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Minimal clinically important thermal asymmetry

Thermal imaging in fibromyalgia

Temperature and pain threshold

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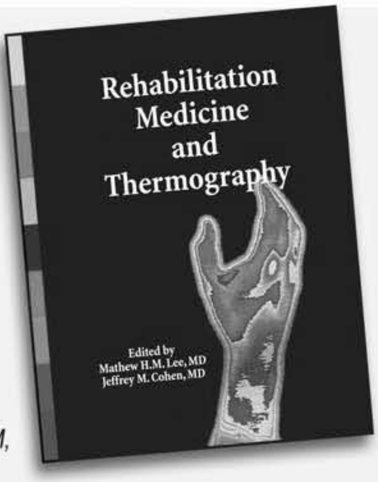

Rehabilitation Medicine and Thermography

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Contents (INHALTSVERZEICHNIS)

A narrative literature review identifying the minimum clinically important difference for skin temperature asymmetry at the knee

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SUMMARY

OBJECTIVES: To identify the value for the minimum clinically important difference in skin temperature asymmetry of the anterior knee, based on existing clinical data.

METHODS: A literature search of electronic databases was initially undertaken. Papers obtained were then cross referenced and appropriate articles ordered through inter-library loans. Only primary clinical research studies on the lower limb that clearly defined a normal skin temperature asymmetry were included.

RESULTS: A total of 5 papers met the eligibility criteria for review.

CONCLUSION: There have been few clinical thermal imaging studies investigating the minimum clinically important difference for contralateral lower limb thermal symmetry. The available evidence found in this review suggests that a temperature asymmetry of the anterior knee of greater than 0.5°C is clinically important.

KEY WORDS: Thermal imaging, anterior knee, skin temperature asymmetry, minimum clinically important difference.

EINE NARRATIVE LITERATURÜBERSICHT UM DIE KLEINSTE, KLINISCH BEDEUTSAME TEMPERATURASYMMETRIE AM KNIEGLENK ZU ENTDECKEN

ZIEL DER STUDIE war es, anhand der publizierten klinischen Daten den Wert der kleinsten, klinisch bedeutsamen Symmetriestörung der Hauttemperatur über dem vorderen Anteils des Kniegelenks zu finden.

METHODE: Zuerst wurde ine Literatursuche in elektronischen Datenbanken durchgeführt-. Die gefundenen Publikationen wurden querverwiesen und die geeigneten Artikel wurden aus Bibliotheken bestellt. Es wurden nur klinische Studien an der unteren Extremität berücksichtigt, die eindeutig Normalwerte für die symmetrische Hauttemperatur angaben.

ERGEBNISSE: Insgesamt entsprachen nur 5 Arbeiten den Einschlusskriterien der Übersicht.

SCHLUSSFOLGERUNG: Nur wenige klinisch-thermographische Studien haben an der unteren Extremität den kleinsten klinisch bedeutsamen Temperaturunterschied zur Gegenseite untersucht. Die aus dieser Literaturübersicht abgeleitete Evidenz empfiehlt, einen Temperaturunterschied an der Knievorderseite von mehr als 0,5 Grad als klinisch bedeutsam zu erachten.

KEY WORDS: Thermographie, Knievorderseite, Asymmetrie der Hauttemperatur, minimaler klinisch bedeutsamer Unterschied.

Thermology international 2008, 18: 41-44

Introduction

In medicine thermal imaging is advocated as a useful diagnostic tool, as it is technically easy to produce consistent skin temperature T*sk* readings [1,2]. T*sk* is reported to reflect underlying changes in sympathetic nervous control and local chemical mediators, both of which can be associated with pathophysiology [3].Thermal imaging is also used to detect changes in surface blood flow, particularly in relation to painful conditions [4].

For the purposes of diagnosis and confirmation of pathology numeric data relating to T*sk* are required to highlight any deviation from what is accepted as normal or healthy, based on data collected from asymptomatic individuals. In medicine a concept which is gaining ground in terms of helping clinicians understand the meaning of numeric data of this type is the minimum clinically important difference (MCID). The MCID represents the threshold difference which is considered meaningful or important by the patient [5]. Defining the MCID for T*sk* will help clinicians to interpret whether their thermographic findings are of clinical significance or not. However, little data are available to inform MCID for T*sk*. One way to approach this problem is to consider MCID from the point of view of contralateral limb T*sk* symmetry / asymmetry.

It is accepted that in healthy subjects there is generally close symmetry in the T*sk* of the contralateral limbs. Asymmetry in the T*sk* of contralateral limbs may therefore be indicative of pathological processes or alterations in vascularity. For example a rise in T*sk* may be associated with an inflammatory process whereas a decrease in T*sk* may indicate an ischaemic disorder.

The focus of this paper is the MCID of T*sk* of the knee, in particular the anterior aspect, which may be implicated in patients suffering from patellofemoral pain syndrome (PFPS). A model of PFPS has been proposed whereby the condition may be mechanical, hypoxic (leading to lower

Table 1
Summary of key findings of included papers

Authors	Year of publication	Subjects	Key Findings
Uematsu [13]	1985	32 healthy subjects	Contralateral T*sk* asymmetry of 0.23°C
Uematsu et al. [14	1988	90 healthy subjects	Contralateral T*sk* asymmetries of <0.5°C was the normal range
Vardasca et al [15]	2007	26 healthy subjects	The maximum contralateral T*sk* difference was 0.19°C
Davidson & Bass [10]	1979	46 patients with PFPS	31 PFPS patients displayed a T*sk* asymmetry of >0.5°C which was defined as abnormal
Ben-Eliyahu [3]	1992	30 patients with PFPS & 40 healthy subjects	29 out of 30 PFPS patients displayed a T*sk* asymmetry of at least 1°C 36 out of 40 healthy subjects displayed a T*sk* asymmetry of <0.5°C

PFPS=patellofemoral pain syndrom, T*sk* =skin temperature

T*sk*) or inflammatory (leading to raised T*sk*) in origin [6]. Sanchis Alfonso et al (2003) have discussed the importance of ischaemic changes in their 'neural model' of the pathophysiology of patellofemoral pain [7]. Clinical data have been published which reported a clinical subgroup of PFPS patients who had cold knees which were therapy resistant, unfortunately no temperature data were collected as part of that research [8]. However more recent work has confirmed that a group of patients with a significantly lower T*sk* of 1°C (p=0.46), as measured by a digital InfraRed thermal imaging camera, forms a clinical subgroup of PFPS [9].

Other previous clinical studies using thermal imaging have also demonstrated pathophysiology specifically within the patella region of the anterior knee [10,11]. Thermal imaging has been cited as being highly sensitive and specific in PFPS, with the patella demonstrated a hypothermic image [12]. However, to date no definition of the MCID for contralateral T*sk* asymmetry of the anterior knee has been proposed. The purpose of this review is to examine the existing literature in order to propose a value for the MCID of T*sk* of the anterior knee, based on existing clinical data.

Search Strategy

This review was undertaken on articles published in English between 1979-2007; the electronic databases EMBASE, Medline, Pro Quest and Science Direct were searched. The key phrase "lower limb thermal imaging", was used. In addition relevant grey literature was searched by hand. Eligibility criteria were primary clinical research studies published in the English language on the human lower limb that clearly defined a normal temperature asymmetry. Review papers or studies using secondary sources were excluded. The papers were then cross-referenced and appropriate articles were obtained. The search initially yielded 13 papers, after these were scrutinised 7 were deemed unsuitable as they were not based on primary data, leaving a total of 5 for review for this paper. Of these 5 papers, 3 examined healthy subjects, 1 investigated patients with PFPS and 1 investigated healthy subjects and patients with PFPS.

Results

The key findings of the five papers are summarised in Table 1.

Discussion

It can be seen from Table 1 that there is very little primary data on defining the minimum clinically important T*sk* variation between contra-lateral knees. One of the common features of many papers that were published but which could not be included in this review was that they did not include T*sk* symmetry data. For example Salisbury et al (1983) published a paper based on 368 healthy normal knee joints and 588 joints of patients with known knee pathology [16]. The focus of this work was on thermal patterns rather than on T*sk* therefore unfortunately no T*sk* symmetry data were presented. Two other common limitations from the studies that were eligible for review were, use of Pre-digital technology and T*sk* data extraction methods that were not very robust.

The 1985 study by Uematsu [13] investigated 62 subjects, 32 healthy and 30 with peripheral nerve impairment. A Colour Telethermograph camera was used to provide thermal images but no details were provided on its specifications. A whole body thermal image of each subject was initially taken and then a series of 32 computer generated regions of interest (ROI) which corresponded to the distribution of the major peripheral nerves were super- imposed on the thermogram. Analysis of the results from the healthy subjects involved comparing the average skin temperature differences from one side of the body to the other for the various ROI. In the healthy subjects knees the average T*sk* asymmetry was 0.23ºC between contralateral knees, in the patient population with peripheral nerve injury average T*sk* asymmetry was much greater at 1.55ºC between contra lateral knees. Measuring T*sk* using computer generated ROI is a commonly used method but it does have limitations. The system is not specific to individual patients; the same ROI is applied to all subjects regardless of their morphology and therefore can result in varying proportions of the involved limb being covered.

In a later study the normal T*sk* asymmetry in 90 healthy subjects was investigated [14]. Two different imaging systems; a JTG-500 M and an Infra-Eye-160 were used. Details of the systems were provided although the statement that they were capable of identifying temperature differences of as little as 0.03ºC appears ambitious considering the study utilised pre-digital technology. Modern digital thermal imaging cameras are not that sensitive when measuring human temperatures. The methodology used was very similar to the earlier study [13] with computer generated ROI used to define the areas to be measured. Ten measurements were taken for each region of interest and then means and standard deviations were calculated from these data. In the case of the knee a normal T*sk* asymmetry between contralateral knees of <0.5ºC was reported.

Much more recently Vardasca et al [15] used the latest high resolution digital thermal imaging technology to examine thermal symmetry in 26 healthy subjects. Computer generated ROI were defined similar to those described in earlier studies. Analysis of the data revealed a maximum T*sk* difference between contralateral limbs of only 0.19ºC. This figure is the lowest of all the studies and possibly reflects how the advances in technology over the course of the last 30 years, particularly the advent of digital imaging, have resulted in the accurate recording of more subtle temperature differences.

Davidson & Bass [10] examined 46 patients with PFPS, there was no control group. A Spectrotherm 2000 camera was used to examine the patients but no details were provided on its resolution or sensitivity. A 15 minute period of acclimatisation was allowed before any measurements were taken. Analysis was undertaken using 3 thermal profile lines (TPL); through the middle of the patella, along the lower border and the long sagittal diameter of the patella. A TPL takes a temperature reading every pixel across the line and therefore gives a very narrow snapshot (1 pixel wide) of the temperature of the region of interest. If a TPL is moved very slightly the T*sk* recorded can vary greatly. When TPL's are used it is essential that they are placed in the same place on each subject, however visual inspection of the images published in this study suggests that this was not precisely done which may have affected the results.

Ben-Eliyahu [3] studied 30 PFPS patients with a mean age of 34 who were identified after clinical and radiographic examination. The study also included a control group of 40 healthy subjects. An Agema Thermovision 870 thermal camera was used to take the thermal images of both the symptomatic and asymptomatic lower limbs of all the subjects. A recognised thermographic protocol involving an equilibration period of 10 minutes was followed. There were no anatomical markers; either computer generated or patient based used in the analysis of the images. Analysis involved scrutinising the images and looking for asymmetry between affected and unaffected limbs. The authors stated that this was a highly reliable method as it is obvious whether a thermogram is symmetrical or not. It was then reported that 90% of normal subjects had an asymmetry of <0.5ºC whereas 96% of the PFPS patients had a temperature difference of at least 1ºC between contralateral limbs. Unfortunately however the paper does not discuss exactly how these values were acquired.

Conclusion

As previously discussed; to date there have been few clinical thermal imaging studies investigating the value for minimum clinically important differences in skin temperature asymmetries of the anterior knee. Only five eligible papers were found for this review. However, there have been other papers in this area that have used secondary data. For example Mayr [17] undertook a study using thermography to evaluate post-operative knee joints. It was stated that any contralateral T*sk* difference between limbs greater than 0.5ºC was abnormal. Other studies have assumed figures for normal T*sk* symmetry without any evidence to justify them. For example Goodman et al [12] compared thermal imaging to radiography in the diagnosis of tibial stress fractures and claimed that a regional asymmetry of >0.5ºC was one factor that would lead to a positive diagnosis.

Despite being limited, the available evidence found through this review suggests that a contralateral T*sk* asymmetry of greater than 0.5ºC is clinically important in relation to the anterior knee. Further experimental work on both healthy and patient populations particularly with PFPS is required to confirm, this.

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Thermal imaging: a diagnostic aid for fibromyalgia ?

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SUMMARY

OBJECTIVE: A retrospective chart review was conducted to analyse the number of hot spots in patients diagnosed with fibromyalgia according to the criteria of the American College of Rheumatology. The findings were compared with those of a group of healthy subjects and also a group of patients who experienced widespread pain but who did not meet the diagnostic criterium of eleven or more tender points.

METHOD: Thermograms of the regions in which tender points are typically located were taken after acclimatization for 15 minutes to a room temperature of 24°C. Hot spots were defined as any small area at least 0.5°C warmer than the surroundings. After the thermographic examination, the typical sites for tenderness were tested.

RESULTS: A total of 312 subjects were included in the study. 204 patients suffered from fibromyalgia and 87 patients with widespread pain did not show a sufficient count of tender points and were therefore diagnosed as localized myalgia. 21 healthy subjects. 20 females and 1 male, served as controls. The tender point count (95 % confidence interval) differed significantly between the three groups (fibromyalgia: 14.5 to 15.2; localized myalgia: 6.3 to 7.5; controls: 0.4 to 1.4) and also the frequency of hot spots was significantly different (fibromyalgia: 9.2 to 9.8, localized myalgia: 6.5 to 7.6, controls: 3.0 to 4.7).

A total of 5616 sites were evaluated for coincidence of hot spots with tenderness resulting in a rate of 35,02% for true positives (hot spot equal to tender site) and 23,24 for true negatives (non hot spot equal to non tender site). The sensitivity of hot spots for tenderness at 18 sites was 53,91 %, specificity was 66,34 %, positive predictive value 74,82 % and negative predictive value 43,69%. Exclusion of the knee sites, resulted in an increase of sensitivity to 58.15 % and a decrease in specificity to 60.88%. Calculation of sensitivity based on 12 sites (after exclusion of supraspinatus muscle, costosternal junction and medial knee) derived a sensitivity of 65.40% and specificity of 56.46%, but predictive values changed only slightly.

CONCLUSION: Hot spot count is rather a specific than sensitive diagnostic procedure in fibromyalgia patients. A high number of hot spots in the thermogram of the total body can assist the diagnosis of fibromyalgia, but cannot replace the palpation of tender points.

KEY WORDS: Fibromyalgia, thermal imaging, sensitivity and specificity

THERMOGRAPHIE: EINE DIAGNOSTISCHE UNTERSUCHUNG BEI FIBROMYALGIEPATIENTEN ?

ZWECK DER STUDIE: In einer retrospektiven Studie wurde an Hand der Krankengeschichten die Anzahl der “Hot spots” in Wärmebildern von Patienten analysiert, die entsprechend den Kriterien des Amerikanischen Rheumatologie Colleges als Fibromyalgie diagnostiziert worden waren. Die Ergebnisse wurden mit denen von gesunden Personen und von Patienten mit Ganzkörperschmerz verglichen, die das diagnostische Kriterium von elf oder mehr druckschmerzhaften Stellen nicht erfüllten.

METHODE: Wärmebilder jener Körperregionen, in denen definierter Weise nach druckschmerzhaften Punkten gesucht wird, wurden nach 15 minütiger Abpassung an eine Raumtemperatur von 24°C aufgenommen. “Hot spots”wurden als kleine Flächen definiert, die zumindest 0,5° wärmer sind als die Umgebug. Nach der thermographischen Untersuchung wurden die typischen Stellen auf Druckempfindlichkeit überprüft.

ERGEBNISSE: Insgesamt wurden Daten von 312 Personen ausgewertet. 204 Patients litten an Fibromyalgia, während 87 Patienten mit generalisierten Schmerzen, jedoch ohne ausreichende Anzahl von Druckpunkte als lokale Myalgien diagnostiziert worden waren. 21 gesunde Personen. 20 Frauen und 1 Mann, wurden ald Kontrollen verwendet. Die Zahl der Druckpunkte (95 % Vertrauensintervall) war in allen drei Gruppen signifikant unterschiedlich (Fibromyalgie: 14.5 bis 15.2; lokale Myalgien: 6.3 bis 7.5; Kontrollen: 0.4 bis 1.4). Ebenso unterschied sich die Anzahl der “Hot spots” signifikant (Fibromyalgie: 9.2 bis 9.8, lokale Myalgien: 6.5 bis 7.6, Kontrollen: 3.0 bis 4.7).

Insgesamt wurden 5616 Stellen auf die Übereinstimmung von “Hot spots” und Druckempfindlichkeit überprüft. Es wurden dabei 35,02% for richtig Positive (”Hot spot” entspricht der Druckdolenz) und 23,24 % richtig Negative (kein “Hot spot” an indolenten Stellen) gefunden. Unter Berücksichtigung aller 18 Prädilektionsstellen für Druckschmerz betrug die Sensitivität der “Hot spots” für Druckempfindlichkeit 53,91 %, die Spezifität 66,34 %, der positive Voraussagewert 74,82 % und der negative Voraussagewert 43,69%. Der Ausschluss der Knieregion erhöhte die Sensitivität auf 58.15 % und verminderte die Spezifität auf 60.88%. Die Berechnung der Sensitivität unter Berücksichtigung von 12 Körperregonen (nach Ausschluss des M. Supraspinatus, der Rippengelenke und der medialen Knieregion) fand eine Sensitivität von 65.40% und eine Spezifität von 56.46%, während die Voraussagewerte nur geringe Änderungen zeigten.

SCHLUSSFOLGERUNG: Bei Fibromyalgiepatienten ist die Zahl der “Hot spots” ist eher ein spezifischer als ein sensitiver diagnostischer Test. Der Nachweis zahlreicher “Hot spots” im Ganzkörper-Thermogramm kann die Diagnose einer Fibromyalgie stützen, jedoch die Zahl der druckschmerzhaften Punkte nicht ersetzen.

SCHLÜSSELWÖRTER: Fibromyalgie, Thermographie, Sensitivität und Spezifität

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Introduction

In healthy subjects, the temperature distribution of the body surface is highly symmetric (1,2,3). In disease state, small areas of higher temperature than the surrounding may be detected by thermal imaging. In the past, such "Hot Spots" on thermal images have been related with myofascial trigger points (4), tender tendon insertions (5, 6) and tender points (7, 8).

Fibromyalgia is a chronic disease of unknown etiology. According to the classification criteria of the American College of Rheumatology (9) the disease is characterized by chronic (i.e. symptoms longer than 3 Months) widespread pain (i.e. pain in both sides of the body, pain above and below the waist ; in addition, axial skeletal pain must be present.) plus tenderness/pain in 11 of 18 predefined sites on digital palpation.

Few studies have investigated thermal imaging in fibromyalgia patients (7,8, 10,11;12,13,14). A study from Italy investigated 156 patients with fibromyalgia and compared the thermographic findings with the tender point maps of these patients and also with thermographic findings in patients with degenerative spinal disease and in healthy controls. The patients with fibromyalgia syndrome showed a non specific hyperthermic pattern, corresponding to painful muscular areas, which was also seen in patients with degenerative spinal disease. Previous own studies found a close correlation between the number of hot spots and the tender point count in fibromyalgia patients (7,8).

A study from Belgium found that the symmetry of temperature distribution in thermal images of the back is not disturbed, similar as in healthy subjects, but different to back pain patients with unilateral symptoms (11).Radhakrishna & Burnham were unable to detect tender points over the upper and midtrapezius in patients with myofascial pain or fibromyalgia by measuring the skin temperature with an hand-held infrared radiometer (12).

