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Pentoxyphylin for treating pain-a thermographic study

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# THERMOLOGY INTERNATIONAL

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# Infrared thermography for pain influenced by a Xanthine derivative: An attempt to assess chronic pain objectively

P. Henk E. van der Veen

Chronic Pain Science Foundation, Heerhugowaard, The Netherlands

**SUMMARY**

**BACKGROUND:** There have been no diagnostic options for objective pain diagnostics until recently. Infrared thermography seemed to be a promising technique that could be applied, especially when following the progress of a case. The goal of the study was to check if infrared thermography could be of use to objectify pain sites and pain sensation.

**METHODS:** During this study, 63 temperature measurements were done in patients suffering chronic pain in one extremity. They were followed during the pre- and post-treatment of Pentoxyfilline (PTX). The contralateral side of each patient was used as the control. The temperature of the pain site and the symmetrical contralateral extremity were measured prior to and after treatment. Only the change in pain sensation was registered, using gradations of: reduced, equivalent, or worse.

**RESULTS:** There were 53 cold spots and 10 hot spots out of the 63 pain sites measured. There was a significant left-right difference ($p = 0.001$). After treatment with PTX there was no longer any significant left-right difference ($p = 0.061$), whereas the temperature on the pain side increased significantly ($p < 0.001$). There was a significant correlation between the change in temperature as measured by the thermographic image and the pain sensation ($p < 0.001$, Spearman's rank correlation coefficient: 0.5567).

**CONCLUSIONS:** Infrared thermography and PTX are probably possible instruments applicable for assessing chronic pain lacking any anatomical substrate. The majority of the pain sites that cannot be seen by the naked eye (>70%) are colder than their surroundings, which confirms studies performed previously The impact of PTX on this study suggests that prostaglandin and cytokine have an effect on the development of these pain sites.

**KEYWORDS:** Chronic pain, infrared thermography, pain sensation, cold spot, pain diagnostics.

**INFRAROTTHERMOGRAPHIE BEI DURCH EIN XANTHINDERVAT VERÄNDERTEN SCHMERZEN: VERSUCH EINER OBJEKTIVEN SCHMERZBEURTEILUNG**

**HINTERGRUND:** Bis vor kurzem gab es keine diagnostischen Optionen für eine objektive Schmerz-Diagnose Infrarot-Thermografie scheint eine vielversprechende Technik sein, die vor allem für die Verlaufsbeobachtung eines Erkrankungsfalls angewendet werden kann. Ziel der Studie war es zu überprüfen, ob die Infrarot-Thermografie schmerzhafte Regionen und Schmerzempfindung objektivieren kann.

**METHODE:** In dieser Studie wurden 63 Temperaturmessungen bei Patienten mit chronischen Schmerzen in einer Extremität durchgeführt. Die Patienten wurden vor und nach Behandlung mit Pentoxyfilline (PTX) untersucht. Die kontralaterale Seite jedes Patienten wurde als Kontrolle verwendet. Vor und nach der Behandlung wurde die Temperaturen an der Schmerzstelle und an der, der Schmerzstelle entsprechenden, Region an der kontralateralen Extremität gemessen. Die Änderung der Schmerzempfindung wurde mit den Abstufungen von vermindert, unverändert oder schlechter registriert.

**ERGEBNISSE:** An insgesamt 63 Schmerzstellen fanden sich 53 kalte Flecken und 10 heiße Flecken. Es zeigte sich ein signifikanter Temperaturunterschied zwischen Links und Rechts ($p = 0,001$). Nach der Behandlung mit PTX gab es keinen signifikanten Seitenunterschied mehr ($p = 0,061$), da die Temperatur an der schmerzhaften Schmerzen sich signifikant erhöht hatte ($p < 0,001$). Zwischen der Änderung der thermographisch gemessenen Temperatur und der Schmerzempfindung fand sich eine signifikante Korrelation ($p < 0,001$, Spearman's rank correlation coefficient: 0.5567).

