Lunch

14:00 The influence of environmental ambient conditions on Infrared Thermography of animals

14:30 Common causes of musculoskeletal disorders of horses

15:00 Standardization in the field of In-frared Imaging of horses

15:30 Coffee break

16:00 Infrared Thermography cameras for veterinary use -challenges, suitability, affordable models

16:30 After IRI recording and measure-ment - how to deal with images, data and results

17:00 First experiences using Infrared Thermography in a veterinary clinic

17:30 Infrared Thermography in the zoological garden - experience from the Frankfurt Zoo

18:00 Break

19:00 Evening lecture

20:00 Banquet

Sunday, June 24th, 2007

9:00 Infrared Thermography guided tour across the Opel Zoo (including recording of various animals)

10:00 Presentation and discussion re-garding the Zoo animal records

11:00 Coffee break

11:30 Infrared Thermography in combi-nation with a serum proteomic method - first experience

12:00 Discussion

13:00 Lunch
14:00 Workshops in Equine Infrared Thermography (parallel)

WS 1 Infrared Thermography of the hoof
WS 2 Infrared Thermography of the joints
WS 3 Infrared Thermography of the trunk and back
WS 4 Infrared Thermography cameras and systems in the practical use
15:30 Coffee break
16:00 Final discussion
17:00 End of the conference

Speakers :
Michael Baxter, International Academy of Equine Sports Therapy, Warendorf, Germany
Prof. Dr. med. Reinhold Berz, President DGTR, Hilders, Germany
Dipl.-Inform. Julian Berz, Burgrieden, Germany
Dr. med. vet. Gerhard Dittus, DVM, equine veterinary expert, Karlsruhe, Germany
Dr. med. vet. Alexandra Ferschl, Zirl, Tirol, Austria
Dr. med. vet. Sarah Kalinowski,DVM, Vet Clinic Dr. Kreling Binger Wald, Germany
Jean Koek, Expert of equine Thermography, Perth, Australia
Dr. med. vet. Dr. rer. nat. Sabine Hilsberg-Merz, DVM, PhD, Hofgeismar, Germany
Gerson Machado, PhD, biomedical engineer, Horsham, UK
Dr. med. Helmut Sauer, MD, Vice President DGTR, Waldbronn, Germany
Dr. med. vet. Dietrich Graf von Schweinitz BSc DVM MRCVS, Equine Veterinary Clinic Puttenham, UK
Armgard von der Wense, Therapiezentrum Rittergut Holdenstedt, Germany
Horst Zirfas, Farrier and Thermographer, Petershagen, Germany

Applied for ATF (continuing education) Credits (Akademie für tierärztliche Fortbildung): 16 hrs

All participants will receive a DGTR Certification of Attendance.

Conference fees

The conference fees are 320,- Euro plus 19 % VAT (in total 380,80 Euro) Members of the DGTR only.

415,- Euro plus 19 % VAT (in total 493,85 Euro)
All other participants

The conference fees cover the attendance at the scientific program, the conference documents, the entrance fees of the Opel Zoo, the coffee break fees and the attendance at the evening lecture and the banquet on Saturday.

Further details and responsibility

Prof. Dr. med. Reinhold Berz, MD
President DGTR, MIRA, InfraMedic AG
Harbach 5. D-36115 Hilders / Rhön
Phon +49 (0) 66 81 - 72 70, Fax +49 (0) 66 81 - 85 51
Reinhold.berz@inframedic.de, www.thermomed.org

27th- 29th June 2007

15th International Conference on Thermal Engineering and Thermogrammetry (THERMO) in the House of Technology Budapest, V., Kossuth Lajos tér 6-8.

For any further information and personal inquiries please contact the following address:
Dr. Imre BENKÖ,
H 1112 Budapest, Cirmos u. 1, 6/38, Hungary
Phone/fax: +361 310-0999.E-mail: ibenko@freestart.hu

4th -6th July 2007

8th Residential Course on the Theory and Practice of Infra Red Thermal Imaging in Medicine,

University of Glamorgan. Pontypridd CF37 1DL, UK

Speakers:

Prof. K. Ammer, MD PhD (Hanuschkrankenhaus, Vienna/University of Glamorgan)
Prof. F.J. Ring, DSc FIPEM (University of Glamorgan)
Dr. P. Plassmann, PhD (University of Glamorgan)
Dr. R. Thomas,. PhD (University of Swansea)
Prof. G. Machin), PhD (National Physical Laboratory, London

Registration Fee

£370 (students £220). Cheques should be made payable to The University of Glamorgan.

The fee includes:
lunch and refreshment breaks,
book on thermal imaging in medicine, searchable CD of archived "IR Imaging in Medicine" publications.

Information:
Prof Francis Ring
Medical Imaging Research Group,
Faculty of Advanced Technology,
University of Glamorgan, Pontypridd CF37 1DL, UK
Email: efring@glam.ac.uk

17th November 2007

20th Symposium of the Austrian Society of Thermology, SAS Hotel Vienna, Austria

Topic: What is the place of thermal imaging in medicine?

Speakers : Prof. F. Ring, University of Glamorgan, U.K
Prof B. Wiecek, University of Lodz, Poland
Dr R. Thomas, Swansea, UK
Prof. Anna Jung, Warsaw, Poland
Prof R. Berz, Hilders/Rhön, Germany
Prof K. Ammer, Vienna, Austria

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Thermology International

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An advisory board is drawn from a panel of international experts in the field. The publications are peer-reviewed.

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