In contradiction to the hyperthermic findings in tender tendon insertions at the elbow (5,6),which have been successfully used as an outcome measure (13, 14), other authors (15,16) reported lower temperatures of tender points in fibromyalgia and interpreted this findings by decreased microcirculation (15). The low temperature of the back in fibromyalgia patients was related to an increased activity of the sympathetic nerve system (16).

Methods

A retrospective chart review was conducted to analyse the number of hot spots in thermal images from patients diagnosed with fibromyalgia according to the criteria of the American College of Rheumatology. The following data were extracted: gender, age, occurrence of wide spread pain, duration of the pain symptoms , the count of hot spots identified in thermal images recorded from the regions in which tender points are typically located and number tender points counted immediately after thermal images being recorded. Figure 1 shows the typical set of views for the investigation of fibromyalgia patients.

Thermal imaging

Thermograms were recorded with an AGEMA 870 after acclimatisation for 15 minutes without clothes to a room temperature of 24°C . Primary image processing was performed with the CATS software by an automatic mode for false colour setting that devided the range between the minimum and maximum temperature by 16. Low pass filter removed then low temperatures from the image which resulted in larger areas of high temperature.

About 40% of all images were converted to the thermal image format of the CTHERM sofware format. CTHERM images were not further processed for further evaluation.

In both image formats, processed CATS images and CTHERM images, hot spots were defined as any small area at least 0.5°C warmer than the surroundings. Assumed hot spot were accepted after spot temperature measurements within the hot spot and the near surrounding area.

The final hot spot count represents the sum of hot spots identified in the total series of thermal images from an individual patient.

Statistical analysis

The SPSS 10.0 software package was used for statistical analysis. Descriptive statistics including scatter plots were calculated. The concidence of hot spots with tender points was labeled as true positiv finding. Based on the rate of true positives, true negatives , false positives and false negatives, the diagnostic sensitivity and specificity of hot spots for tendereness was calculated when hot spots have been found in 18, 16 or 12 tender sites..

Results

Data from 312 subjects (290 female. 22 male, age range: 18 to 81 years) were included in the study.204 patients suffered from fibromyalgia and 87 patients with widespread pain did not show a sufficient count of tender points and were therefore diagnosed as localized myalgia. 21 healthy subjects. 20 females and 1 male, served as controls.

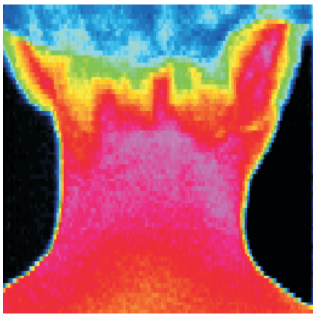
Table 1 shows the mean tender point count (95 % confidence interval) that differed significantly between the three groups. The scatter plot on figure 2 clearly indicates, that less hot spots than tender points were identified in all three diagnosis groups, although the mean number of hot spots

Table 1
tender poinzs count and hot spot count

Diagnosis	Mean count of tender points	95% confidence interval	Mean count of hot spots	95% confidence interval
Fibromyalgia	14.85	14.5 to15.2	9.5	9.2 to 9.8,
Localized myalgia	6.91	6.3 to 7.5	7.1	6.5 to 7.6
Controls	0.9	0.4 to 1.4	3.9	3.0 to 4.7

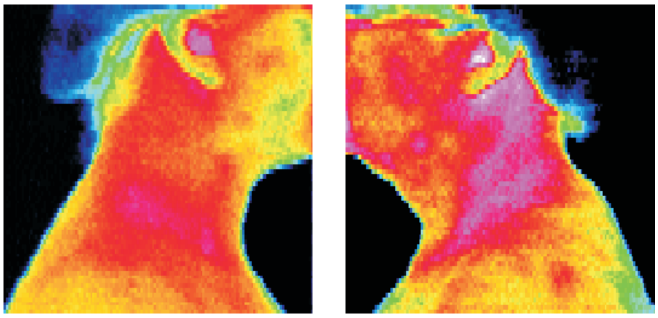
Figure 1
Typical set of views for in investigation of a patient with fibromyalgia

View.: Dorsal neck



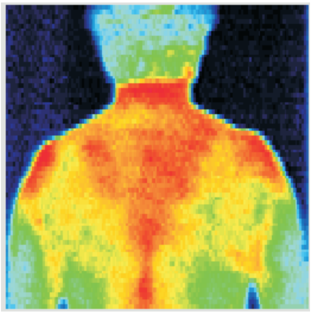
Location and (number) of tender sites:
Occiput (2) at the suboccipi-tal muscle insertions

Lateral views of the cervical spine



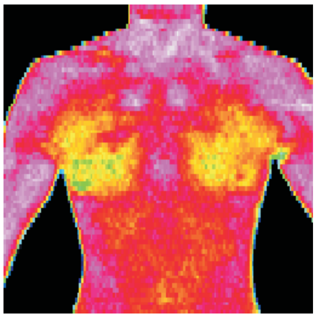
Location and (number) of tender sites:
Low cervical (2) at the anterior aspects of the intertransverse spaces at C5- C7

View.: Upper back



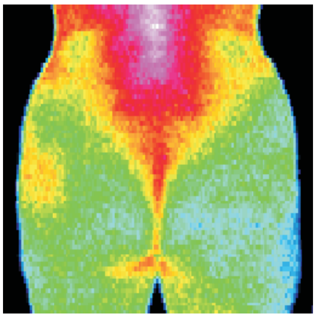
Location and (number) of tender sites:
Trapezius (2) at the mid-point of the upper border.
Supraspinatus (2) at origins, above the scapula spine near the medial border

View.: Thorax



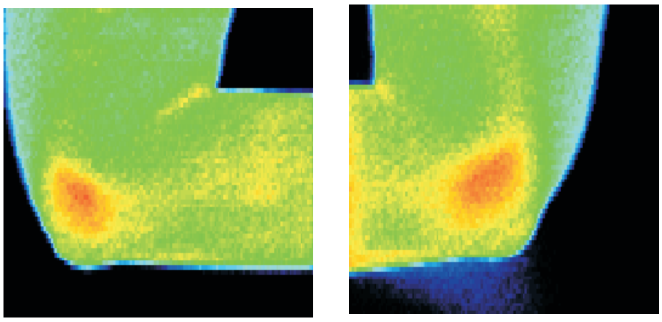
Location and (number) of tender sites
Second rib (2) upper lateral to the second costochondral junction

View.: Lower Back



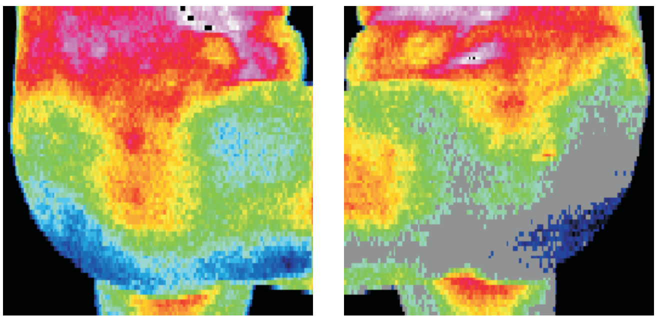
Location and (number) of tender sites:
Gluteal (2) in upper outer quadrants of buttocks in anterior fold of muscle

View.: Both elbows



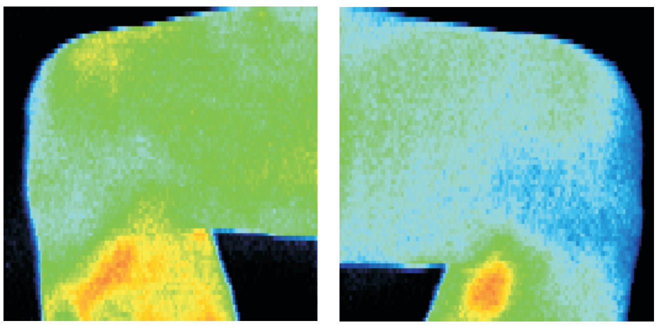
Location and (number) of tender sites
Lateral epicondyle (2) 2 cm distal to the epicondyles

View.: Lateral thigh



Location and (number) of tender sites
Greater trochanter (2) posterior to the trochanteric prominence

View.: Medial knee



Location and (number) of tender sites
Knee (2) at the medial fat pad proximal to the joint line.

and tender points have been very close in patients with localised myalgias.

The concidence of hot spots with tender points is listed in table 2 with respect to the body sites investigated. Table 3 shows the diagnostic sensitivity and specificity in the investigated regions od the body and cumulated for all 18 sites. The sensitivity of hot spots for tenderness at 18 sites was 53,91 %, specificity was 66,34 %, positive predictive value 74,82 % and negative predictive value 43,69%. The lowest sensitivity was calculated for the knees, followed by the supraspinaturs muscle and the second rib. Exclusion of the knee sites, resulted in an increase of sensitivity to 58.15 % and a decrease in specificity to 60.88%. Calculation of sensitivity based on 12 sites (after exclusion of supraspinatus muscle, costosternal junction and medial knee) derived a sensitivity of 65.40% and specificity of 56.46%, but predictive values changed only slightly.

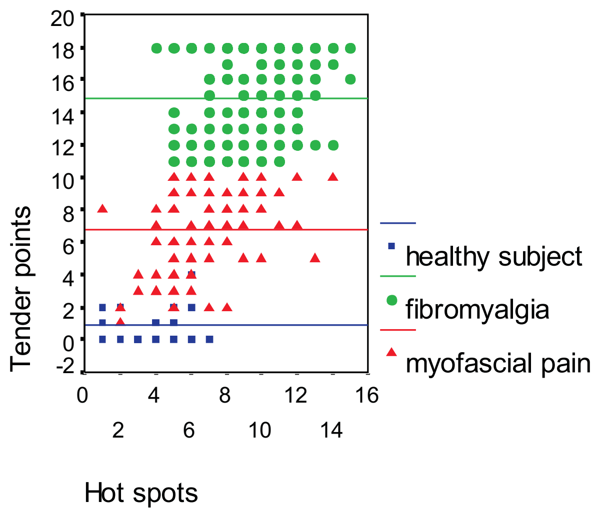


Figure 2
Scatterplot hot spots versus tender points

Discussion

As in previous studies reported (7,8), a high number of hot spots was reported in fibromyalgia patients and also in patients with patients suffering from widespread pain due to regional myalgias. However, the pathogenesis of hot spot in thermal images remains remains unclear. Increased blood flow in perforating vessels (17,18) is a well accepted mechanism for the generation of hot spots. Chemical compounds (19) and short living substances with the potential to induce vasodilation in skin vessels (20) and neurotransmitters(21) may also cause hot spots. In principal, metabolic heat production in deeper tissue layers due to tumour growth may also contribute to the fact, that small areas of increased temperature become visible at the body surface. However, the magnitude of heat generation in growing tumours is much too small to override the effect of perfusion.

Muscular activity is a major source of heat generation inside of the body. During short-time muscular con- tractions only little of the generated heat becomes visible at the body surface, but the skin temperature increases rapidly after ceasing muscular work (22,23,24). Regular sports activities can lead to the development of typical patterns of temperature distribution with hot areas corresponding to the muscles exercised (25). In athletes, a higher temperature was reported on the dominant forearm than on the non-dominant arm (26). This findings was explained by a higher level of muscular heat generation due to higher activity of the dominant arm.

Hypothetically, hot spots of tender muscles could be the result of heat generated by muscular activity and con-

Table 2
Diagnostic accuracy of hot spots for tender points for all investigated sites

Site	true negative	false negative	false positive	true positive
Occiput right hand side	117	94	30	71
Occiput left hand side	128	84	22	78
Low cervical right hand side	60	83	43	126
Low cervical left hand side	50	86	52	124
Upper trapezius right hand side	22	44	37	209
Upper trapezius left hand side	33	39	32	208
Supraspinatus right hand side	83	132	24	73
Supraspinatus left hand side	84	138	20	70
Second rib right hand side	82	111	34	85
Second rib left hand side	83	104	40	85
Lateral epicondyle right hand side	45	31	62	174
Lateral epicondyle left hand side	43	38	67	164
Gluteal right hand side	60	73	44	135
Gluteal left hand side	67	113	44	88
Greater Trochanter right hand side	59	77	54	122
Greater Trochanter left hand side	79	78	41	114
Knee right hand side	105	179	8	20
Knie left hand side	105	178	8	21
All	1305	1682	662	1967
percentage	23,24	29,95	11,79	35,02

ducted to the surface after ceasing the muscular contractions. Fischer measured the temperature in deeper tissue layers under- neath hot spots and on the contralateral side not showing a hot spot (4). He found identical temperature values at both measurement sites and refuted therefore the hypothesis that hot spots are the result of heat conduction from deeper layers. Hot spots were related with myofascial trigger points where active, symptomatic trigger points showed higher temperatures than latent non symptomatic trigger points (27, 28). Active trigger points showed also a lower threshold for pain provoked by pressure (4,29) This findings were challenged by other authors (12, 30,31), who did not confirm the relationship between tenderness and hot spots over myo fascial trigger points. However, there is good evidence for the relationship between tenderness and increased temperature over the tendon insertion in patients with tennis elbow (5,6,13,14). Patients with hot spots at the elbow have 9-fold risk to have a threshold for pressure pain below 2.5 kg/cm² and 1.3-fold risk to develop pain at resisted wrist extension (6).

It must kept in mind, that myofascial trigger points and fibromyalgia are two different pain syndromes, but both are characterised by local tenderness. The ability to identify tender points in fibromyalgia is an important expertise of physicians and therapists (32). When hot spots are used as an outcome measure, the reproducibilty of hot spot detection is essential- A chart review of patients suffering from fibromyalgia did not found evidence that the hot spot count has sufficient sensitivity to change.(33). This may be caused by the fact, that both intra- and interrater reproducibilty of coun ting hots spots in thermal images of fibromyalgia patients is rather poor (34).

The diagnostic accuracy (percentage of true positives and true negatives) of hot spots for tender points detected in this study was similar in range as in previous investigations (7,8). Restriction of hot spot count to 16 or 12 tender sites, increases the diagnostic sensitivity. Such a modification might be useful, when the hot spot count is considered as outcome measure in clinical trials. However, the reproducibility of the hot spot count must be increased , before it can be recommended as an outcome measure-

The hot spot count is rather a specific than a sensitive diagnostic procedure in fibromyalgia patients. A high number of hot spots in the thermogram of the total body can assist the diagnosis of fibromyalgia, but cannot replace the palpation of tender points.

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Table 3
Diagnostic sensitivity, specificity and predictive values of hot spots for tender points for all investigated sites

Site	Sensitivity	Specificity	positive predictive value	negative predictive value
Occiput right hand side	43,03	79,59	70,30	55,45
Occiput left hand side	48,15	85,33	78,00	60,38
Low cervical right hand side	60,29	58,25	74,56	41,96
Low cervical left hand side	59,05	49,02	70,45	36,76
Upper trapezius right hand side	82,61	37,29	84,96	33,33
Upper trapezius left hand side	84,21	50,77	86,67	45,83
Supraspinatus right hand side	35,61	77,57	75,26	38,60
Supraspinatus left hand side	33,65	80,77	77,78	37,84
Second rib right hand side	43,37	70,69	71,43	42,49
Second rib left hand side	44,97	67,48	68,00	44,39
Lateral epicondyle right hand side	84,88	42,06	73,73	59,21
Lateral epicondyle left hand side	81,19	39,09	71,00	53,09
Gluteal right hand side	64,90	57,69	75,42	45,11
Gluteal left hand side	43,78	60,36	66,67	37,22
Greater Trochanter right hand side	61,31	52,21	69,32	43,38
Greater Trochanter left hand side	59,38	65,83	73,55	50,32
Knee right hand side	10,05	92,92	71,43	36,97
Knie left hand side	10,55	92,92	72,41	37,10
18 sites	53,91	66,34	74,82	43,69
16 sites	58,15	60,88	74,19	45,34
12 sites	64,40	56,46	74,55	46,84

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Effects of Repeated Immersion of the Forearm in Cold Water on the Habituation of Pain Thresholds in Healthy Subjects

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SUMMARY

BACKGROUND: The cold pressor test (CPT), which involves immersion of body extremities in cold water, is well known for its cardiovascular effects. Less studied are the responses to pain, which are influenced by age, gender (specifically the point in the menstrual cycle for premenopausal women) and the cognitive attitude of the subject in regard to preparation for the test.
METHODS: In order to further examine the roles of proposed mechanisms that account for the resultant pain, including the habituation response, which is a sign of cold water adaptation, we recruited 17 healthy male subjects and measured cardiovascular parameters and pressure pain threshold at baseline and after immersion of the forearm in cold water (4 degrees C). In intervention 1, the subjects had their forearms immersed 6 times for 1 minute, with 5 minutes between immersions. In intervention 2, the subjects had their forearms immersed 4 times for 1 minute, with 15 minutes between immersions.
RESULTS: Both groups demonstrated increases in heart rate and blood pressure following initial immersion, but in intervention 2 we observed a further increase in heart rate following the third immersion, and slightly higher blood pressure compared to subjects in intervention 1. In regard to pain threshold, the subjects in intervention 2 showed a significantly higher pain threshold compared to subjects in intervention 1.. We also observed a slightly higher temperature in the forearms of subjects in intervention 2 compared to subjects in intervention 1. Overall the results indicate that subjects in intervention 2 had a higher pain threshold for a given forearm temperature.
CONCLUSIONS: The results suggest that habituation to cold water immersion contains a component that involves nociceptive inhibition of pain at the segmental level of the spinal cord. In addition, while we did not observe the large fluctuations between subjects in response to the CPT that has been occasionally reported, we suggest that cold pressor response results be interpreted with caution in clinical and experimental pain studies.

KEY WORDS: habituation, pain threshold, blood pressure, autonomic nervous system

EINFLUSS EINES WIEDERHOLTEN KALTEN TAUCHBADES DES UNTERAMS AUF DIE HABITUATION VON SCHMERZSCHWELLEN VON GESUNDEN PERSONEN

HINTERGRUND UND ZWECK DER STUDIE: Der Cold-Pressure-Test (CPT) ist ein Reiz-Reaktionsmodell, das vielfach verwendet wird um Kreislaufreaktion und –regulation zu untersuchen. Weniger bekannt sind dabei die Reaktionen auf Schmerz, bedingt durch Alters- und Geschlechtsunterschiede sowie premenopausale Zyklusabhängigkeit.

METHODE: Um zu klären ob die Habituation von Druck-, Hitze- und Kälteschmerzschwellenreaktionen auf Kältereize vom Applikationsintervall abhängig sind, wurden bei 17 gesunden männlichen Probanden kardiovaskuläre Parameter, Druck-, Hitze- und Kälte-schmerzschwellen nach Immersion (1 Minute) des Unterarmes in 4°C kaltem Wasser bestimmt. Es wurden zwei Interventionen mit unterschiedlichen Intervallen durchgeführt. In Intervention 1 mussten die Probanden die Unterarme 6mal eintauchen mit einem 5 Minuten Intervall zwischen den Immersionen, in Intervention 2 mussten die Probanden die Unterarme 4mal eintauchen mit einem Intervall von 15 Minuten.

ERGEBNISSE: Beide Gruppen zeigten Zunahmen der Pulsfrequenz und des Blutdruckes. Die Probanden zeigten in Intervention 2 im Vergleich zu Intervention 1, eine deutlich erhöhte Schmerzschwelle. Es wurden auch höhere Hauttemperatur in der Intervention 2 gemessen. Die Höhe der Schmerzschwellen korreliert in hohem Maße mit der sinkenden lokalen Oberflächentemperatur.

SCHLUSSFOLGERUNG: Die Ergebnisse dieser Studie deuten daraufhin, dass bei der Habituation auf Kältereize die noziptive Hemmung auf spinaler Ebene möglicherweise eine Rolle spielt. Da keine signifikanten Unterschiede zwischen den Probanden auf den CPT beobachtet werden konnte, sollte der CPT in Zukunft bei klinischen und experimentellen Schmerzstudien mit Vorsicht zur Interpretation der Ergebnisse herangezogen werden.
SCHLÜSSELWÖRTER: Habituation, Schmerzschwelle, Blutdruck, autonomes Nervensystem

Thermology international 2008; 18: 51- 56

Introduction

The autonomic nervous system is greatly influenced by painful stimulation (1). In particular, the sympathetic nervous system is involved in the regulation of muscular blood flow and endogenous pain modulation, constituting a potential link between peripheral and central mechanisms.