**SCHLUSSFOLGERUNG:** Infrarot-Thermografie und PTX erscheinen als mögliche Instrumente, die für die Beurteilung von chronischen Schmerzen mit fehlendem anatomische Substrat eingesetzt werden können. In Übereinstimmung mit früheren Untersuchungen ist die Mehrheit der Schmerzstellen(> 70 %), die mit dem bloßen Auge nicht identifiziert werden können, kälter als ihre Umgebung. Die Auswirkungen von PTX in dieser Studie legen nahe, dass Prostaglandine und Cytokine auf die Entwicklung von schmerzhaften Stellen Einfluss haben.

**SCHLÜSSELWÖRTER:** Chronischer Schmerz, Infrarot-Thermographie, Schmerzempfindung, kalter Fleck, Schmerzdiagnostik

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## Introduction

This article is based on research on chronic pain carried out from 1988 to 1989. The results have not been published previously. The topic and the results are still current and relevant. The original data have been recalculated using modern techniques in 2013 with more impressive results as in 1989.

Chronic pain is defined as "*Unpleasant sensor and emotional experience brought into relation with actual or potential tissue damaging or described in terms of such damage and lasting longer than six months*" (1). It has been a major problem for decades. There are psychological, micro-economical, macro- economical, and sociological implications.

Chronic pain influences the life and surroundings of a patient such that life is focused mainly on the pain. Pleasant, happy people become depressive, they do not see the positive things in life and go through a change of character (2,3,4).

There were no objective diagnostic methodologies in 1988, not even for explicitly evident conditions, which were then known as Sudeck's atrophy, algodystrophy, or reflex dystrophy. These are now categorized under the diagnoses CRPS type I and CRPS type II.

It was only in 1993 that the IASP developed criteria for objective diagnostics (5). These criteria proved to be extremely sensitive, but for the purpose of research, they were not sufficiently specific. The IASP criteria were more suitable to curative purposes and the Bruehl criteria to research. Those criteria do not have a predictive value; therefore, still to this day, there is no consensus regarding the early stage of CRPS. A different way must be found for objective diagnostics for pain.

The experience of pain is subjective, but it is common that chronic pain patients can indicate the pain site on their skin. In 1954, a publication appeared in which 43 pain sites were examined with contact thermometry. The majority of the sites [30] were cold in comparison to their reference areas. (6). Perhaps there is something going on there that we cannot see. Would expanding our field of vision by using the infrared spectrum be sufficient to reveal what was previously invisible? (7,8,9) Does this make infrared measuring devices applicable for assessing chronic pain sites?

In 1988 the original research question was: Can the situation of chronic pain be an early stage of reflex dystrophy and can this situation be objectified by infrared thermography? (9). That question cannot be investigated without knowing if infrared thermography in itself can tell anything about pain sites.

Thirty years of thermography research has not answered that question incontrovertibly. In 1988, the generally adapted view among thermography researchers was that a static picture had little added value for diagnostics while it was known "that thermography is a very suitable method to reveal the effect of the treatment." The research question of the study changed to: Can "invisible subjective" pain sites be objectified by means of dynamic non-contactual infrared research? (10)

## Methods and Materials

The research method was a confirmatory explanatory experimental investigation in which the pain site that the patient indicated was scanned. An equivalently sized area on the symmetrically contralateral side of the patient's body was used as a control area. After stimulation with PTX, both the pain area and control area were then scanned again.

Measurements were done in two different ways:

A.Skin temperature measurement using infrared equipment before and after administering a pharmaceutical

B.Registration of the pain change by a three-dimensional scale: improved, equivalent, or worse

The hypothesis was that the cold pain sites found would become less painful through improvement of blood perfusion and the warm sites more painful (11). The warm sites would become less painful by deterioration of blood perfusion. More than 70% of the pain sites was expected to be cold.