The cold pressor test (CPT), in which the cardiovascular system is challenged by cold immersion of body sections or extremities, triggers in healthy subjects a vascular sympathetic activation and an increase in blood pressure (2). Originally, the repeatability of autonomic response measurements, such as blood pressure and heart rate was thought to be fairly constant but this has been questioned (3). This variability has been clarified more recently suggesting that individual repeatability is high, but that the range of response, especially in regard to heart rate can be large (4). Moreover, the response depends on the presence of pain-coping strategies, or the cognitive process of "pain catastrophizing" (5). Thus, coping variables can predict cardiovascular responses, while the characteristics of the painful stimulus cannot. Another way of expressing this concept is the extent to which perceived control over anxiety-related events, such as immersion in cold water, can predict pain tolerance and endurance, but not pain intensity, threshold, or heart rate (6). In addition, the cold response in paraplegics, which leads to a suppressed blood pressure response, suggests that the cold pressor response is in part due to an independent thoracic spinal mechanism (7).

Many researchers have explored the adaptation to cold water immersion. For example, Polianski et al concluded that tolerance to tonic painful pressure and cold stimulations was specific to stimulus modality, indicating that separate nociceptive mechanisms might be in play (8). Adaptation to cold water also depends on many factors, including gender. While males and postmenopausal females showed relatively little change in pain tolerance and threshold when exposed to repeated CPTs, premenopausal women exhibited much larger adaptations, depending on the points of their menstrual cycle when they were tested (9). Hormone analysis has also demonstrated that the increased perceived pain intensity associated with high progesterone concentrations was significantly reduced with increasing levels of estradiol (10).

We have also observed that the associated pain sensitivity resulting from serial immersions of the affected body area in cold water, as indicated by the pressure-pain threshold, and which we term the cold pressure reaction (CPR), decreases after repeated presentations of stimulus. Moreover, this decreased response, or habituation, depends on the interval of time between exposures to the stimuli. Typically the habituation disappears after about an hour (11). As the habituation of pain sensitivity caused by repeated cold stimuli has not been reported in detail, and the repeatability of such measurements predicates the potential for their clinical use, in this study, we wished to address the habituation of the CPR in healthy subjects by varying the interval between repeated CPTs.

Materials and Methods

Subjects

A total of 17 healthy male subjects were recruited for the study. Exclusion criteria included severe ongoing pain, circulatory disorders, cardiac problems, hypertension, fibromyalgia, neurological diseases, acute inflammatory conditions, wounds and systemic use of any pharmacological agents.

Study protocols

Subjects were seated for 5 min and informed about the procedures. There was no attempt to cognitively influence the subjects in relation to how they should prepare for the tests. The study was designed as crossover: subjects were randomized so that the second series of experiments were performed after a 72-hour washout period. Patients gave written consent to participate in the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki with the Edinburgh revision and according to current Good Clinical Practice guidelines and was approved by the local Ethics Committee.

After pulse and blood pressure measurements, pressure pain thresholds (PPTs) were assessed by pressure algometry at the processus styloideus radii. The pressure algometry apparatus (Druck Schmerzschwellenmessgerät, Model PTH, PDT 20100, Germany) used in the study applied approximately 40-60 kPa/s/cm²2 and the diameter of contact with the skin was approximately 1 cm. The temperature of the forearm skin was measured before and after the immersions using the Thermo Check M (Steinel Thermo Check M/Strahlungsthermometer, Germany) that operates via an infrared sensor; the probe was directed to the forearm at a distance of 5 cm. With spectral compensation, the achieved accuracy was ± 0.3°C. Prior to experimental use, calibration was performed for the necessary temperature range (10ºC-42°C). The absolute accuracy after calibration was ± 0.3°C and the relative accuracy ± 0.1°C. The emissivity (epsilon) was adjusted to 0.97 according to the manufacturer's recommendations for skin temperature measurements; the response time was < 1 second.

All study parameters were measured with the forearm in air at room temperature. After obtaining baseline measurements, the arm was adducted the elbow flexed at an angle of 90º, and the whole dominant forearm immersed in a water (city tap water) bath containing ice cubes that measured approximately 4ºC, for 1 minute. Following temperature measurement, a pain threshold measurement was performed, and this procedure was repeated after every immersion. In intervention 1, there were 6 immersions with 5minute intervals between immersions, while in intervention 2 there were 4 immersions with 15-minute intervals between immersions. Study parameters were measured after each immersion.

Hot and cold pain thresholds were determined using a computerized contact thermode Thermotest (Somedic A/B, Stockholm, Sweden) (12). This device is capable of heating or cooling the skin, and consists of semiconductor junctions that produce a temperature gradient between the upper and lower stimulator surfaces produced by the passage of an electric current, thereby eliciting a cooling or heating effect. It is assumed that A-delta-fibres mediate cold sensations, and most likely C-fibres mediate cold pain in humans (13). All thresholds were assessed using a 2.5 x 5.0 cm thermode. The heat pain threshold was the lowest temperature perceived as painful obtained by starting at 32ºC and increasing the thermode temperature to 52ºC with a rate of change of 1ºC sec^{-1}. Similarly, the cold pain temperature was then obtained by starting at 32ºC and decreasing the temperature. Subjects were instructed to react to the first trace of pain by pressing a button connected to the device,

Table 1.
Differences between baseline and the mean immersion portion of the interventions for pressure, hot, and cold pain threshold values. Figures in parentheses are standard deviations.

	Pain (Pa)	**Cold (ºC)**	**Hot (ºC)**
		Intervention 1	
Baseline	5.7 (0.2)	10.7 (1.0)	43.6 (0.6)
Immersion	9.6 (0.2)	2.3 (0.5)	48.2 (0.6)
Difference	3.9	–8.4	4.6
		Intervention 2	
Baseline	6.0 (0.2)	9.2 (0.7)	43.2 (0.5)
Immersion	9.6 (0.1)	2.6 (0.4)	46.8 (0.5)
Difference	3.6	–6.5	3.6

which recorded the threshold. All thermal thresholds were determined as the average of 5 trials performed at 5 sec intervals. Measurements were made at baseline, and at the conclusion of each intervention for each subject.

Statistical analysis

SPSS (SPSS, Chicago IL, version 15) was used for statistical analysis. Quantitative data are presented as mean values and standard deviations, and changes within groups or between groups were tested for statistical significance by ANOVA (t tests, simple or two correlated samples) where relevant. The Pearson correlation coefficient was calculated to examine the linear relationship between 2 quantitative measures. A significance level of 0.05 was chosen, with all tests performed as 2-sided.

Results

The mean age of the subjects was 24.9 (3.76) years with a range of 18 to 35 years.

After the first immersion, the mean surface temperature of the forearm swiftly dropped from 31.8ºC to 21.8ºC (intervention 1) and from 31.2ºC to 23ºC (intervention 2) with smaller decrements of temperature after subsequent immersions (Figure 1). While the pattern for both interventions was similar, the temperature at each point during the intervention was about 1°C consistently higher for intervention 2 compared to intervention 1. The temperature change within both groups was statistically significant ($p < 0.001$), and between points 0 and 4 comparing the groups was extremely significant ($p < 0.0001$).

Figure 1
Surface temperature of forearm at baseline (point 0) and following each immersion with intervals of 5 minutes (points 1-6) or intervals of 15 minutes (points 1-4). Horizontal bars represent standard deviations.

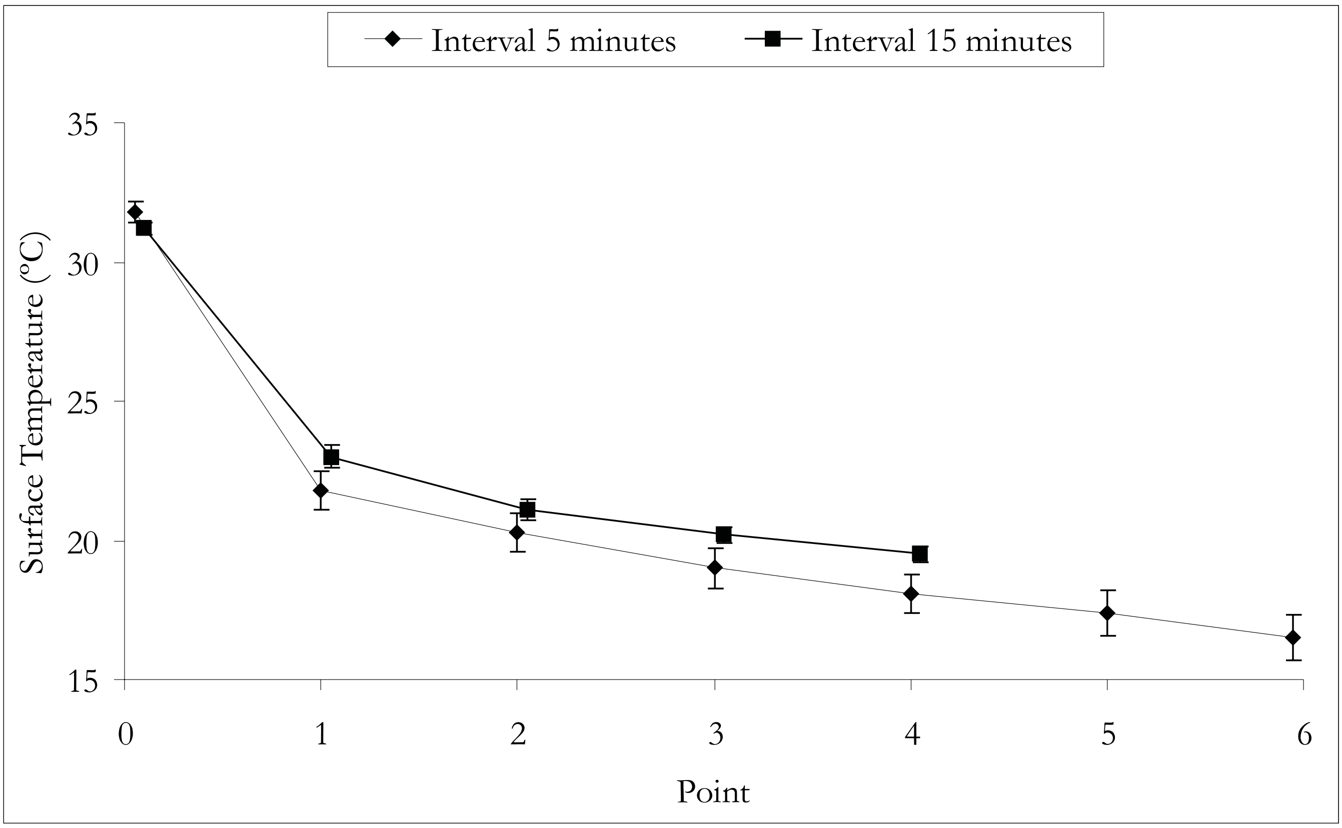


Figure 2
Heart rate (beats per minute) at baseline (point 0) and following each immersion with intervals of 5 minutes (intervention 1, filled diamonds) or intervals of 15 minutes (intervention 2, filled squares). Horizontal bars represent standard deviations.

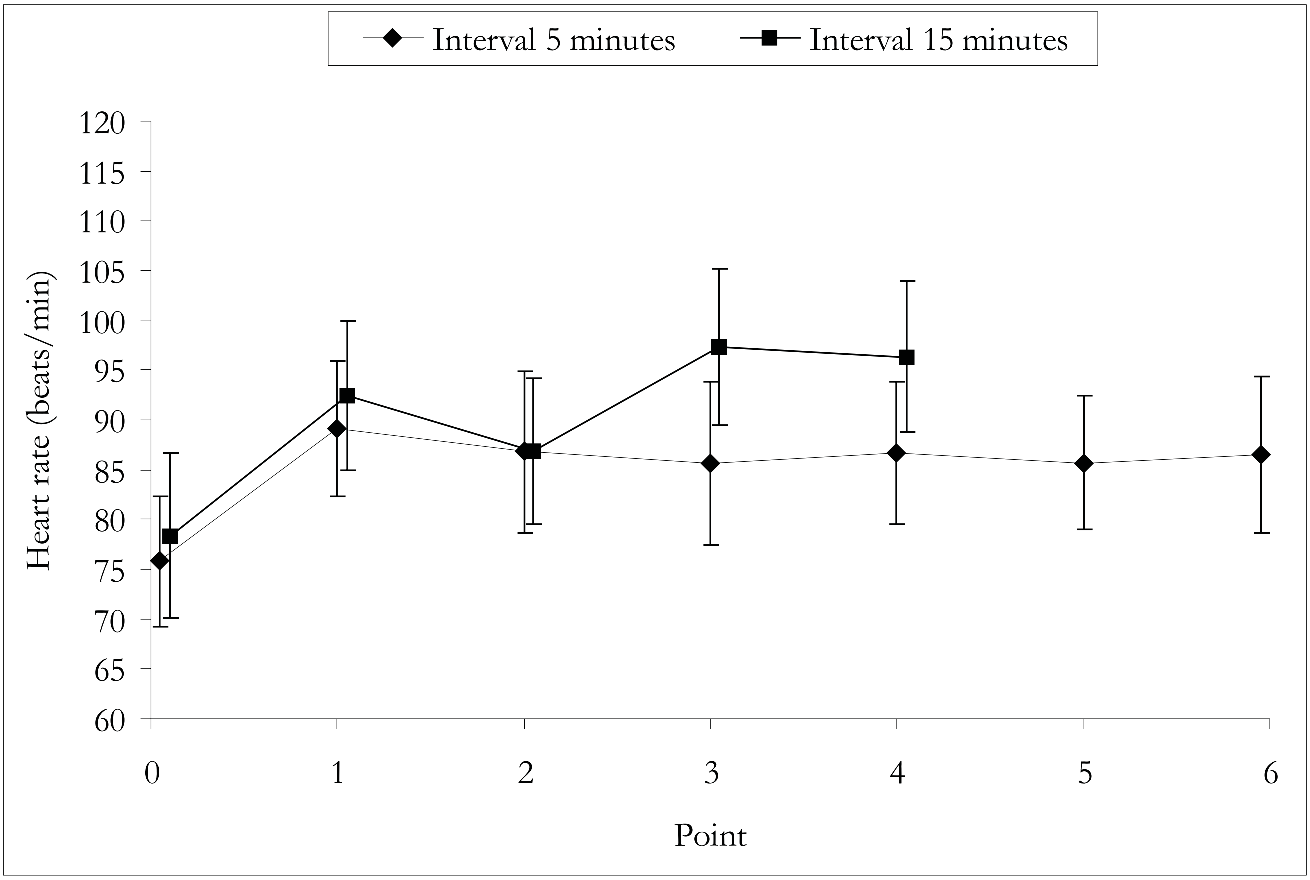
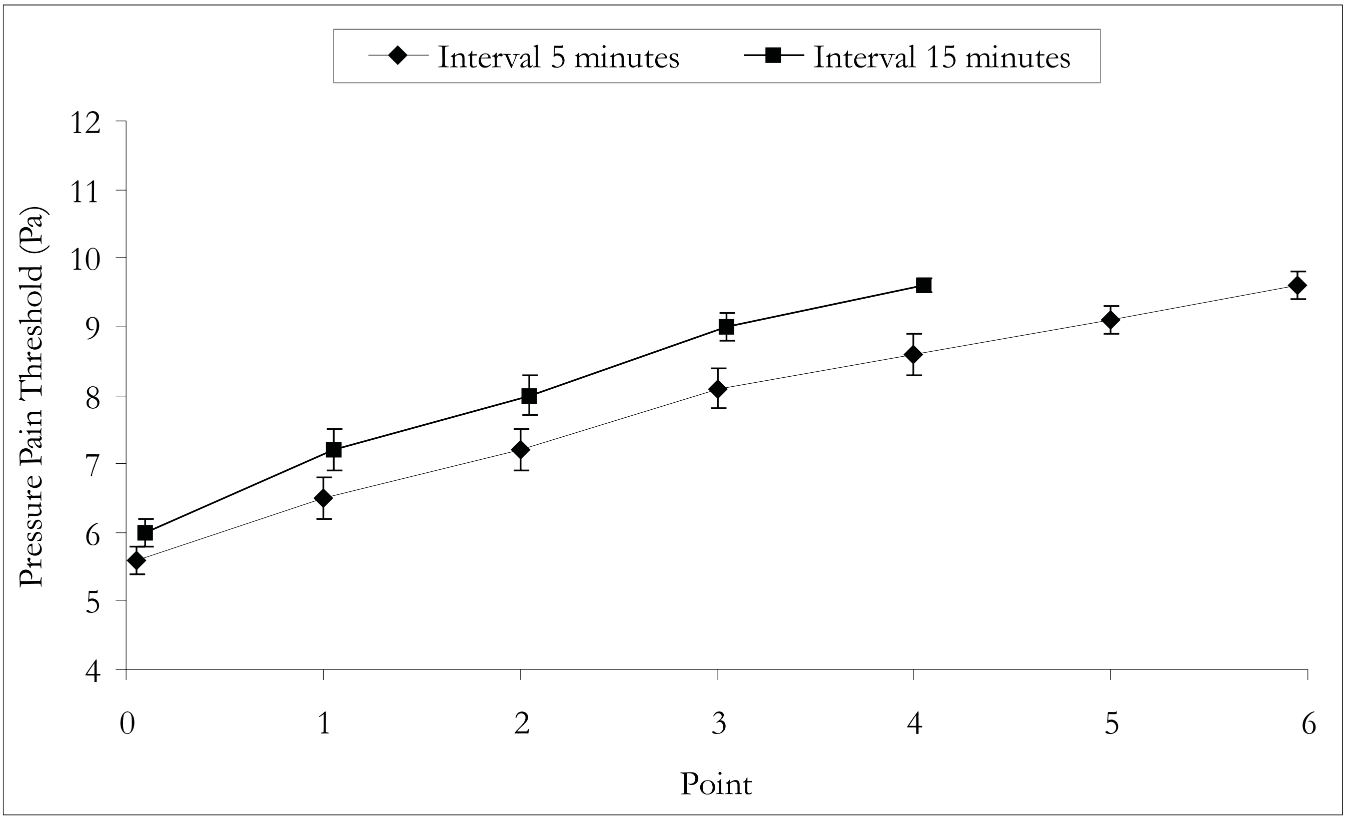


Figure 3
Pressure pain threshold (Pa) at baseline (point 0) and following each immersion with intervals of 5 minutes (intervention 1, filled diamonds) or intervals of 15 minutes (intervention 2, filled squares). Horizontal bars represent standard deviations (points 1-6) or intervals of 15 minutes (points 1-4). Horizontal bars represent standard deviation



Heart rate increased after the first immersion by approximately 18% in both interventions, but while in intervention 1 it remained relatively constant for the remainder of the experiment, in intervention 2 a higher excursion occurred beginning with the third immersion (Figure 2). Both diastolic and systolic blood pressure increased after the first immersion with ranges of 16 to 19% and 13 to 15%, respectively. However, while diastolic pressure remained constant thereafter in both interventions, in intervention 2 the pressure was slightly and consistently higher. Systolic blood pressure behavior was more complicated: in intervention 1 the pressure dropped slightly after the second immersion and remained constant, but in intervention 2 the pressure rose after the second immersion, before becoming constant. No statistical differences were observed between the groups, although the blood pressure changes within groups were extremely significant ($p < 0.0001$).

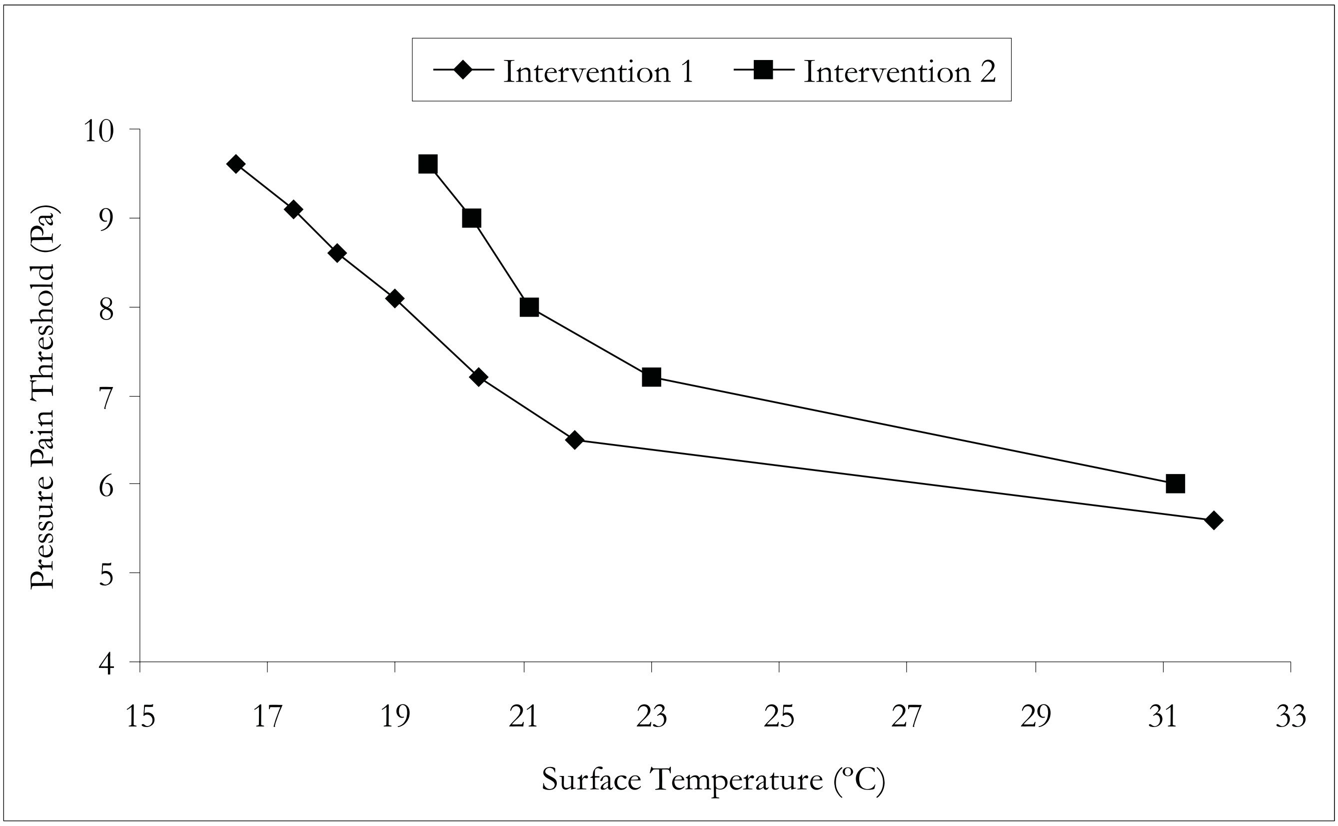
While the pressure pain threshold was elevated following each immersion, for the first 3 immersions it rose in a linear-like fashion, but then the rate of increase noticeably decreased to a lower but steady increase (Figure 3). The difference between baseline pressure pain threshold and the mean value obtained for the immersion portion of the interventions was similar for both interventions, but the differences for the cold and hot pain thresholds were larger (Table 1). The mean ranges for temperature tolerance were 32.9ºC (1.3) at baseline and 45.9ºC (0.7) during the immersion phase for intervention 1, and 34.0ºC (1.0) and 44.2ºC (0.7), respectively, for intervention 2.

The Pearson correlations between surface temperature and pressure pain threshold were good for both interventions (intervention 1: 0.63, $p < .0001$; intervention 2: 0.7, $p < 0.0001$). However, due to a moderate amount of heteroscedascity in both cases, the correlations between these parameters were best visualized by plotting mean values (Figure 4). The correlation in both cases is shaped like a "hockey stick," although the slopes for intervention 2 are marginally steeper compared to intervention 1. Correlations between the pressure and hot pain thresholds or hot and cold pain thresholds were non-existent, but were fair for pressure and cold pain thresholds (intervention 1: 0.39, $p < 0.11$; intervention 2: -0.29, $p = 0.26$), and fair to moderate for diastolic blood pressure (intervention 1: 0.30, $p < 0.00079$; intervention 2: 0.51, $p < 0 .0001$)..

Discussion

The CPT is used as to assess autonomic nervous system function. In healthy individuals, the afferent signals of the cold pressor reflex are mediated by cold temperature nociceptors and sensory nerve fibers. These signals are then integrated in the central nervous system (CNS) and the vasomotor center of the medulla oblongata. The efferent limb of the cold pressor response is believed to be mediated by the vagus and sympathetic nerves to the heart and peripheral blood vessels (14). Typically, the CPT causes peripheral vasoconstriction, an increase in heart contractility, and is followed by heart rate acceleration, and a rise in both diastolic and systolic blood pressure. The hemodynamic ef-

Figure 4
Correlation using mean values between surface temperature and pressure pain threshold for both interventions..



fect reaches a maximum within 60 seconds postimmersion, with significant pain reported (14).

In our study, in intervention 1, the heart rate rose after the first immersion and remained relatively constant thereafter. However, in intervention 2, at point 3 (Figure 2), we observed a further heart rate increase that was persistent. Because this phenomenon was only observed for 2 data points, it is unclear whether this is an artifact or real increase. Blood pressure increased following the first immersion for both groups, but both systolic and diastolic blood pressure were slightly elevated in intervention 2 in comparison intervention 1, although the differences were not statistically significant. However, at point 2, no changes in blood pressure were observed. The overall results suggest that lengthening the interval between immersions may have a small effect on hemodynamics, resulting in a more aggressive cardiovascular response.

Repeated cold water immersion causes a habituation reaction to occur in regard to pain threshold, and both groups demonstrated a substantial rise in pain threshold over several serial immersions. However, the effect in intervention 2 was consistently and significantly higher, suggesting that longer periods between immersions exert a more powerful effect over raising the pain threshold. The surface temperature of the arm after immersions between the groups was slightly different (as expected) with the group in intervention 2 demonstrating overall slightly higher temperatures. When temperature is plotted against pressure pain threshold (Figure 4) this produces an apparent effect of higher pain threshold at a given temperature when the period of time between immersions is increased.

The habituation, or decreased pain sensitivity due to repeated stimulus, may be the result of one of two mechanisms: either it could be due to peripheral dampening of the sensitivity of pain receptors or it may be a consequence of neuron inhibition at the segmental level of the spinal cord according to the gate control theory, which asserts that nonnociceptive fibers interfere with pain fiber signals, and inhibit pain (15). If the former concept were true, we might expect to see a higher pain threshold result from a lower skin surface temperature, provided that temperature is cause of the peripheral dampening. In our study, this appears not to be the case, suggesting a role for non nociceptive inhibition of pain. Although Catz et al did not investigate pain in their study, the cardiovascular responses in their control, paraplegic, and tetraplegic groups to the CPT also led them to conclude that an independent thoracic spinal mechanism contributes to the cold pressor response (7).

Finally, we did not observe the large variability between subjects that has been occasionally reported (3,4), although we agree that the specific methodology of the CPT can have a major influence, as well as the factors of age, gender (with regard to point in menstrual cycle), and "psychological status," or how the experimenter instructs the subjects in regard to the test. Thus, while this study supplies evidence for the reliability of CPR, such findings should be used cautiously in interpreting clinical and experimental pain studies.

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12th National Congress of the Polish Association of Thermology, 28th-30th March 2008, Zakopane

Programme

28th March 2008. Friday

19:00 Opening of the conferrence

19:10 - 20:00 Opening lecture
Chairman: Prof. A. Jung.

Prof Ring E.F.J. New developments and opportunities for infrared thermal imaging in health science.

29th March 2008, Saturday

9:00-10:45 Session I
Chairman: Prof. K. Ammer, Prof. J. Mercer.

1. Renkielska A., Nowakowski A., Kaczmarek M., Grudzinski J., Stojek W - Termiczna odpowiedz oparzonej i nieoparzonej skóry na pobudzenie zimnem. - Thermal response of burned and unburned skin to cold excitation

2. Ammer K. - Identification of hot spots in infrared images using a set of three isotherms.

3. Nica S.A., Mologhianu G., Murgu A., Ojoga F., Sirghii B., Ilie S., Meila A. - Thermography study of patients with stroke in the post-acute stage treated in a rehabilitation department.

4. Hidden P., Fuller A., Fick L., Mercer J.B.- Infrared Thermography in semi-free running domesticated African Elephants (Loxodonta africana) - preliminary results from a pilot study.

5. E.F.J. Ring, A. Jung, J. Zuber, P. Rutkowski, B. Kalicki, U. Bajwa - Examination of fever in Children by Infrared Thermography.

Coffee break

11:15 - 13:00 Session II
Chairman: Prof. F. Ring,

1. Vardasca R., Ring E.F.J., Plassmann P., Jones C.D. - Thermal symetry and temperature values of healthy volunteers on elbow, neck, shoulder and wrist.

2. Berz R. - MammoVision and BIRAS - a semi automatic evaluation system for female breast health assess.

3. Siniewicz K., Wiecek B., Pasnik J., Zeman K. - Diagnostyka termowizyjna u dzieci z hiperplazja grasicy w przebiegu zapalenia pluc.- Thermovision investigations in children with thymus hyperplasia during pneumonia.

4. Moderhak M. - Problems of analysis of thermal processes in breast tumor diagnostics. / Problemy analizy zjawisk termicznych w diagnostyce nowotworów piersi.

5. Klosowicz S.J., Czuprynski K.L., Jaremek H., Stepien J. - New approach to early cancer screening by using of specific thermographic markers for preliminary differentiation of pathologies with hypo- and hyper-thermic expression vizualized on Continuous Liquid Crystal Film Termographic Tester.- Nowe podejscie do wczesnego wykrywania raka sutka z uzyciem markerów termograficznych dla wstepnej diagnostyki patologii o hipo- and hipertermiczne ekspresji obrazowanej za pomoca testera cieklokrystalicznego.

15:00- 17:00 Training course
Chairman: Prof. S. Klosowicz, Dr med. B. Kalicki

1. Rutkowski P. - Praktyczne aspekty badan termograficznych. - Thermography examination in medical diagnostics.

2. Wiecek B. - Wielospektralne systemy termowizyjne.- Multicolor quantum- well infared detectors and their applications.

3. Nowosci z zakresu sprzetu i mozliwosci zastosowan w badaniach termograficznych.. News in thermology equipment.

30th March 2008, Sunday

10:00-12:30 Session III
Chairmen: Prof. B. Wiecek, Dr med. J. Zuber

1. Cicchanowska K., Lukowicz M., Weber-Zimmermann M., Szymanska J., Zalewski P. - Thermovision examination of treatment methods within physical medicine. - Termowizyjna analiza oddzialywania termicznego zabiegów leczniczych w zakresie medycyny fizykalnej

2. Wiecek B. - Wybrane aspekty przetwarzania obrazów do zastosowan medycznych.. Chosen aspects of thermal image processing- software for medical image classification.

3. Zalewski P., Lukowicz M., Ciechanowska K., Pawlak A., Pawlikowski J. - Thermovision examination of high intensity laser therapy - HILT thermal effects in relation to radiation energy doses, wavelength and application technique.- ermowizyjna analiza oddzialywania termicznego laseroterapii wysokoenergetycznej- HILT w odniesieniu do dawki energii promieniowania, dlugosci fali oraz techniki aplikacji.

4. Suchowirski M. - System do nadzoru temperatury badanego obiektu w aktywnej termografii dynamicznej.

5. Seweryn P., Laszczynska J. - Rozklad temperatury powirzchni ciala czlowieka po ekspozycji na szybka zmiane cisnienia barometrycznego (o róznym czasie trwania dekompresji) w obrazie termowizyjnym -/ Distribution of human body surface temperature following exposition to rapid change of barometric pressure (with different decompression time) in thermovision image.

NEW DEVELOPMENTS AND OPPORTUNITIES FOR INFRARED THERMAL IMAGING IN HEALTH SCIENCES

E.F.J.Ring

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Since the early days of medicine, the importance of temperature assessment has been recognised. When thermal imaging became accessible to medicine in the late 1950's, the prime interest seemed to be in the possible use for breast cancer diagnosis. Yet more successfully, the cancer specialists and dermatologists found a good application in the screening of myelomas on the skin for malignancy. Many other applications were also used in a research application, including the assessment of burn injuries, the viability of skin grafts and even amputation levels. Few of those applications have been taken up on a wider scale. There is still a more widely used application in rheumatology, for inflammation and nerve damage, and for examination of the hands for Raynaud's phenomenon.

Modern camera systems have advanced, with reduction in physical size, improved optical resolution and stability, enhanced computer processing and lowered cost.

Has this contributed to a wider spectrum of use in health care sciences? Undoubtedly, some applications for thermal imaging in the surgical operating room have shown good value, in heart and circulation procedures. Smaller cameras can be mounted overhead, now that nitrogen cooling is not essential. New health screening possibilities have been tested in Poland recently. An initiative for screening in shopping malls is underway with a target of 28 cities across Poland. Thermal Imaging of the face is used to look for sinusitis in subjects who could benefit from simple drug therapy. Also, the ISO committee is currently working on a proposed guideline for the use of thermal imaging for fever detection, especially in airports. This was used during the SARS crisis in China, and a new generation of a thermographic screening camera may emerge to meet any future threat of a pandemic influenza virus infection. Interestingly, both the latter screening programs are using images of the face, which can be easily imaged, and is least influenced by varying ambient conditions.

THERMAL RESPONSE OF BURNED AND UNBURNED SKIN TO COLD EXCITATION

A. Renkielska[1], A. Nowakowski[2], M. Kaczmarek[2], J. Grudzinski[1], W. Stojek[3]

[1] Department of Plastic Surgery and Burns, Gdansk Medical University, Gdansk, Poland
[2] Department of Biomedical Engineering, Gdansk University of Technology, Gdansk, Poland
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This study was devoted to the question if cold excitation may be effectively used in active dynamic thermal imaging (ADT) for diagnostics of skin burn depth. The experiments on animals presented quantitatively the reaction of healthy and burned pigskin to forced cold excitation.

We used high quality IR camera Flir SC 3000, quantum well FPA LW of 25 mK resolution and 60 Hz acquisition rate. For external cold excitation cryogenic CO2 rehabilitation instrumentation with specially designed applicator to get uniform cooling of tested skin was applied. Histopathological confirmation of burn depth was done on the contra lateral wounds, not tested with ADT, to avoid the influence of the biopsy on the thermal state of the wound. The study compared thermal transients of healthy and burned fields of controlled depths.

The measurement results showed that increasing the time of cooling we obtained stronger decrease of the temperature drop (T) and visible increase of the thermal time constant ( ) at the surface of tested skin. We also observed that for wounds healing within 3 weeks after burn (shallow) was shorter comparing to unburned skin. Wounds not healing within 3 weeks (deep) were characterized by longer than unburned skin.

The results confirmed high value of cold stress in ADT in burn depth evaluation and good correlation of heat flow mechanisms with the physiology of the living skin.

THERMOGRAPHY STUDY OF PATIENTS WITH STROKE IN THE POST-ACUTE STAGE TREATED IN A REHABILITATION DEPARTMENT

Adriana Sarah Nica, Gilda Mologhianu, Andreia Murgu, Florina Ojoga, Brindusa Sirghii, Svetlana Ilie, Ana Meila

University of Medicine and Pharmacy, Bucharest, Romania

INTRODUCTION. After the central neurological injury, zhe patient with stroke develops secundary problems relateded to the central and especially peripheral thermal adaptation system in the affected area of the body.

The consequences are clinical, symptomatical and objective and they can be studied in the vasomotor and thermal context.

The application of infrared thermography for the detection of local pathologies on the upper and lower limb used to observe some is generally recognized, but the systemic and local changes of patients with stroke may be a new issue in thermographic research.

MATERIAL: We have studied 100 in-patients with recent stroke, using an EDP medical thermograph in standard evaluation conditions.

METHOD: We applied a standard program of physical therapy using electrostimulation, ultrasounds, massage and kinesotherapy.

We recorded thermograms before and after each procedure. We have studied temperature gradients for single areas, we have compared the temperature gradients between the left and the right part of the body, and finally we have observed the therapy effect in time.

RESULTS:The results were biostatistically transformed and interpreted They underline different degrees of circulatory problems and different types of response in relation to the severity of the neurological damage.

IDENTIFICATION OF HOT SPOTS IN INFRARED IMAGES USING A SET OF THREE ISOTHERMS

Kurt Ammer

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Medical Imaging Research Group, Faculty of Advanced Technology, University of Glamorgan. Pontypridd, Wales, UK

Hot spots in thermal images are important features for assisting the diagnosis in breast disease, epicondylitis and fibromyalgia. However, the reproducibility of identified hot spots is poor.

A novel approach to improve the reliability of hot spot identification is based on the use of a set of 3 isotherms, 0,5 degrees apart. Moving this set over the total range of temperature within a thermal image, can easily detect hot spots as the temperature difference between the 1^{st} isotherm with the lowest threshold and the 3^{rd} isotherm with highest threshold is at least equivalent to the chosen temperature between the isotherms.

This approach was tested in a set of 10 thermal images previously used for testing of the reproducibility of hot spot identification. All images were evaluated twice on different days by the same reader, who was blinded at the second evaluation to the results of the first reading.

Figure 1 shows an example of a typical set of isotherms. Figure 1 shows an example of a typical set of isotherms. The reproducibility of hot spot identification was good (Single Measure Interclass Correlation: 0.699; 95% confidence interval: 0.138 to 0.917, Reliability Coefficient alpha: 0.807). The reproducibility of hot areas was poor (Single Measure Interclass Correlation: 0.14; 95% confidence interval: -0.162 to 0.580, Reliability Coefficient alpha: 0.413).

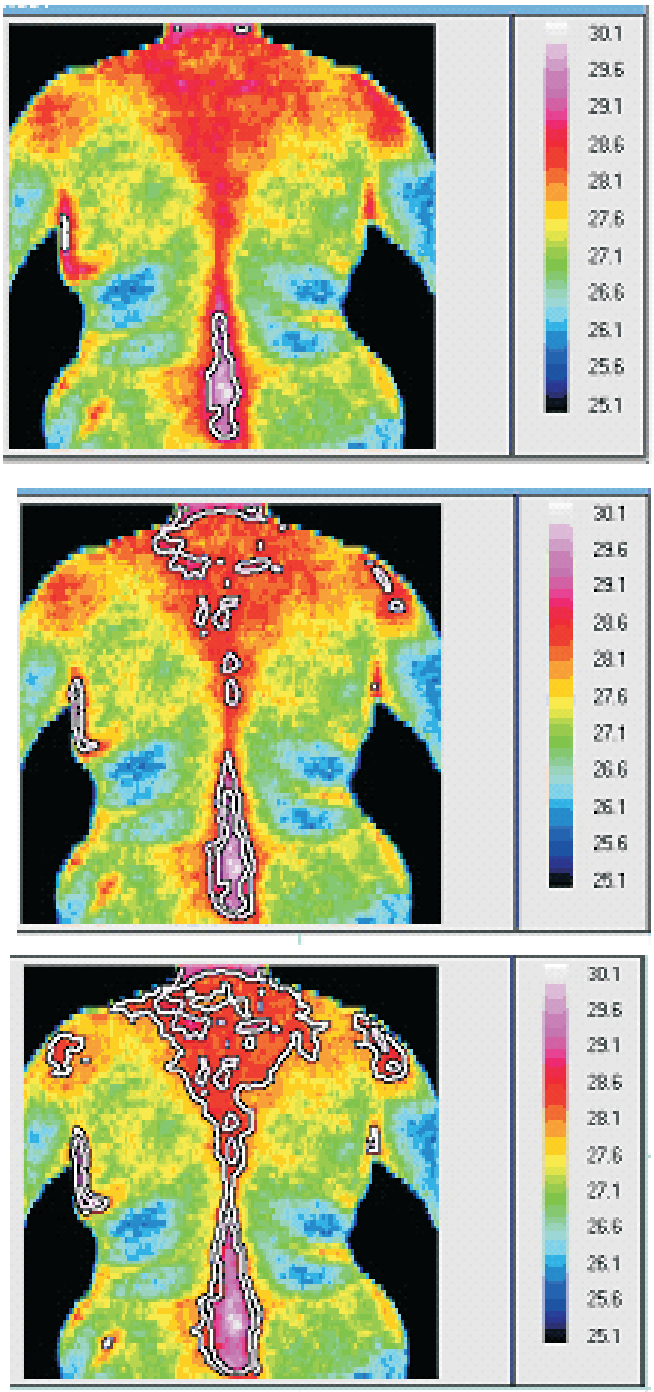

Figure 1
3 isotherms were defined at an temperature interval 0,5 degrees ranging from 29.0 to 28.0°C. 2 hot spots and one hot area were identified

The rather disappointing low degree reproducibility may be caused by several causes. Firstly, the maximum size of a hot spot and the minimum size of a hot area were not cleary defined. This might have caused false classifications of big sized hot spots as a hot areas and vice versa. The threshold for the isotherms with the highest and the lowest temperature differed between the two readings. Finally, very small hot spots may have been overlooked, particulary in the range of lower temperatures and when located close to an irregular shaped isotherm.