Treatment was applied with a rheological pharmaceutical called pentoxyphylline (PTX), which is registered for perfusion problems (Intermittent claudication). It was already known in 1988 that the Xanthine derivatives, of which PTX is an example, have a prostaglandin agonistic and antagonistic activity (10). Prostaglandins have been shown to modulate pain (12,13). There was no known research performed on thermography and the administration of PTX.

There was literature about the relation between guanethidine and prostaglandin in "Field stimulation of desheathed preparations of guinea-pig vas deferens": prostaglandin E2 reduced the muscle twitching but potentiated the contractual effects of noradrenalin (14). In addition, the PGE2 effect was found on smooth muscle tissue and an indirect effect via sympathetic nerve fibers (15). Arterial stimulation of a rabbit ear exposed to noradrenalin or agonist led to vasoconstriction, which was neutralized by PGE1 and PGE2 (16).

In 2012, we know that, along with its prostaglandin, agonistic and antagonistic effects, PTX also has a non specific inhibiting effect on phosphodiesterase and on TNFα, IL 6, IL1A, and IL1B (17,18).

In 2012, the manufacturer reports: "Both veterinary and human studies have demonstrated that Pentoxyfilline can increase the capacity of transforming of the erythrocytes - this capacity has changed by the disease - as a result of which the viscosity of the blood decreases. This is particularly due to the increase of the intracellular ATP concentration in the erythrocyte. Pentoxyphylline reduces the abnormally increases plasma level of fibrinogen, inhibits the aggregation of the erythrocytes and reduces the thrombocyte aggregation by stimulating the synthesis of prostacyclin which favorably influences the rheological properties of the blood.

The research group consisted of men and women. They were eligible to participate in the research on condition that they met the following inclusion criteria:

- Had pain that could not be explained by a clinical diagnosis.
- Had not taken vasodilators or pain medication before the study or would not take these during study.
- "Should not undergo pain-reducing techniques during the study

- Should not smoke during the study
- Had no clinically manifest diseases before or during the study.

The study included 58 patients (39 women and 19 men) who had pain. Some had pain for years, others for just a few of weeks. An evident organic substrate to explain the pain was found in none of them. None of these patients had a segmental separation of the pain. Two areas were measured in six patients, hence, there were 64 measurements taken. One measurement was electronically damaged such that it was no longer eligible for further processing. This resulted in a total of 63 pain sites and 63 control sites. The experiment took almost one year. The age and gender distribution of participating patients is shown in figure 1.