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

Philippa Hidden, Andrea Fuller, Linda Fick & James B. Mercer*

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*Department of Medical Physiology, Faculty of Medicine, UiTø, Tromsø, Norway

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

EXAMINATION OF FEVER IN CHILDREN BY INFRARED THERMOGRAPHY

EFJ Ring [1], A Jung [2], J Zuber [2], P Rutkowski [3] , B Kalicki [2], U Bajwa [1]

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

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

To date, 174 children aged from 3 months to 16 years have been tested in the clinical using a clinical thermometer in the axillary, under arm position, and thermal imaging of the anterior face. The ambient temperature has been maintained at 22 – 23^{0}C. The subjects were seated before the camera, and in front of a cloth screen. Thermal images were recorded, and regions of interest around the eyes and centre forehead were used. Mean and maximum temperatures from these regions of interest were determined.

RESULTS: In total, 160 of 174 subjects recorded temperatures in the normal range (defined as <37.5^{0}C) axillary, and had no direct disease or clinical problem affecting their temperature. Fourteen children had raised temperatures >37.5 with 7 being 38°C and over. Forehead temperatures were consistently lower in value than the inner canthi of the eyes.

AFEBRILE CHILDREN			FEBRILE
Anat.site, n=160	Mean temp°^{0}C	S D	Temp.Range n=14
Forehead	34.85	0.64	36.3 – 37.2
Inner Canthi	36.4	0.52	35.5 – 38.6
Axilla	35.9	0.81	37.5 – 39.0
Ear tymp, n=64	35.96	0.49	

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

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

THERMAL SYMMETRY AND TEMPERATURE VALUES OF HEALTHY VOLUNTEERS ON ELBOW, NECK, SHOULDER AND WRIST

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Medical thermal imaging is an objective screening modality for investigating skin temperature in arthritis, neuromusculoskeletal injury and circulatory pathology, 100% safe, highly accurate involving no radiation or contact. Its use is increasingly growing. Most parts of the body are thermally symmetrical, being that indicator an important factor on the supportive information to the clinician when assessing abnormalities in specific pathologic state.

Some injuries or syndromes commonly related with upper limb work related disorders affect articulations of the body like elbow, neck, shoulder and wrist, documented information about thermal symmetry on these areas of the body is needed. The object of this study is to analyse the collected data following a standard protocol and using the software package CTHERM to study thermograms of 40 healthy volunteers.

Results have shown that the acceptable values for thermal symmetry on the upper body articulations is 0.5° C difference between the mean temperature of two areas of interest divided by the longitudinal axis of the human body with a standard deviation of no more than 0.3° C.

MAMMOVISION® AND BIRAS® – A SEMIAUTOMATIC EVALUATION SYSTEM FOR FEMALE BREAST HEALTH ASSESSMENT

Reinhold Berz

German Society of Thermography and Regulation Medicine, Harbach 5, D-36115 Hilders, Germany

Despite widespread adoption of screening programs there is still an increase of breast cancer in European and other countries. Traditional screening methods are able to detect breast cancer lumps with at least 5 mm in diameter. However they generally will not detect smaller cancers or breast cancer in pre-clinical stages, which may take about 5 to 10 years to be detectable with such technologies. Thus unless other methods are used, there may be a lack of clinical information regarding the risk of developing breast cancer or other breast diseases.

Infrared thermography applying a physiological cooling stimulus (IRI = Infrared Regulation Imaging) is an innovative method that could fill the gap between early signs of breast metabolism deregulation and the manifestation of breast cancer lumps. The multi-patented MammoVision® examination is based on a grid system for each breast including several statistical functions for automatically generated evaluations and an expert rating of the breast vascular pattern.

More than 8 years of clinical application demonstrate that there is a correlation between severe thermal signs of altered breast metabolism and the occurrence of breast cancer. A recent study including more than 50 cases of breast cancer indicated that all these cases show clear signs of enhanced and altered breast metabolism calculated from the MammoVision® expert system. False negative results are very low, tending to zero, however there are many women without breast cancer also showing altered and enhanced breast metabolism. If the focus of the screening is on disease ("breast cancer"), some results could be considered false positives. However if the screening focuses on "deviation from breast health", these suspicious results of women not having breast cancer can actually indicate the need or opportunity for a preventive strategy including early interventional measures which could preempt the disease stage.

In Europe, MammoVision® (and ReguVision® for full body thermal imaging) are the only officially registered infrared imaging systems for medical purposes that entirely comply with the MDD (Medical Devices Directive, CE certified).

PROBLEMS OF ANALYSIS OF THERMAL PROCESSES IN BREAST TUMOR DIAGNOSTICS

Mateusz Moderhak

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Department of Biomedical Engineering

The aim of this work is to discuss problems of breast tumor diagnostics by the analysis of thermal processes forced by external excitation and observed by thermal IR camera. The history of breast tumor diagnostics by means of thermography goes back to the early sixties of the recent century. The value of breast diagnostics with use of classic mammography, thermal mammography, microwave and near IR examinations is still an up-to-date problem. The basics of thermal flow analysis and simulation forced by external excitation with the aim of medical diagnostics will be discussed. Basic thermal models and the procedures of active dynamic thermography (ADT) examination in breast diagnostics will be presented. Also the course of further research, especially with use of ADT and thermal tomography, will be introduced.

NEW APPROACH TO EARLY BREAST CANCER SCREENING USING SPECIFIC THERMOGRAPHIC MARKERS FOR PRELIMINARY DIFFERENTIATION OF PATHOLOGIES WITH HYPO- AND HYPER-THERMIC EXPRESSION VISUALIZED ON CONTINUOUS LIQUID CRYSTAL FILM THERMOGRAPHIC TESTER.

S. J. Klosowicz[1], K. L. Czuprynski[1], H. Jaremek[2], J. Stepien[3]

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[2] GREHEN Ltd, Poland
[3] Glammeron Manner Ltd, Poland Division

Liquid-crystalline contact thermography (LCCT) has been developed for at least 40 years, mainly in medical applications. It would seem that rapid development of thermovision revealed some disadvantages of this method. However, very recently some new concepts regarding its technology and usage has been introduced.

As early as 1976, at the Third International Symposium on Detection and Prevention of Cancer in New York, thermography was established by consensus as the highest risk marker for the possibility of the presence of an undetected breast cancer. It had also been shown to predict such a subsequent occurrence. The Department of Advanced Technologies and Chemistry of the Military University of Technology (MUT) presented a summary of its long-term researches and findings in the area of Liquid-crystalline Contact Thermography, which has remained undisputed. This, combined with other reports, has confirmed that persistently abnormal thermogram should be treated as the highest risk indicator (early marker) for the future development of breast cancer (in a study of 58.000 women screened with thermography, Gros et. al. followed 1,527 patients with initially healthy breasts and abnormal thermograms for 12 years - of this group, 40% developed malignancies within 5 years - this study concluded that "an abnormal thermogram is the single most important marker of high risk for the future development of breast cancer

In medical applications the LCCT seems to be considerably undervaluated, however, the most recent discoveries and significant technological progress in the area of liquid crystal engineering, including one-molecular layer imposition and polymer-hermetization elaborated in the laboratories of the MUT allow on mounting of an advanced thermosensitive compound that may be suitable for precise breast's thermoimaging. The aim of current researches is to develop an objective Breast-Health Test for frequent personal use also in out-of-clinic conditions, due the simplified examination and improved evaluation methodology (with remark that such self-diagnosis should be confirmed by other objective methods interpreted by physician).

New diagnostic methodology is developed on innovative concept based on separation of all thermographic pathologies into two groups (thermopathologies with hypothermic expression usually not-malignant, like degeneratio fibro-cistica, and thermopa thologies with hyperthermic expression - typically for malignant processes, like fast growing ductal carcinoma). The clinical validation studies with participation of scientists from the Military Medical Institute in Warsaw are already initiated with intend to provide solid data to confirm the usefulness of such a thermographic test for screening examination (positive/negative thermograms), especially in a group of patients with BRCA1/BRCA2 gene expression, with strong indication to continuous breast monitoring but at the same time with contraindication to make X-Ray mammography.

SOME ASPECTS OF THERMAL IMAGE PROCESSING - SOFTWARE FOR MEDICAL IMAGE CLASSIFICATION

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[2] Laser Diagnostic and Therapy Center at Technical University of Lodz

The main aim of the paper is to show the usefulness of 2D wavelet transform in thermal image processing for medical applications. Wavelet transformation is actually used in many domains, such as telecommunication and signal processing for compression and to extract quantitative data from a signal. In image processing it can be employed to get new features, representing both global and detail information. Wavelet transformation is based on image filtering represented by rows and columns using low and high pass linear filters (Fig. 1). After filtering, decimation is used to reduce number of pixels. The procedure can be repeated

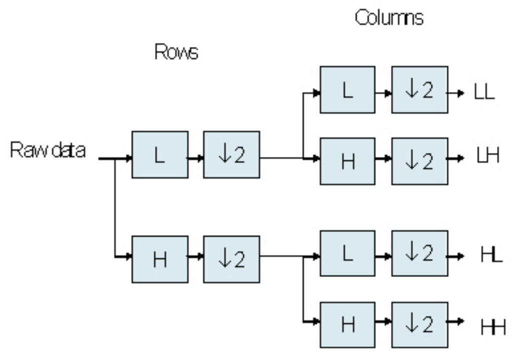

Figure 2.
Neural network example with input, single hidden and output layer

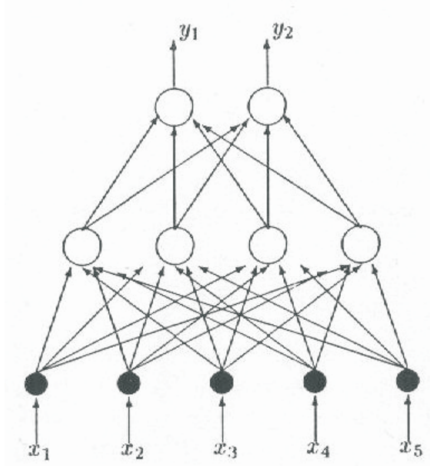

Figure 1
Wavelet transformation of an image

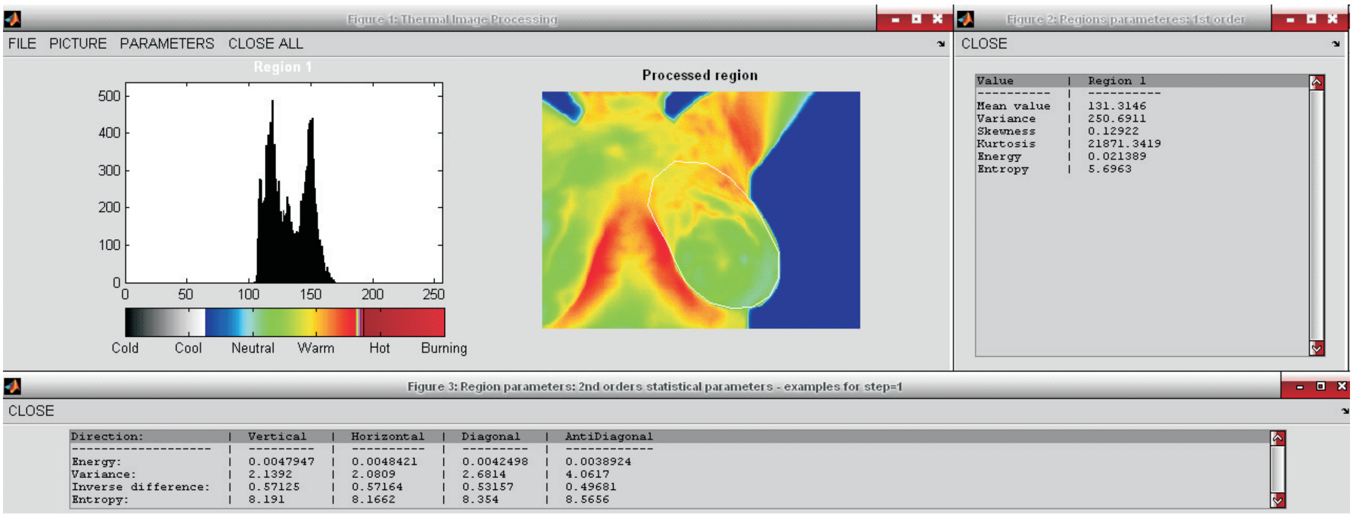

Fig.ure 3.
Histogram and calculated features of a thermal image

until 1x1 images are obtained. Practically, the processing is stopped earlier, after 2-4 steps, and then the features are derived from the filtered subimages.

The next aim of the paper is to present the artificial neural network as an effective tool for image classification. The selected image features has been used as inputs. It means that the number of inputs nodes if the neural network is equal to the number of features. Number of neuron in the first hidden layer can be equal or lower than the number of features in the classification, as shown in Fig. 2. ANN can have user-defined next hidden layers which allow additional nonlinear processing of the input features. As ANN is the nonlinear system and such technique allows the additional decorrelating and data reduction, what finally improves the classification. Such approach is known as Nonlinear Discriminant Analysis (NDA) [3].

It is well known that the training of ANN is the very important step in the entire protocol. It is an multivariable optimization problem typically based on backpropagation technique. In the general case, it can lead to wrong solutions if the there is no single minimum of the error function. That is why we need enough data during learning phase, and sometimes it is necessary to repeat training of ANN with different initial values of the neuron weight coefficients.

In order to verify the research assumptions, novel software was created in MATLAB environment (Fig.3). In Laser Diagnostic and Therapy Center, at Technical University of Lodz, the laboratory for diagnosis of breast diseases using mammography, ultrasonography and thermography in parallel, was created. In the same place and in the same time patient can make thermography, digital mammography, and ultrasonography. In our laboratory, a screening program has been started, so we hope to collect enough images for learing Artificial Neural Network. The software which is discussed in the paper is suitable for feature extracting and image classification for either X-ray, acoustic or thermal images.

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MULTICOLOR QUANTUM-WELL INFRARED DETECTORS AND THEIR APPLICATIONS

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In this paper the review of cooled multicolor QWIP (Quantum Well Infrared Photodetector) detectors is briefly presented. Different types of QWIP detectors are mentioned. The limits of detectivity and potential applications of photon detectors are discussed as well as the technological construction of mutiband QWIP detectors.

By changing quantum well size, it is possible to vary the wavelength of absorption. Stacking vertically two QWIPs, multiband detector can be realized (Fig. 1). Ohmic contacts of 0.5µm thickness are made from highly doped GaAs. Each QWIP is fabricated as 20-period GaAs/AlxGa1-xAs structure [7]. At the bottom of the pixel, optical coupler is realized to achieve high quantum efficiency. In some applications, random reflector is successfully used. The important precautions have to be considered to isolate readout circuit from the sensing device by epoxy layer.

Another solution of multicolor IR detector is so-called interlace dual-band structure, where the sensing elements are placed in odd and even rows one after another [7]. One row of pixels de-

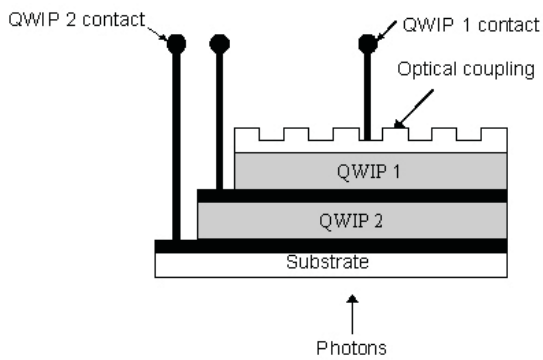

Figure 1
Vertically stacked dual-band IR detector [1]

tects 8-9μm LWIR radiation, while the following one is sensitive to 14-15μm VLWIR spectrum as shown in Fig. 2.

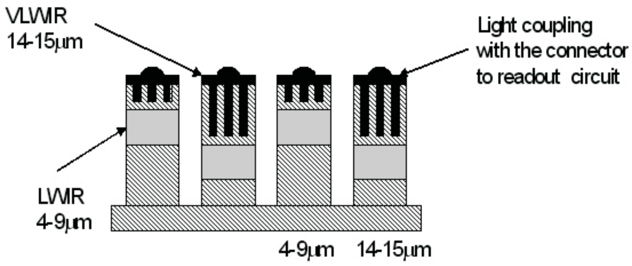

Fig.ure 2
Interlace dual-band IR detector matrix [9]

The typical operating temperature of QWIP detectors varies between 40-100K, mainly realized using Stirling coolers. Bias of each detector should be adjusted separately for both detectors to obtain the maximum responsivity, which is typically in the range of 300-350 mA/W [7]. Unfortunately, the quantum efficiency reaches the level of 10% only. for 20-period MQWIPs. In contrast, such efficiency for MCT detectors is better than 70%. Typical value of NEDT (Noise Equivalent Differential Temperature) at 24mK and 35mK for blue (MWIR) and red (LWIR) sensors has been obtained [7]. In addition to above figures, it is necessary to mention that the lifetime of thermally generated carriers for QWIP detectors is rather short (10ps) in comparison to MCT structures (1μs), what results in much higher integration time, which reaches the level of ms [7]. It is a direct consequence of slowing down the QWIP cameras and their limited applications for fast thermal processes investigations. Detectivity of QWIPs is of 2 orders of magnitude lower than for HgCdTe detectors, and it is at 2×1010cmHz ½ W-1. Reassuming, comparing the figures of merit for MCT and QWIPs, one can conclude that the detectors and IR cameras based on HgCdTe composite semiconductors are much better. It is the truth, but on the other hand, there are undoubted advantages of using QWIPs, such as very high spatial resolution and multicolor applications. Additionally, the cost of QWIP's production should be much lower for high-dense focal plane arrays, due to the low cost, massive production of large bandgap semiconductor devices and integrated circuits, the QWIP detectors are based on.

Temperature measurement with emissivity correction is one of the possible applications of the multicolor thermal detectors. Let's assume, that signal generated by thermovision equipment is a function of wavelength, temperature and the object's emissivity. Typically, the system responsivity depends the wavelength as well, what has to be taken into account by the calibration procedure (Fig. 3).

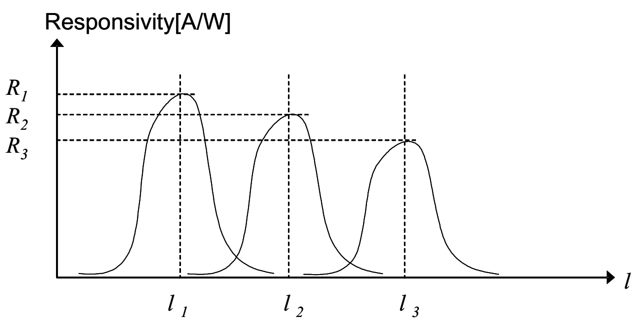

Fig.ure 3
.Spectral characteristics of multiband thermal system

Having the multispectral measurement possibility, according Planck's formulae, the camera generates different signals for a given wavelengths (λi) – egn.(3).

$$S(\lambda_i,T)=A_i\varepsilon(\lambda_i)\frac{2\pi hc^2}{\lambda_i^5\left(e^{\frac{hc}{\lambda_i kT}}-1\right)}\approx\varepsilon(\lambda_i)\frac{2\pi hc^2}{\lambda_i^5 e^{\frac{hc}{\lambda_i kT}}} \quad (1)$$

where: h=6,6260755·10-34 J·s, k =1,3806·10-23 J/K – Planck's and Boltzmann's constants, while A_i is the apparatus constant for a given wavelength λ_1. Wien approximation presented in the egn. (1) is valid for λT<0,003m·K, what denotes that for objects at T=300K, λ<10μm. For T=3000K, wavelength should fulfill the condition λ<1μm. Assuming, that emissivity does not depend on wavelength i.e.: ε(li)=const, for double wavelength thermal system we can easily derive the following equation to get the temperature value:

$$T=\frac{\frac{hc}{k}\left(\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right)}{5\ln\left(\frac{\lambda_1}{\lambda_2}\right)+\ln\left(\frac{S_1}{S_2}\right)+\ln\left(\frac{A_2}{A_1}\right)} \quad (2)$$

where: S1=S(λ1,T) and S2=S(λ2,T) are the system output signals for the chosen wavelengths, respectively. It denotes that the temperature readout from the system is regardless from the emissivity, and depends on the ratio S1/S2 only.

For long wavelength range, i.e: for λT?>0,778m·K, the Rayleigh-Jeans is valid. In this case, the formulae describing the signal obtained from the camera takes a form:

$$S(\lambda_i,T)=\frac{2\pi ckT}{\lambda_i^4} \quad (3)$$

More advanced applications assume that the emissivity dependence on the wavelength is a given function, e.g.: power or exponential ones [8]. To increase the precision of emissivity compensation, it possible to acquire the thermal images for more then 2 bands, e.g. 3-4 wavelength systems already exist in practice [10]. For example, let's assume that we have 3-band thermal system operating for λ1, λ2, λ3 and the emissivity varies according the following relation: ε(λ1)/ε(λ2)=ε(λ2)/ε(λ3). It denotes that value of emissivity depends linearly on the wavelength. For such a case, the temperature can be evaluated without emissivities, as:

$$T=\frac{\frac{hc}{k}\left(\frac{2}{\lambda_2}-\frac{1}{\lambda_1}-\frac{1}{\lambda_3}\right)}{5\ln\left(\frac{\lambda_1\lambda_3}{\lambda_2^2}\right)+\ln\left(\frac{S_1S_3}{S_2^2}\right)+\ln\left(\frac{A_2^2}{A_1A_3}\right)} \quad (4)$$

Emissivity compensation during the thermographic measurements is the only one possible application of multiband thermal systems. There are much more very useful applications of multiband thermal systems, such as watching through smoke and fog, or object detection and recognition.

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DISTRIBUTION OF HUMAN BODY SURFACE TEMPERATURE FOLLOWING EXPOSITION TO RAPID CHANGE OF BAROMETRIC PRESSURE (WITH DIFFERENT DECOMPRESSION TIME) IN THERMOVISION IMAGE

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Within the scope of training (according to STANAG 3114) in aviation medicine, conducted by the Military Institute of Aviation Medicine the pilot's organism is exposed to rapid change of barometric pressure (decompression). Literature data suggest that such a changes in physical conditions of the environment may cause life threatening physiological incidents with signs and symptoms of decompression illness. In body systems and organs, decompression provokes a range of functional and anatomical disturbances. The study was conducted to assess organism's adaptive reactions to decompression with thermovisual imaging of skin blood flow distribution in response to rapid environmental pressure changes.

The study was carried on 12 healthy volunteers (men aged 24±6 years; BMI = 21,8±2,8), qualified to the study by Aero Medical Board Warsaw. The subjects were studied in the low-pressure chamber with decompression effect (Ta = 22°C). In order to minimize the risk of decompression illness, each examination was preceded by nitrogen desaturation, achieved by breathing with pure oxygen for 30 minutes. During subsequent study days, subjects underwent decompression from the simulated altitude of 3000 meters above sea level to 7000 meters above sea level, lasting 2 seconds (profile I) and 14 seconds (profile II). Thermographs were recorded (AGEMA 900) immediately before and after decompression. HR, SBP, DBP and SpO_2 were monitored throughout the examination.

Following decompression, a transient increase of monitored haemodynamic parameters was observed. Duration of decompression did not significantly influence these changes. Thermographs revealed symmetrical body temperature distribution, with isothermal lines distribution of highest temperature ("T") characteristic to adult humans. During decompression lasting 14 seconds, rapidly subsiding, insignificant decrease of mean body surface temperature was noted on the area of thorax.

Decompression of 2 and 14 seconds duration did not cause any significant changes of the temperature distribution in human adult body surface.

CRPS/RSD: Diagnostic/Technical Advances in the Understanding of Autonomic Function

Venue

NYU Medical Center 550 First Avenue
New York, NY 10016

Target Audience

Physicians and allied health professionals who have an interest in the diagnosis and management of chronic pain

Course Description

The diagnosis and management of Reflex Sympathetic Dystrophy (RSD)/Complex Regional Pain Syndrome (CRPS), Rheumatological disorders, Vasomotor disorders, Thoracic Outlet Syndrome, Sports Injuries and Migraine headaches will be presented with an emphasis on the role of Computerized Infrared Imaging (CII) /Thermography.

Correlation with other modalities (MRI/EMG etc) will be presented as well as a discussion of how to set up a Thermography laboratory and associated costs. A diverse faculty with an expertise in pain management drawn from the fields of rehabilitation medicine, neurology and veterinary medicine will be presenting.

Statement of Need

Patients with chronic pain are often referred too late for successful treatment. Similarly, patients with RSD/CRPS are often diagnosed too late for successful rehabilitation. There is a need for practitioners to better understand the role of CII/Thermography as a diagnostic tool in the evaluation of chronic pain, and, specifically, to better understand how such technology can be used in making an early diagnosis of RSD/CRPS. The American Academy of Thermology recognizes a current and ongoing need for practitioners to understand that CII is the only non-invasive technology available to image and map disorders of thermoregulation.

Learning Objectives

Utilize Computerized Infrared Imaging (CII) to effectively diagnosis and manage chronic pain in order to improve patient outcomes

Employ CII to make an early diagnosis of RSD/CRPS in patients to allow for prompt rehabilitation

Apply CII to properly diagnose patients with migraine headaches so they can begin appropriate treatment.

Agenda

8:00 am Registration and Continenal Breakfast

8:50Introduction The Power, Beauty and Vision of Thermography .- Mathew H. M. Lee, M.D., M.P.H.

9:00Thermography-Introduction, History and Represen tative Cases- Jeffrey M. Cohen, MD Course Director

9:15 AAT Guidelines for Neuro-musculoskeletal Thermography - Robert Schwartz, MD

10:00 Infrared Thermographic Vasomotor Mapping and Differential Diagnosis - Robert G. Schwartz, MD

10:45 Coffee Break

11:05Thermograpgy in Migraine Headaches and Trigeminal Neuralgia - Srini Govindan, MD

11:35 Thermography and Chronic Regional Pain Syndrome Bryan O'Young, MD

12:05 Q & A Round Table

12:20 Lunch

1:20 Stress Thermography-Functional Cold H_2O Autonomic Challenge Testing- Timothy Conwell, DC

2:05Thermographic Evaluation of Neurovascular System Ram Purohit, DVM, PhD, DACT

2:50 Coffee Break

3:05 Practical Issues in the Establishment of A Clinical Thermology Facility - Philip P. Hoekstra, III, PhD

3:35Advancements in medical IR high sensitivity applications:fusion IR imaging and 3D IR/MRI softwares - Marcos Brioschi, MD

4:10Q & A Round Table

4:30 pm Adjournment

Faculty

NYU Faculty

Jeffrey M. Cohen, MD
Clinical Associate Professor of Rehabilitation Medicine
Department of Rehabilitation Medicine
New York University School of Medicine
Medical Director
Kathryn Walter Stein Chronic Pain Laboratory
Rusk Institute of Rehabilitation Medicine

Mathew H. M. Lee, MD
Howard A. Rusk Professor of Rehabilitation Medicine
Chairman, Department of Rehabilitation Medicine
New York University School of Medicine

Bryan O'Young, MD
Clinical Associate Professor of Rehabilitation Medicine
Department of Rehabilitation Medicine
New York University School of Medicine

Guest Faculty

Marcos Brioschi, MD
Pain Center. Department of Neurology. University of Sao Paolo Medical School. Sao Paolo, Brazil

Timothy Conwell, DC
Director, Colorado Infrared Imaging Center
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Srini Govindan, MD
Neurologist, Neuropathologist and Nuclear Medicine
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Philip P. Hoekstra, III, PhD
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Ram Purohit, DVM, PhD, DACT
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College of Veterinarian Medicine
Auburn University
Auburn, Alabama

Robert G. Schwartz, MD
Medical Director,
Physical Medicine & Rehabilitation
St. Francis Community Hospital
Director, Piedmont Physical Medicine and Rehabilitation
Greenville, South Carolina

Abstracts

HISTORY OF THERMOGRAPHY, CLINICAL INDICATIONS FOR THERMOGRAPHY AND REPRESENTATIVE CASES FROM THE RUSK INSTITIUTE OF REHABILITATION

Jeffrey Cohen
Department of Rehabilitation Medicine,
New York University School of Medicine

The history of thermography begins in antiquity. An overview of the clinical use of temperature measurement for patient care will be presented. This talk will date from the twenty-ninth century B.C. in which the Egyptians used the scanning capacity of their fingers to determine heat to the present day computerized infrared imaging systems. Next, an overview of the role of thermography in the evaluation of common musculoskeletal, neurological and vascular conditions will be presented. This will be based upon a review of the literature and highlight clinical areas where thermography is felt to be a valuable diagnostic tool and those areas where it is not recommended. Finally, three representative cases from the Rusk Institute of Rehabilitation Medicine's Kathryn Walter Stein Chronic Pain Laboratory will be presented.

AAT GUIDELINES FOR NEURO-MUSCULOSKELETAL THERMOGRAPHY

Robert G. Schwartz
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Infrared thermography of the extremities and spine is performed to provide an overview of the location, extent and severity of vasomotor abnormality. The thermographic evaluation can be performed from the cranium to the base of the spine (inclusive of all segments) and torso to the extremities, extended to the fingers and toes.

The guideline was prepared by members of the American Academy of Thermology (AAT) as a guide to aid the neuro-muscular thermologist and other interested parties. It implies a consensus of those substantially concerned with its scope and provisions. The guideline shows the following 7 chapters:

1. Patient Communication and Preparation
2..Patient Assessment
3.Examination Guidelines
4.Review of The Infrared Thermography Examination
5.Presentation Of Exam Findings
6. Exam Time Recommendations
7.Continuing Professional Education

INFRARED THERMOGRAPHIC VASOMOTOR MAPPING AND DIFFERENTIAL DIAGNOSIS

Robert G. Schwartz
Piedmont Physical Medicine and Rehabilitation Greenville, South Carolina

When performed with proper technique and under controlled conditions, thermography (Computerized Infrared Imaging or CII) is the test of choice for mapping of vasomotor instability and asymmetry. The findings provide important clinical insights into those structures that generate aberrant sympathetic responses for pain syndromes such as Reflex Sympathetic Dystrophy (RSD), Complex Regional Pain Syndrome types I and II (CRPS), Thoracic Outlet Syndrome (TOS), Cervical Brachial Syndrome, Fibromyalgia, and Barre- Lieou. In addition, the presence of abnormalities and the distribution of findings can be invaluable in differential diagnosis of these conditions.

The medical community has demonstrated increased awareness of sympathetic pain syndromes over the last decade. New interventions and approaches toward alleviating symptoms in those afflicted have been tried, some with success. Even better results can be achieved through a greater understanding of which structure is initially responsible for generating the condition.

THERMOGRAPHY IN MIGRAINE HEADACHES AND TRIGEMINAL NEURALGIA.

Srini Govindan
Department of Neurology, West Virginia University School of Medicine.Wheeling, West Virginia

The Presentation will focus on Imaging Extracranial / Facial blood flow in Migraine Headaches and Trigeminal Neuralgia, under 1) Anatomy, Functional/ Physiological, 2) Angiosomes, 3) Referred pain and trigeminal neurovascular control. 4) Thermography and Extracranial blood flow Criteria for Trigeminal/ Facial blood flow imaging, 5) Extracranial vascular receptors, 6) Pathophysiology, 7) Protocal for Migraine and Facial Neuralgia, 8) Clinical case Presentations, 9) Future Applications.

1) Anatomy/ Functional, Physiological.
Correlating thermography images clinically, allows us to incor-

porate in the words of Michael Salmon, functional anatomy (the internal and external carotid territory angiosomes) with physiologic anatomy (clinical state dependent activation of perivascularly located mast cells and its neurosensitizing and vasoactive mast cell mediators).

2) Angiosomes

The basic anatomy of the cutaneous vessels, coupled with an appreciation of the factors that influence its structure in different regions of the body has clinical application in correlating thermography findings. The works of Manchot, Salmon and Taylor helps us to understand the blood supply to the skin and the underlying deep tissues and segregate the body anatomically in to three-dimensional vascular territories that are named “angiosomes”. Forty angiosomes have been described, which can be subdivided further into smaller composite units. Forehead-Nose Thermal Ratio is based on Angiosomes. In the words of Michael Salmon, between anatomy and physiology there in room for functional anatomy, for a physiologic anatomy. Uematsu and Goodman have documented skin temperature symmetry and asymmetry, physiologic anatomy, which along with mast cell heterogenicity/ function will form a basis for using angiosomes in interpretation of thermograms, in the context of functional anatomy to image/ correlate thermal patterns of angiosomes during dysfunction, physiologic anatomy, focal/ regional or systemic.

3) Referred pain and trigeminal neurovascular control.

The pain from cephalic vasculature is referred to superficial or surface structures such as skin and underlying tissue mediated through the trigeminovascular system.

4) Thermography and Extracranial blood flow Criteria for Trigeminal/ Facial blood flow imaging,

Imaging the extracranial blood flow using dynamic thermography testing meets the extracranial microcirculation measurement criteria by its ability to 1) Image and monitor the primary vasoactive response of the individual, based on pre-existing vasomotor tone/ the vasomotor capacitance of the individual. 2) Evaluate the biological limit of vasomotion, i.e, Vasoconstriction/Vasodilation,3) Provide the methodology to document the effect of agonistic and antagonistic drugs on the extracranial blood flow/ vasomotion under the regional control of trigeminovascular system, 4) Help to understand the control processes that may occur in response to dynamic conditions by using a protocol involving changing rather than static conditions such as superimposed vasomotor and pharmacological challenges, and 5) Visualize blood flow changes in real time. The dynamic nature of extracranial vasomotion appears to be predictable within the physiological limits of vasoconstriction and vasodilation.

5) Extracranial vascular receptors:

Extracranial vascular receptors react differently to vasomotor stress. Clinical case studies also indicate differences in the vaso-re active properties of the external carotid artery in humans. Different vasoactive properties of the extracranial vascular receptors may have a role in its capacity to alter extracranial flow independent of the metabolism by microcirculation arteriovenous shunting.

6) Pathophysiology:

Cranial microcirculation is under the trigeminal neurovascular control. The rich innervation of the vasculature and meninges of the brain provides a dense plexus of mainly unmyelinated fibers that arise from the trigeminal ganglion and to a lesser extent the upper cervical dorsal roots. The pharmacology of the trigeminovascular system is complex. The peripheral branch consisting of the cranial circulation and dura mater receives sympathetic, parasympathetic, and sensory nerve fibers, all containing their own characteristic neurotransmitters. Sympathetic nerve fibers arising from the superior cervical ganglion supply the cranial vasculature with neuropeptide Y (NPY), noradrenaline (NA), and adenosine triphosphate (ATP). Parasympathetic nerve fibers arising from the sphenopalatine and otic ganglia as well as carotid minigangl ia, supply the cranial vasculature with vasoactive intestinal peptide (VIP), peptide histidine isoleucine (PHI), Acetylcholinesterase (AChE), peptide histidine methionine 27 (PHM, human version), pituitary cyclase-activating peptide (PACAP), and other VIP-related peptides. Sensory nerve fibers arising from the trigeminal ganglia supply the cranial vasculature with substance P (SP), calcitonin gene-related peptide (CGRP), neurokinin A (NKA), and PACAP. Bipolar trigeminovascular afferents innervating the cranial structures project centrally and synapse on second order neurons in the trigeminal nucleus caudalis (TNC), which is the key relay center for transmission of information to higher brain structures.

7) Protocal for Migraine and Facial Neuralgia,

Should be based on symptomatic or asymptomatic, in remission/ exacerbation, effect of other vasoactive drugs, type of administration, oral/ nasal spray/ subcutaneous or transdermal, half life of neuropeptide implicated in the pathophysiology, site action of the drug, presynaptic/ post synaptic or smooth muscle.

THERMOGRAPHY AND COMPLEX REGIONAL PAIN SYNDROME

Bryan O’Young, Jeffrey Cohen

New York University School of Medicine

During the last 2 decades, there has been an expanding role for the use of thermography in the diagnosis of Complex Regional Pain Syndrome (CRPS). As pain management becomes an important part of the clinician’s role and as CRPS has often been an elusive diagnosis, there is an increased recognition and appreciation of thermography. The session will review the important role of thermography for the diagnosis of patients with CRPS and in the facilitation of its treatment. The session begins with the discussion of the general principles relative to CRPS and its diagnosis. This is followed by a review of the common diagnostic tools used in confirming CRPS. The session concludes with a series of case studies reviewing the role of thermography in diagnosing and facilitating the management of CRPS.

THE ROLE OF COLD WATER AUTONOMIC FUNCTIONAL STRESS TESTING IN THE EVALUATION OF PATIENTS WITH PRESUMPTIVE CRPS-1

Timothy D. Conwell, DC

Colorado Infrared Imaging Center, Denver, Colorado

Complex Regional Pain Syndrome Type 1 (CRPS-1) is a clinical diagnosis based on IASP criteria describing signs and symptoms of the disease. Internal and external validation research suggests problems with over diagnosis using the IASP criteria. Cold water autonomic functional stress testing is helpful in evaluating the function of the ANS vasoconstrictor reflex in patients with presumptive CRPS-I. Cold water autonomic functional stress testing is performed by utilizing dynamic subtraction imaging software that is available on most medical IR programs. Real-subtraction imaging is achieved by choosing a starting reference image, then choosing to view only the differences from the re -ference to the current image. If the individual pixel temperature rises, the difference will be shown in color; if the temperature drops, the image will be displayed in shades of gray. All thermal data have a dynamic range of 12 bits enabling the user to view .05-degree difference in a 0-50 $^{\circ}$ C temperature range. ANS stress testing is performed by imaging the symptomatic and contra-l ateral asymptomatic distal extremity for five minutes while an asymptomatic limb is placed in a 12-16° C cold-water bath. The immersion of a non-involved limb activates autonomic thermoregulatory function. If autonomic function is intact, there is vasoconstriction in all four extremities due to the central vasoconstrictor reflex. If the autonomic vasoconstrictor reflex is inhibited or there is autonomic failure, then an axon vasodilatation reflex will occur. This reflex will be visualized by a warming of the symptomatic distal extremity, and on occasion the bilateral asymptomatic distal extremity, during the five-minute cold-water autonomic functional stress test. In normal healthy asymptomatic patients or posttraumatic patients with limb pain without CRPS-1 the ANS vasoconstrictor reflex is intact with the expected cooling of the distal extremities when a non-involved extremity is placed in a cold-water bath. Evaluating the function of the vasoconstrictor reflex through cold water autonomic functional stress testing provides an objective method that increases the sensitivity and specificity of evaluating patients with presumptive CRPS-1.