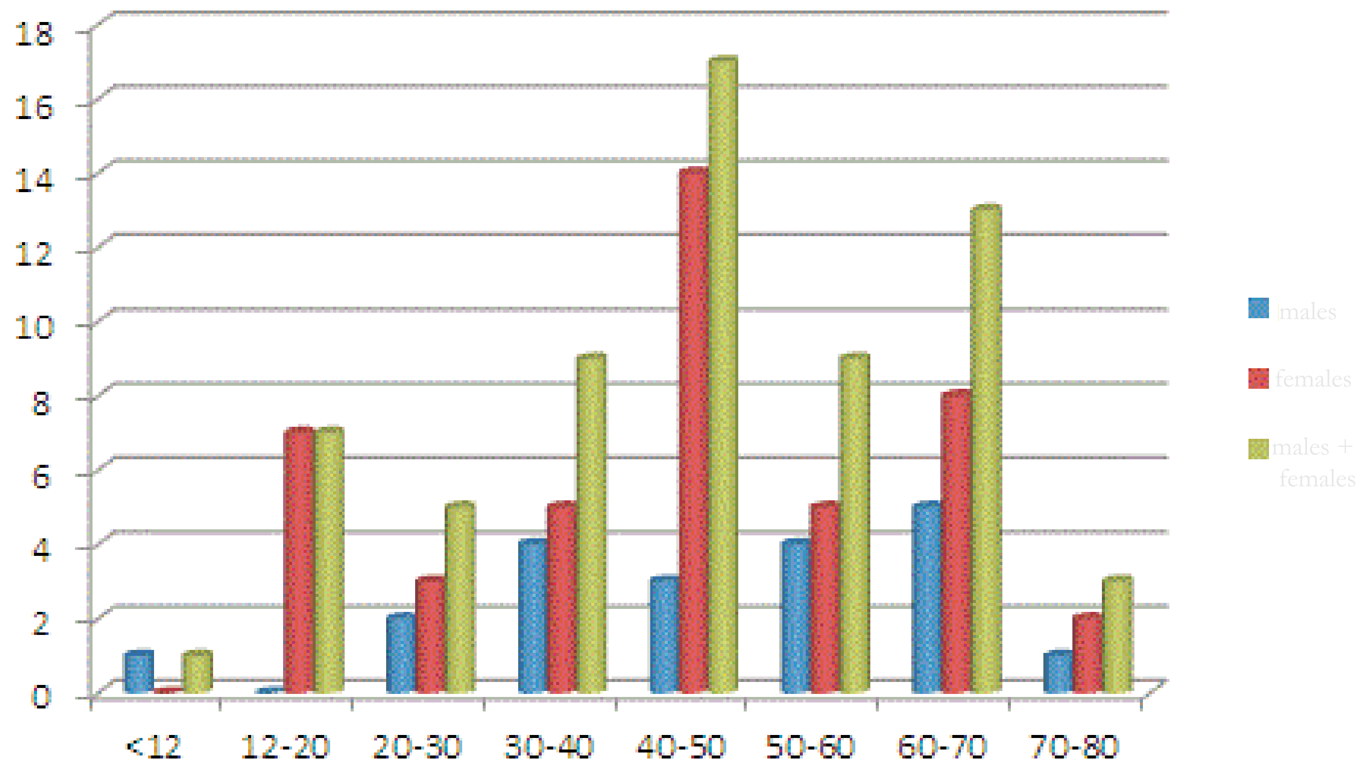
The patients were thoroughly instructed orally about the purpose of the study, the known effectiveness and the side effects of the drug used (pentoxyphylline: PTX). The fact that there is an experimental component to this study was emphasized. Written Informed Consent were not implemented at the time, and according to the Declaration of Helsinki (Second revision, 1983), also not necessary at the time. In 1988, Medical Ethics Review Committees did not exist yet either.

The following design was chosen. The pain sites that were measured were from different locations: hands, lower arms, shoulders, buttock area, upper legs, knees and ankles/feet. More sites were measured on some of the patients. First, the pain site and, as reference, the corresponding symmetrical contralateral side of the body were measured. Then a PTX dosage of 400 mg twice a day was prescribed to the patient for a period of two weeks. After two weeks, the pain experienced was re- gistered: reduced, equal, or worse. A check measurement identical to the first one was done. In order to avoid having the registration of pain experience from being influenced by the check measurement, the pain sensation was noted first.

Considering the choice of the pharmaceutical, an increase of pain was expected at "hot spots". Prostaglandins do indeed play a role in warm pain. These prostaglandins have both vasodilatation and pain-inducing properties. We know PTX is a prostaglandin agonist/antagonist since 1977 (10). The possibility of pain worsening was discussed with the patients beforehand. By doing so, the effect of expectation by acceptance of that risk might influence the end result.

Infrared thermography was used to register the temperature. Infrared thermography is based on the principle of registration of heat radiation emitted by the skin at a wavelength of 0.8 µm to 15µm (7,19). It provides the possibility to examine large areas of skin without having the skin temperature become influenced by contact with measuring instruments. A Philips infrared thermograph was used (modification 1980) with a range of 10 °C with a black level of 26.5 °C (7). Vertical images can be made with the patient in the prone position by using a mirror. This results in inverted images. This inversion was not corrected when the images were processed in order to avoid any loss of information that might have occurred during a correction process. The measuring accuracy of the temperature dif- ferences was 0.1 °C. The output images were imported in a Atari Mega ST4 computer by a SAM digitizer (SAM is a registered brand by Silicone Solutions LTD) and stored in NEOchrome format (± 32 K per image). The final image calculation was performed using the AIM