THERMOGRAPHIC EVALUATION OF NEUROVASCULAR SYSTEM

Ram C. Purohit [1, 2]

[1].Department of Clinical Sciences and Biomedical Sciences, School of Veterinary Medicine, Tuskegee University, Tuskegee, AL
[2].Professor Emeritus, Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Auburn, Alabama, USA

The purpose of this study is to present clinical uses of thermography in the diagnosis of neurovascular conditions in various animal species. Cutaneous circulation is under sympathetic vasomotor control. Thus, the nerve injuries and nerve compression can result in skin surface vascular changes that can be detected thermographically. Inflammation and nerve irritation may result in vasoconstriction, causing cooler thermal patterns in the affected areas. Whereas transaction of a nerve and /or damage to the extent that there is a loss of sympathetic tone, which causes vasodilation can provide warmer thermal patterns in the affected areas. This rational becomes more complicated with different types of nerve injuries, and the duration of injuries. Biphasic changes in peripheral circulation of affected areas occurs, depending on the duration and extent of the injuries.

Painful conditions associated with peripheral neurovascular and neuromuscular injuries are easy to confuse with spinal injuries associated with cervical, thoracic, and lumbosacral areas. Similarly, inflammatory conditions such as osteoarthritis, tendonitis and other associated conditions may be confused with other neurovascular conditions. Thus several studies were done by Purohit et.al, (1-5) which have demonstrated the efficacy of infrared thermography in the differential diagnosis of neuro-va scular conditions.

References

1. Purohit RC, McCoy MD. Thermography in the diagnosis of inflammatory processes in the horse. Am, J. Vet. Res., 1980; 41: 1167-1174.

2. Purohit RC, DeFranco B. Infrared thermography for determination of cervical dermatome patterns in the horse. Biomed. Thermology 1995; 15: 213-215.

3. Purohit RC, Pascoe DD, DeFranco B, Schumacher J. Thermography evaluation of the neurovascular system in equine. Thermology International. 2004; 14: 89-92.

4. Purohit RC. History and research review of thermography in veterinary medicine at Auburn University. Thermology International. 2007; 17(4): 127-132.

5. Purohit RC. Use of Infrared Imaging in Veterinary Medicine. Biomedical Engineering Hand Book, 3rd Edition. Edited by JD Bronzino, Pub. CRC Taylor & Francis 2006: 35 (1-8).

PRACTICAL ISSUES IN THE ESTABLISHMENT OF A CLINICAL THERMOLOGY FACILITY

Philip P. Hoekstra, III, Ph.D.

Abnormalities in the patterns, emission levels and behavior of skin temperatures provides a practical adjunctive technique in the assessment of many peripheral neuropathies. While certain ambient conditions must be controlled, patient preparation is minimal and a variety of modern thermographs provide an ready assessment of many significant peripheral neuropathies. Establishing an imaging laboratory may only require a few modifications to an existing facility and selecting equipment, software and technique commensurate with the specific application. Adequate training of a technician and the thermologist is essential to the successful application of neurologic thermology.

ADVANCEMENTS IN MEDICAL IR HIGH SENSITIVITY APPLICATIONS: FUSION IR IMAGING AND 3D IR-MRI/TC SOFTWARE.

Marcos Leal Brioschi, PhD. MD

Brazilian Society of Thermology., Pain Center, University of Sao Paulo Medical School (FMUSP), Brazil.
Dept of Mechanical Engineering - Federal University of Parana
InfraredMed Clinics - www.infraredmed.org

The measurement of temperature variation at the surface of the body, provided by high sensitivity infrared imaging (IR), is becoming a valuable auxiliary tool for diagnosis and investigation of functional changes of the skin by accurate thermal mapping of static and provoced vasomotor patterns. These neurovascular dysfunctions may be caused by breast and thyroid tumors, reflex sympathetic dystrophy/complex regional pain syndrome, thoracic outlet syndrome, cerebral and peripheral vasomotor disorders, rheumatological disorders, fibromyalgia syndrome, sports injuries, headaches and also during cardiac bypass surgery.

Most of these diseases are characterised by particular or related anatomical changes, but as a 2D technique IR does not provide sufficient anatomical information to differentiate in cases with unclear anatomical background. However, multimodal image registration and fusion with anatomical imaging, as magnetic resonance (MRI) or computer tomography (CT), may overcome this difficulty and provide additional information for diagnosis. Combining anatomical and physiological information into one image dataset may ease the clinical analysis and decision.

In this paper, a new method of registering and merging 2D IR and 3D MRI/CT is presented. Registration of the images acquired from the two modalities is necessary since they are acquired with different imaging systems. Firstly, the body volume of interest is scanned by a MRI/CT system and a set of 2D IR of the same body is acquired at orthogonal angles. Registration of these two different sets of images is achieved by creating 2D MRI/CT projections from the reconstructed 3D MRI/CT volume and alignment with the IR. Once registered, the IR is then projected over the 3D MRI/CT. After the 3D reconstruction, the user can rotate the object in any direction (3 axes - x, y and z - in the clockwise and anticlockwise directions). Slicing of the image, scaling (increase and decrease of the image) and transparency voxels function become possible. The software has been validated using seventeen sets of medical images from different modalities (MRI/CT). The data obtained by merging both imaging techniques, allows the determination of the extent of anatomic and physiological compromise separately, thus leading to a better and more adequate disease approach. The programme developed to assess the proposed method to combine MRI/CT and IR resulted in a new tool for fusing two different image modalities. Such a tool may help medical doctors to understand the anatomical and physiological background of diseases in a single imaging process.

News in Thermology

Thermal imaging andSleep Medicine

Dr. Govindan, executive director of the American Academy of Thermology (AAT), promoted temperature measurements from infrared thermal images as an investigative technique for diagnosing sleep disorders. He presented a poster at the 26th Annual Conference on Sleep Disorders in Infancy and Childhood, held on January 17-19, 2008 at the Annenberg Center for Health Sciences in Rancho Mirage, California. See the abstract of Dr Govindan below (reprinted with permission of Annenberg Center for Health Sciences at Eisenhower)

FOREHEAD NOSE TEMPERATURE RATIO IN EXCESSIVE DAYTIME SLEEPINESS/ NARCOLEPSY.

S.Govindan

Wheeling Hospital, Wheeling, WV

Objective: Altered skin-temperature regulation in narcolepsy relates to sleep propensity. Forehead temperature is a reliable index in calculating ratio's for altered skin- temperature regulation in sleep medicine. Forehead Nose Temperature Ratio (FNTR), representing the internal and external carotid angiosomes under the regional control of trigeminovascular system was imaged using committee for the protection of human subjects approved protocol before and after treatment and correlated with clinical response.

Study Design: The study was done at Wheeling Hospital. Three Caucasian females with EDSS, ages 51-67, all had normal AHI and SaO_2 in PSG, and elevated Epworth Sleepiness Scale, MSLT abnormal in two and HLADQ 6 positive in two.

Committee for the Protection of human subjects approved methodology was used in a temperature and humidity controlled and draft free laboratory to monitor facial temperature using infrared technology. Thermograms were done at baseline and following vasomotor challenge with induced hyperoxia (100% Oxygen inhalation for 5 minutes) before and after the drug Modafinil (Provigil™), Addrell™ (Dextro Amphetamine/Amphetamine) and Ritalin™ (Methy- phenidate).

Results: Normal FNTR, Nose is colder. Normal vasomotor response to hyperoxia is vasoconstriction. Forehead Nose Temperature Ratio was calculated at baseline and following vasomotor or drug challenge. 0.5° C or more change in temperature was significant. Clinical improvement after the drug was correlated with change in vasomotor response and in Forehead Nose Temperature Ratio.

Conclusion: Thermography of Cranial Angiosomes to monitor changes in facial skin temperature regulation in the microcirculation in patients with EDSS using FNTR correlated with clinical response. Hyperoxia stress results correlate with possible role of oxygen radicals in EDSS pathophysiology. This has potential as an out patient office monitoring methodology for circadian stabilization of thermoregulation.

References

1. Fronczek R. Sleep: 29; 11, 1444-1449
2. Govindan S. Thermology international 2005; 15/3: 116.
3. Govindan S. Biomedl Thermol 1999; 19 (1): 38.
4. Govindan S. Thermology international 2003; 13/3: 91-98

Thermography thesis sucessfully defended

The Department of Medical Physiology at the University of Tromsø continuously extents its expertise in thermal imaging. Recently, Ashild Odden Miland defended sucessfully her thesis entitled "Dynamic Infrared Thermography on the assessment of skin perfusion". After examination by distiguished experts from UK and USA , she was awarded with the degree of Doctor Scientiarum.

During the last 8 years the Department of Medical Physiology became a major player in thermal imaging in Europe and is now the most important center for medical thermal imaging in Scandinavia. Head of the department and driving engine of thermographic research is Prof James Mercer. His web-site (www.medical-thermography.com) demonstrates very nicely the thermographic achievements made in recent years. Particularly the research in tissue viability by using thermal imaging for the assessment of the flap perfusion is an inportant contribution to quality assurance in plastic surgery. The information, provided by a thermal imager on the perfusion in manipulated tissues can help to reduce failures in flap surgery and increase in this way the health condition of surgical patients.

References

1. Odden Miland A. Dynamic Infrared Thermography in the assessment of skin perfusion- a clinical and experimental study. Dissertation for the degree of Doctor Scientiarum. University of Tromsø, Faculty of Medicine, Department of Medical Physiology, March 2008
2. De Weerd, L, Mercer, J.B. and Bøe Setså, L. (2006). Dynamic infrared thermography, a novel method for monitoring free DIEP flap perfusion intraoperatively. Annals of Plastic Surgery. 57(3); 279-284.

Establishment of a Scandinavian Society for Medical Thermography

On Professor Mercer´s website the following call for the establishment of a Scandinavian Society of Medical Thermology is available.

This is a message to all Scandinavian based colleagues working in the field of Medical Thermography who think that it would be a good idea to establish a Scandinavian Society dedicated to this field. As far as I am aware none of the Scandinavian countries have their own National Societies in Medical Thermography. While it sounds attractive to establish National Societies I feel that there are simply too few of us working in this field in each of the Scandinavian countries to make National Societies viable and for this simple reason it would be more sensible to establish a Scandinavian Society.

If you are interested in joining and/or assisting in organising such a Society then please let me know.

An obvious starting point is to try and form a list of people using this technology in Scandinavia that could be circulated to all concerned. I am prepared to co-ordinate the groundwork and eventually organize an inaugural meeting in Tromsø, Norway (I am also open to suggestions for other venues).

Please spread the word to any friends or colleagues that you think may also be interested.

Professor James Mercer

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E-mail: james.mercer@fagmed.uit.no

3rd May 2008

NYU Medical Center, 550 First Avenue
New York, NY 10016

CRPS/RSD: Diagnostic/Technical Advances in the Understanding of Autonomic Function

Registration Form ➔

30. und 31.Mai 2008

8. gemeinsamer Kongress der Deutschen Gesellschaft für Thermographie und Regulationsmedizin & der Gesellschaft für Ozon- und Sauerstoff-Anwendungen in Medizin und Technik (GOS)
der Internationalen Ärztegesellschaft für funktionelle Proteomik (CEIA)

im Steigenberger Ho tel: Mannheimer Hof in Mannheim

Anmeldung bei der Geschäftsstelle der DGTR:
Rheinstr. 7
76337 Waldbronn

Tel. 0 72 43 / 6 60 22
Fax 0 72 43 / 6 59 49
email: sauer@hsauer.de

June 7th 2008

Summer work shop on medical infrared imaging (MammoVision breast imaging and ReguVision full body and regional infrared imaging).

Organiser German Society of Thermography and Regulation Medicine, International Medical and Veterinary Thermographers (IMVT)

Venue will be in Moerfelden near the Frankfurt airport.

.

For members of the DGTR the attendance is free, all other participants will have to pay a fee of 90 Euro including lunch and coffee breaks.

The meeting is scheduled for Saturday, June 7th from 9 am to 6pm.

COURSE REGISTRATION FORM

Register online at www.med.nyu.edu/courses/cme/pain

CRPS/RSD: Diagnostic/Technological Advances and Understanding Autonomic Function • Course #381 • Saturday, May 3, 2008 • (Please do not reduce or enlarge this form)

PLEASE PRINT ALL INFORMATION CLEARLY IN BLOCK LETTERS AND NUMBERS

Name ______ FIRST M.I. LAST

Address ______

City ______ State ______ Zip ______

Day Phone ______ Fax ______

COURSE CONFIRMATION: Please supply your e-mail address to receive a confirmation letter. Written confirmation **will not** be mailed. Make sure your email address is clearly written.

E-Mail ______
(REQUIRED FOR CME CREDIT)

Degree ______ Specialty ______

(On-site registrants will incur an additional $20 charge)

COURSE FEES

Full Fee Physicians/Dentists:	☐	**$125**
Reduced Fee:	☐	**$75**

Reduced fee applies to NYU School of Medicine alumni, former residents and fellows, M.D.'s employed by the Department of Veteran's Affairs Medical Center; full-time active military personnel; nurse practitioners and all other non-M.D. healthcare professionals.
Eligibility for reduced fee must be indicated below:

METHODS OF PAYMENT **(cash and telephone registration are not accepted).**
If faxing, do not mail or refax, this will result in a duplicate charge to your account.

☐ **CHECK** IN U.S. DOLLARS ONLY $ ______

☐ **CREDIT CARD PAYMENT** (See below)

☐ **INTERNATIONAL POSTAL MONEY ORDER** (Foreign registrants, including those from Canada, must pay by either International Postal Money order or credit card) $ ______

After May 1, 2008 Only On-site Registration Available

MAKE PAYABLE TO: NYU Post-Graduate Medical School

SEND TO: Registration Department, NYU Post-Graduate Medical School, P.O. Box 1855, Murray Hill Station, New York, NY 10016

PAYMENT BY CREDIT CARD Credit card payments may be faxed to (212) 263-5293

Card # ______

Amount to be charged: $______ Bill to: ☐ Visa ☐ Master Card ☐ American Express

(Please Print)
Member's Name ______ Expiration Date: ___ / ___

Signature ______

REFUND POLICY: An administrative charge of $75 will be assessed for cancellations prior to **APRIL 18, 2008**. Cancellations must be in writing and postmarked no later than the above date (faxes are not accepted). Cancellations will not be accepted after the above date.

COURSE CANCELLATION POLICY: In the unusual circumstance that this course must be cancelled, two weeks notice will be given and tuition will be refunded in full. The NYU Post-Graduate Medical School is not responsible for any airfare, hotel or other costs incurred.

Special Needs or Requests: ______

To help fulfill your educational needs, submit a question or topic relating to this course:

30th June – 2nd July 2008

6th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2008)
University of Pretoria, Pretoria, South Africa

Detailed information is available on the following website: http://www.africaspecials.com/hefat2008/

2nd -5th July 2008

QIRT 2008 - 9th International Conference on Quantitative InfraRed Thermography at the AGH University of Science and Technology, Krakow, Poland

Conference Organiser:Institute of Electronics
Faculty of Electrical, Electronic, Computer and Control Engineering of the Technical University of Lodz, Poland
and
Faculty of Mining Surveying and Environmental Engineering
AGH University of Science and Technology, Krakow, Poland

The Quantitative Infrared Thermography (QIRT) conference is an international forum, which brings together specialists from industry and academia, who share an active interest in the latest developments of science, experimental practices and instrumentation, related to infrared thermography.

Following conferences in Paris (1992), Sorrento (1994), Stuttgart (1996), Lodz (1998), Reims (2000), Dubrovnik (2002), Brussels (2004), and Padova (2006),

the 9th Quantitative Infra Red Thermography conference, QIRT2008, will take place on July 2-5, 2008 at the AGH University of Science and Technology, Krakow, Poland

CONFERENCE FEE

Regular participants
The conference fee is € 300 (before May 15, 2008) and € 400 (after May 15, 2008).

The fee covers Conference Procedings, welcome reception and conference dinner, lunches and coffee break facilities, but not the accomodation.

Students:
The conference fee is € 150 (before May 15, 2008) and € 200 (after May 15, 2008). Without Conference Procedings, welcome reception and conference dinner, but including lunches and coffee break facilities.

Accompanying persons: The conference fee is €100. The price includes welcome reception and conference dinner.

Pre-conference course

On Wednesday, July 2, 2008, preceding the conference, the following courses will be organised:

A) Basic Thermography (4 hours)

by Prof. X. Maldague, Université Laval, Canada
by Prof. V. Vavilov, Tomsk Polytechnic University, Russia

Introduction

Mechanisms of heat transfer
conduction, convection, radiation

Basics of Infra Red
- Radiation laws (emissivity, absorptivity, reflectivity)
- Radiometry and temperature measurement
- Noise considerations

Solving thermal problems by mathematical modelling
- Transient 1D analytical modelling
- Numerical modelling for 1D, 2D, 3D geometry in solid materials

On thermal stimulation in the active approach
- Pulse thermography
- Step heating (long pulse)
- Lockin thermography
- Vibrothermography

Experimental techniques
- IR Detectors
- Experimental setup

Deployment, data processing and applications
- Data processing
- Applications

(B) Applications of Thermography to Thermo-Fluid-Dynamics (3 hours)

by Prof. G. M. Carlomagno, Universita di Napoli Federico II, Italy

Basics of infrared thermography

The fundamental laws

Performance of an infrared scanning radiometer

Restoration of the thermal image

Heat flux sensors for convective heat transfer measurements

Operating modes

Detailed applications of the:
- heated-thin-foil steady state technique
- thin-film sensor unsteady technique

Other application examples, in brief

Conclusions

(C)Application of thermography to buildings (3hours)

by Prof. E. Grinzato, CNR-ITC, Padova, Italy

Introduction

From the energy to the surface temperature

Thermal model of buildings in steady and transient regime

IR Thermography indoor and outdoor

Boundary conditions monitoring

Evaluation of thermal properties of building materials:
- Thermal diffusivity

Thermal effusivity
Thermal conductivity
Heat Capacity

The energy saving problem

NDE of structure strengthening

Moisture detection on buildings

Envelope and Heating Ventilating Air-Conditioning (HVAC) plant per for mances

Case study: floor and ceiling radiant heating systems

Heritage Buildings:
Decay of the structure and finishing
Hidden structures location and identification (NDT)
Painted sur faces Non Destructive Evaluation (NDE)

Conclusions

(D) Medical Thermography (1 day)

by Prof. E. F. J. Ring, Dr P. Plassmann, Prof. K. Ammer, Dr R. Thomas; Medical Imaging Research Group, Faculty of Ad vanced Tech nol ogy, Uni ver sity of Glamorgan, UK

Historical Introduction *F. Ring*

IR Detectors and cameras, *R. Thomas*

Quality Assurance in Thermography, *P. Plassmann*

Principles of thermal physiology, *K. Ammer*

Film, Hot and cold "Living Body", *F. Ring*

Standard protocols for thermography, *F. Ring*

Causesof human temp. increase & decrease, *K. Ammer*

Provocation tests, *F. Ring*

Image processing principles, *P. Plassmann*

Educational resources, *K. Ammer*

(E) Application of dynamic thermography to Non destructive Testing (3 hours)

by Prof. G. Busse, University Stuttgart, Germany

Introduction: Constant temperature fields
Thermography with no heating
Thermography with constant external heating
Thermography with constant internal heating:
Vibrothermography
Activation of internal heat sources by selective spectral heating
Resistive heating

Dynamic thermography: response of solids and sub-surface defects
Oscillating temperature fields (Thermal waves, Lockin-Thermography)
Transient thermography (Step function response)
Burst thermography (Principle and applications)
Pulse thermography (Principle and applications)

Methods of Lockin-Thermography and their application
Thermal waves and photothermal detection
Lockin-thermography = phase sensitive thermography= multiplex photothermal imaging
3.1 Lockin thermography with op ti cal ex ci ta tion (OLT)
Coatings (paint, veneered wood, ceramics on metal.)
Laminates
Electronics

3.2 Lockin thermography with sound or ultrasound excitation (ULT)
(Heating with loss angle or friction : defect-selective NDE)
Cracks
Delamination
Impact
Corrosion

3.3 Induction Lock-in thermography (ILT)
Crack tips in metal
Impact damage in CFRP
Disbond in C-SiC-Ceramics

Conclusion
Advantages/Disadvantages as compared to other NDE-methods
Emerging developments

The Courses are sched uled on Wednes day, July 2, 2008.