Figure 1 Age-Gender Distribution



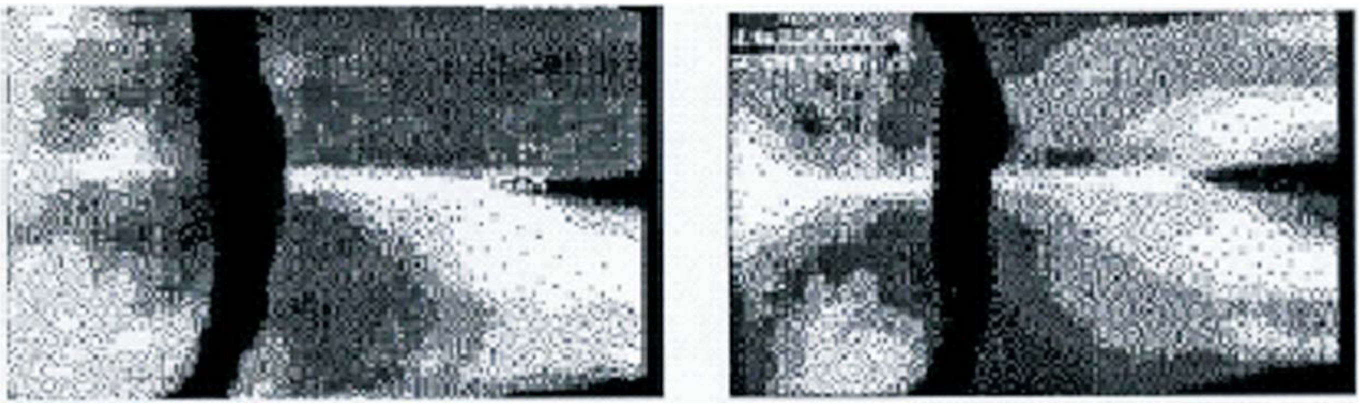


Figure 2
The image before medication is on the left; on the right, after three weeks of medication. Dorsal image. Cephalo-caudal in the direction from left to right. On this mirror inverted image, right and left are inverte**d.**

image-pro- cessing program (version 3.0). (AIM: Atari Image Mana- ger is Public Domain Software developed by TU Delft).

The measurements were performed under standard conditions: Targeted dynamic air- conditioning was used for 30 seconds with a wall ventilator at a distance of 2 metres, followed by three minutes of adaptation in accordance with the described method of dynamic cooling (20). A thermogram was made before starting with the medication and after having used the medication for two to three weeks, depending on the patient's ability to return. An increase of temperature resulted in the thermogram becoming lighter (more white pixels in the image). A decrease resulted in a darker thermogram (more black pixels in the image).