Con cern ing the QIRT, please con sult the QIRT website.

QIRT Journal page: http://qirt.revuesonline.com.

QIRT 2006 page: http://qirt2006.pd.cnr.it.

CON TACT: Please address inqui ries to qirt@p.lodz.pl.

Secretary of QIRT2008
Technical Univesity of Lodz (TUL),
Institute of Electronics, Wolczanska 211/215,
PL 90-924 Lodz, Poland

Phone (+48) 42 631 2656, 2657, 2637
Fax (+48) 42 636 2238.

For the scientific programme see the following pages (74-77)

July 3, Thursday

8:00-9:00	**Registration**		
9:00-9:30	**Opening**		
9:30-10:15	**Invited paper I**		
10:15-10:45	**Coffee break**		
	Room A	**Room B**	**Room C**
	NDE I, prof G. Busse	Civil engineering, prof. S. Svaic	Thermophysics I, prof. A. Salazar
10:45-11:10	A. Mendioroz, A. Salazar, F. Alonso, I. Sáez-Ocáriz Crack characterization in metallic plates using vibrothermography	A. Colantonio, M. Theauvette Specifying Infrared Services for Building Applications	P.Bison, E. Grinzato, Measurement of building materials thermal properties in transient regime by IR thermography
11:10-11:35	B. Oswald-Tranta Time-dependent evaluation of inductive pulse heatingmeasurements	S. Švai, I. Boras, M. Andrassy, M. Suša Characterization of subsurface defects in building envelope and flat roof structure by means of thermography supported by numerical simulation	D. Legaie, H. Pron, C. Bissieux, V. Blain Thermographic application of black coatings on metals
11:35-12:00	M. Susa, X. Maldague, S. Svaic, I. Boras The influence of surface coatings on the differences between numerical and experimental results for samples subjected to pulse thermography examination	M. Larbi Youcef, L. Ibos, A. Mazioud, Y. Candau, P. Brémond, M. Piro, A. Filloux A non destructive method for diagnostic of insulated building walls using infrared thermography in real situation	B.G. Vainer Quantitative characterization of vapour adsorption on solid surfaces and estimation of emissivity of solids using infrared thermography
12:00-12:25	C. Spiessberger, A. Gleiter, G. Busse Data Fusion of Lockin-Thermography Phase Images	M. Marchetti, S. Ludwig, J. Dumoulin, L. Ibos, A. Mazioud Active Infrared Thermography for Non-Destructive Control for Detection of Defects in Asphalt Pavements	J.Banaszczyk, G. De Mey Infrared thermography of electroconductive woven textiles
12:25-14:00	**Lunch**		
	NDE II, prof. V. Vavilov	Microscale applications I, prof. X. Maldaque	Thermophysics II, prof. E. Grinzato
14:00-14:25	A. Gleiter, C. Spießberger, G. Busse Phase Angle Thermography for depth resolved defect characterization	J. Morikawa, E. Hayakawa, T. Hashimoto, C. Pradere, J.Toutain, J.C. Batsale Micro-scale thermograhy of freezing biological cells in view of cryo-preservation	A. Muscio Measurement of thermal diffusivity by a modification of the Angstroem's method using thermally short specimens
14:25-14:50	A. Gleiter, C. Spießberger, G. Busse Thermography Data Fusion for Failure Analysis	O. Fudym, F. Sepulveda, J.C. Batsale, C. Pradère Averaged field analysis for infrared images processing. Application to microscale thermal characterization	P. Bison, F. Cernuschi Experimental evaluation of absorption coefficient of insulated vehicle sandwich panel
14:50:15:15	G. Mayr, B. Dietermayr, G. Hendorfer, Characterization of defects in curved CFRP samples using pulsed thermography and 3D Finite Element Simulation	P. Ginet, J.-L. Battaglia, C. Pradere, C. Lucat Quantitative infrared on screen-printed metallic electrothermal micro-actuators, comparison with a model	R. Celorrio, M. Costa, S.M. Shibli, E. Apiñaniz, A. Mendioroz, A. Salazar Characterization of subsurface overlapping cylindrical inclusions by infrared thermography
15:15-15:40	C. Zöcke, A. Langmeier, R. Stößel, W. Arnold A new technique to reconstruct the defect shape from Lockin thermography phase images	J. Morikawa, E. Hayakawa, T.Eto, T. Hashimoto Two-dimensional thermal analysis of organic materials by micro-scale thermography	A. Salazar, R. Celorrio, A. Mendioroz, E. Apiñaniz, A. Oleaga Reconstruction of the hardening depth profile of steel rods
15:40-17:00	**Posters session, coffee**		
18:00-22:00	**Social event, bus departure**		

July 4th, Friday

8:00-9:00	**Registration**		
8:45-9:30	**Invited paper II – P. Bison, Measuring thermophysical properties by IR thermography**		
	Room A	**Room B**	**Room C**
	Solid mechanics, prof. D. Balageas	Fluid dynamics I, prof. G. Carlomagno	Applications I, prof. A. Nowakowski
9:30-9:55	E.A. Pieczyska, W.K. Nowacki, H. Tobushi, S. Hayashi Thermomechanical properties of shape memory polymer subjected to tension and simple shear process	C. O. Asma, J. Thoemel, S. Paris, O. Chazot Utilization of Infrared Thermography to Investigate Atmospheric Entry Aerothermodynamics of Space Vehicles at von Karman Institute	A. Bzymek, A. Czupry ski, M. Fidali, W. Jamrozik, A. Timofiejczuk Analysis of images recorded during welding processes
9:55-10:20	M.Y. Choi, S.S. Lee, K.S. Kim, J.H. Park, W.T. Kim, K.S. Kang Predicting the Dynamic Stress Concentration Factor Using the Stress Measuring Method Based on the Infrared Thermography	J.-C. Batsale, J-P. Lasserre, M. Varenne-Pellegrini, V. Desormiere, L. Authesserre, A. Descuns, G. Lamothe, Transient Heat Transfer in Rotating Cylinder – Thermography Measurement to Analyse Intense Heat Flux Distribution	A. Mazioud, L. Ibos, A. Khlaifi, J.F. Durastanti Study of the heat generated by a rolling bearing degradation by IR thermography
10:20-10:45	H.-A. Crostack , R. Zielke, X. Feng , G. Fischer Thermographic study of nucleation and propagation of Portevin-Le Châtelier bands	J.-M. Buchlin, R. Herrero, I. Horvath, Ph. Planquart Thermal study of Flapping Jet by Infrared Thermography	J. Thevenet, M. Siroux, B. Desmet Brake disc surface temperature measurement using a fiber optic two-color pyrometer
10:45-11:15	**Coffee break**		
	Works of art, prof. E. Grinzato	Fluid dynamics II, prof. J.-C. Batsale	Image processing, prof. X. Maldaque
11:15-11:40	A.Tavukcuoglu, P. Cicek, L. Tosun, E. Grinzato Thermal Analysis of an historical bath (hammam) by quantitative IR thermography	C. T'Joen, A. Willockx, M. De Paepe Infrared visualisation of flow within inclined louvered fins	N.M. Nandhitha, N. Manoharan, B. Sheela Rani, B. Venkataraman, M.Vasudevan, P.Kalyana Sundaram, Baldev Raj Wavelet based feature extraction algorithm for porosity and Lack of Penetration detection for On-line Monitoring in Gas Tungsten Arc Welding by IR Thermography in AISI 316 Stainless Steel
11:40-12:05	C. Ibarra-Castanedo, S. Sfarra, D. Ambrosini, D. Paoletti, A. Bendada, X. Maldague Subsurface defect characterization in artworks by quantitative PPT	P. Reulet, D. Donjat, E. Divouron, E. Radenac, P. Millan Infrared thermography analysis of the transient aerothermal evolution in a turbofan core compartment model	G. Cardone, S. Discetti Reconstruction of 3D Surface Temperature from IR images
12:05-12:30	J.-C. Candoré, J.-L. Bodnar, F. Depasse, N. Horny, V. Detalle, P. Grossel Approach of the characterization of delamination in mural paintings	A. Willockx, C. T'Joen, H.-J. Steeman, H. Canière, M. De Paepe IR Temperature Measurements to Determine Fin Effectiveness of Longitudinal Fins	M. Klein, A. Bendada, M. Pilla, C. Ibarra-Castanedo, X. Maldague Enhancing Infrared Images Contrast for Pulsed Thermography
12:30-14:00	**Lunch**		
	Modelling, prof. G. de Mey	Biomedical applications I, prof. K. Ammer	Thermographic system and components, prof. W. Minkina
14:00-14:25	D. Dovi, S. Svai, A. GaloviH. Estimating heat losses in solar collectors by IR thermography and numerical simulations	Trabelsi, M. Gantri, E. Sedik i A Near Infrared Radiation Model in a Biological Tissue	G. Machin, R. Simpson, M. Broussely Calibration and validation of thermal imagers
14:25-14:50	M. Bajorek, M. Kaczmarek Numerical heat transfer model in skin burn depth simulations	J-H. Tan, E.Y.K. Ng, R Acharya Localization of eye and cornea on IR thermogram using genetic snake for early detection of eye disease	M. Vilain, J.L. Tissot, O. Legras, C. Minassian, B. Fièque, J.M Chiappa Uncooled amorphous silicon IRFPA with 25 m pixel-pitch for large volume applications
14:50-15:15	I. Szczygie[3], A. Fic, T. Kruczek, A. Sachajdak Verification of temperature distribution in the system for pad welding b y means of infrared thermograph y	E.F.J. Ring, A. Jung, J. Zuber, P. Rutkowski, B. Kalicki, U. Bajwa Detecting fever in polish children by infrared thermography	D. Rzeszotarski, B. Wiecek Calibration for 3D Reconstruction of Thermal Images
15:15-16:30 17:00-22:00	**Exhibitors panel, coffee, P. Prgowski** **Social event, bus de parture**		

July 5,Saturday

8:30-9:15	**Invited paper III – A. Nowakowski, Advances of QIRT in medical diagnostics**		
	Room A	**Room B**	**Room C**
	Biomedical applications II, prof. A. Jung	Applications II, prof. G. Machin	Energetics, prof. J-M. Buchlin
9:30-9:55	K. Ammer The sensitivity of infrared imaging for diagnosing Raynaud´s phenomenon and for Thoracic Outlet Syndrome is depended on the method of temperature extraction from thermal images	V. Vavilov, W. Swiderski Inspecting localized moisture in building materials by applying surface and microwave heating	P. Pregowski, G. Goleniewski, W. Komosa, W. Korytkowski, S.Zwolenik Dynamic , Multispectral-band IR Thermography Applications in the Petrochemical Furnaces
9:55-10:20	B.G. Vainer, A.S. Moskalev Heterogeneous thermograms: the methods of attack	S. Dudzik Calculation of the heat power consumption in the heat exchanger using artificial neural network	M. Strojnik, G. Paez Temperature evolution during first millisecond after ignition in a gas stove
10:20-10:45	E. F.J. Ring, R. Vardasca, U. Bajwa Monitoring Cooling Agents Applied to the Skin of Normal Subjects by Quantitative Thermal Imaging	M. Broussely, G. Machin, R. Simpson, A. Cozzani, C. Gomez Hernandez Application of IR thermography for quantitative temperature measurements in a Thermal-Vacuum Space Simulator	R. Thomas Quantitative factors to consider during IR inspections of Power Transformers
10:45-11:10	Ruminski - The DICOM standard for medical thermal imaging	T. Kruczek Particular applications of infrared thermography temperature measurements for diagnostics of overhead heat pipelines	I. Benko Improvement of IR-emissivity of ceramic fibre by silicon carbide coating in furnaces
11:10-11:30	**Coffee break**		
	Fluid dunamics III, J-M.Buchlin	Applications III, prof. R. Thomas	Microscale applications II, prof. G. de Mey
11:30-11:55	T. Astarita, R. Giordano, G.M. Carlomagno Convective heat transfer around a wall mounted cylinder	P. Corvaglia, A. Largo IRT survey for the quality control of FRP reinforced r.c. structures	C. Hany, C. Pradere, J. Toutain, J.C. Batsale, M. Joanicot A millifluidic calorimeter without contact for reaction enthalpy and kinetics measurements
11:55-12:20	T. Swiatczak, R. Olbrycht, B. Wiecek Evaluation of convection cooling conditions using Fourier and wavelet analysis in lock-in thermography	N. Hots Theoretical aspects of the integration of thermography and pyrometry methods	L. Bodelot , L. Sabatier, E. Charkaluk, P. Dufrenoy Optical and infrared coupled full-field measurements at a micrometric scale
12:20-12:45	R. Ricci, S. Montelpare, G. Artipoli Thermografic Analysis of Mechanical Disturbances Effects on Laminar Separation Bubble	V. Chatziathanasiou, G. T. Andreou, D. P. Labridis Thermal Analysis of an Installation Fault Concerning a Ripple Control Transformer	
12:45-13:00	**Closing address**		
13:00-15:00	**Lunch**		

POSTERS SESSION

Applications

1.M. Fidali, An idea of continuous thermographic monitoring of machinery

2.W. Wittchen,M. Niesler, M. Borecki, B. Zdonek, Application of thermovision method in analysing metallurgical processes

3.P. Baranowski, W. Mazurek, Chosen aspects of thermographic studies on detection of physiological disorders and mechanical defects in apples

4.P. Bison, A. Dragano, S. Rossi, Experimental evaluation of absorption coefficient of insulated vehicle sandwich panel

5.M. Bednarek, J. Rybiski, T. wietlik, P. Winiewski, Application of microscope thermography in the production technology of semiconductor lasers

Solid mechanics

6.E.S. Lukin, A.M. Ivanov, Influence of material plasticity change on the evolved heat quantity of constructional steel subjected ECAP

Thermophysics

7.M. Dbrowski, R. Dulski, P. Trzaskawka, P. Zaborowski, Measurements of polymerization temperature of light-hardened dental materials by a thermal camera

8.G. Gralewicz, J. Wony, B. Wicek, G. Owczarek, Detecting flaws in composite materials – thermal model and simulation results

9.C. Boué, D. Fourier, Infrared thermography measurement of the thermal parameters (effusivity, diffusivity and conductivity) of materials

IR signature and recognition

10.H. Madura, M. Dbrowski, T. Sosnowski, P. Trzaskawka, Method of automatic recognition of helicopters flying at low altitudes

11.T. Sosnowski, H. Polakowski, R. Dulski, Modelling of IR images of sky and clouds

12.M. Zieli ski, The measurements and simulations of the ship thermal signature

13.M. Kastek, T. Pitkowski, H. Polakowski, T. Sosnowski, Methane detection in far infrared using multispectral IR camera

14.S. Milewski, Detection of small targets in maritime conditions

15.G. Bieszczad, T. Sosnowski, Real-time mean-shift based tracker for thermal vision systems

Energetics16.

E. Popa, I. Pisa, S. Ignat, C. Ciobanu, M. Georgescu, process technology concerning the integrated solid industrial waste management for the paper industry optimized by infrared approach

17.T. Prisecaru, C. Dica, M. Teodorescu, M. Prisecaru, L. Mihaescu, Experimental validation of an hho gas cutting flame cfd model

18.V.V. Ghiea (Ghia), Research and testing methods for establishing of the fuel oil combustion flame emissivity

19.C. Allouis, F. Beretta, Fast Infrared Imaging to study burner fluctuations

Fluid dynamics

20.T. Bury, T. Kruczek, Application of infrared thermography for validation of numerical analyses results of a finned cross-flow heat exchanger with non uniform flow of the agents Biomedical applications

21 . M. Wicek, R. Strkowski, T. Jakubowska, B. Wicek, Software for classification of thermal imaging for medical applications

22. A. Sarah Nica, G. Mologhianu, A. Murgu, F. Ojoga, B. Sirghii, S. Ilie, A. Meila, Thermography Study of the Patient with Diabetic Foot Treated in a Rehabilitation Department

23 . A. Zalewska, G. Gralewicz, G. Owczarek, B. Wicek, Psoriatic lesion regression – thermographic evaluation

24. K. Godziuk, T. Wolski, P. Baranowski, W. Mazurek, O. Kalisz, A. Rojowski, Application of thermography in curing oversweating

25. O. Kalisz, M. Gerkowicz, T. Wolski, K. Godziuk, P. Baranowski, W. Mazurek, Thermographic evaluation of healing process on patients after surgery of cataract with the use of facoemulsyphication

26. M. Moderhak, A. Nowakowski, Problems of 3D breast imaging

27.A. Trafarski, L. Róanski, A. Straburzynska - Lupa, P. Korman, W. Romanowski, The Quality of Diagnosis by IR Thermography as a Function of Thermal Stimulation in Chosen Medical Applications

28.M. Kaczmarek, Thermal imaging and modelling of burned skin

29.R. Vardasca, E.F.J. Ring, P. Plassmann, C.D. Jones, A case study on thermal image monitoring of hand stress during keyboard typing

30.D. Mikulska, R. Maleszka, Thermal imaging compared to dermoscopy in evaluation of skin melanocytic lesions

Civil engineering

31.J-L. Bodnar, A. Szeflinski, J-C. Candoré, L. Ibos, M. Larbi Youcef, A. Mazioud, Y. Candau, Detection of insulation defaults in building structures by active infrared thermography

32.J. Jaworski, The infrared thermography of buildings proceeding its surrounding and their thermal performance

33.A. Wróbel, T.Kisilewicz, Thermographic detection of thermal bridges - aims, possibilities and conditions

Works of art

34.J.C. Candoré, J.L. Bodnar, V. Detalle, P. Grossel, Non destructive testing of works of art by stimulated infrared thermography

35.J. Rogó, A. Cupa, B. Wicek, The analysis of mural painting „The Crucifiction" in St. John the Baptist and St. John the Evangelist basilica in Toru

36.M. Poksiska, A. Cupa, S. Socha-Bystro, Thermography in the investigation of gilding on historical wall paintings

37.M. Poksiska, B. Wicek, A. Wyrwa Thermovision investigation of frescos in Cistercian monastery in Ld - Poland

Calibration and metrology

38.T. Piatkowski, H. Polakowski, N. Hots, Examination of metallic surfaces for IR gray body sources

39.S. Dudzik, W. Minkina, Application of the numerical method for the propagation of distributions to the calculation of coverage intervals in the thermovision measurements

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40.M. Felczak, B. Wicek, Application of genetic algorithms for electronic devices placement

41.M. Michalak, M. Felczak, B. Wicek, A new method of evaluation of thermal parameters of textile material

NDE

42.L. Junyan, W. Yang, D. Jingmin, L. Hui, W. Zijun, Research on the IR Lock-in Thermography Based on the Image Sequence Processing for NDT

43.R. Plum, T. Ummenhofer, Ultrasound excited thermography of load bearing members used in constructional steelwork

44.E. Saarimäki, P. Ylinen, An investigation of non-destructive thermographic inspection exploiting phase transition of water for moisture detection in aircraft structures

45.M. Souza, Defect detection in fiberglass reinforced epoxy composite pipes reproducing field inspection conditions

46.W. Swiderski, D. Szabra, M. Szudrowicz, Nondestructive Testing of Composite Armours by IR Thermography Method

47.W. Yang, L. Hui, L. Junyan, Experimental study of ultrasound excited lock-in thermography

Thermographic systems and components

48.M. Fidali, M. Mikulski, A chip black body model

11th- 13th September 2008

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Speakers: Prof Francis Ring, UK
Prof Kurt Ammer, Austria
Dr. Peter Plassmann, UK

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15th November 2008

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Topic: Recent advances in thermology

Deadline for Abstracts: 10thOctober 2008

Electronic submission is preferred and strongly suggested (Email: KAmmer 1950@aol.com)

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