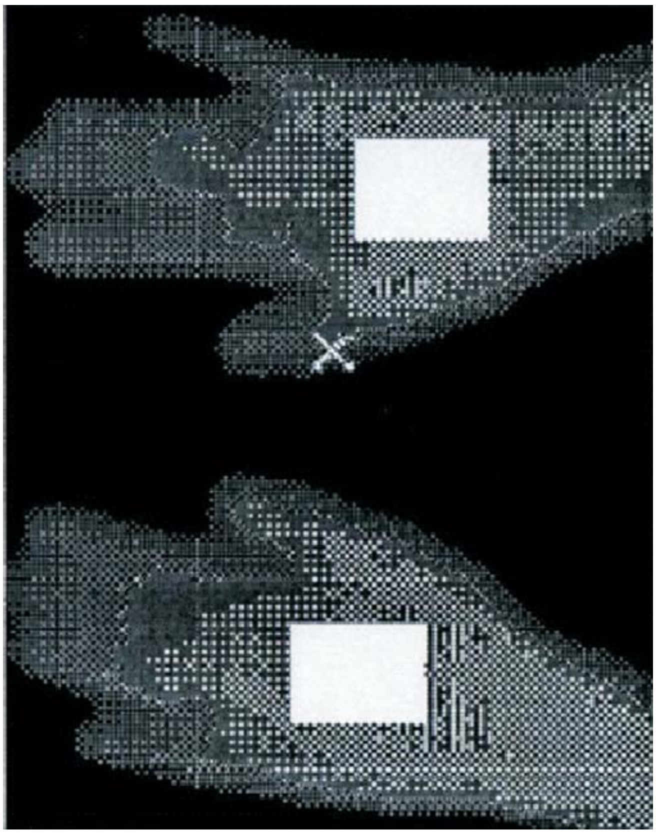


Figure 3
shows the excision of the areas to be adapted. The white surfaces are left over after excision. The dimension of the

Comparisons were made of the original thermograms before and after treatment; see Figure 2.

The image before medication is on the left; on the right, after three weeks of medication. Dorsal image. Cephalo-caudal in the direction from left to right. On this mirror inverted image, right and left are inverted. This is a so-called "typical result" of a patient who has been suffering ischialgia for four years.

Thermographic image of a vasoconstricted area on the pain site. Remarkable is the high degree of symmetry between left and right after treatment (right image).

According to the standardized method with regard to image size, storage and calculations, excisions of the pain sites and their contralateral reference areas were made; see Figures 3 and 4.

The patient points to the excision site as a pain site. The examiner determined the contralateral excised section as symmetrically possible in this area.

These excised sections, were used for the image cal- culations. The images consist of white and black pixels. The value of the black pixels is "0" and the value of the white pixels is "128". The pain areas and their reference areas were compared before and after treatment. For that purpose, the histograms of the images were calculated, see Figure 5.

Figure 4
is the excision (55 x 40 pixels) as indicated by the white squares of Figure 3.


Figure 5
shows the way of processing of the image excisions via AIM. The values are not direct temperature values, but a reproduction of the pixel values of the image, Black represents a "0" and white a "1". The hotter the object measured, the more white and thus the higher the measuring value. With that, there is a correlation with the temperature: the higher the average value, the higher the average temperature.

The higher the skin temperature, the more white pixels there are in the image. The average pixel value of the excision provides a proportional indication of the temperature, but is not equivalent to that temperature. (In 1988, it was not technologically possible to determine symmetrical index areas of the temperature.)

The results underwent a two-tailed t-Test for dependent measurements. In addition, the normal distribution was rechecked and the Wilcoxon Signed-Rank test was performed for the reliability analysis. Finally, the changes in the images of the pain sites were placed in ordinal ranking: improved, equivalent, or worse.

In the area measured there is a situation causing pain. If there is a relation between skin temperature and pain sensation, an increase of temperature in cold pain sites and a decrease of temperature in hot pain sites should lead to a reduction of the pain sensation. When no change of temperature was measured, also no change in in pain sensation is to be expected. The correlation between temperature change and pain sensation was tested using the Spearman's rank correlation coefficient

This design for testing was chosen because other studies also used observation of the current situation on pain sites. It is, however, difficult to find a group of healthy volunteers comparable to the group of patients to be tested. For that reason, stimulation was administered and the effects of the stimulation were compared with the initial situation, both subjectively based on the patient's report of pain and objectively based on the observable situation of the pain area. The frame of reference for the pain sites was the contralateral healthy areas. The selection criteria were strictly adhered to because of the small study population and no comparable tests were carried out. From a methodo logical point of view, a double-blind test model for this study is not relevant. No study was performed for the effectiveness of any specific medicine. The study was about the relation between temperature changes on the pain sites and the reference area, and about a possible relation between changes of pain experience and changes recorded on the pain site, whatever may have caused that experience. Whether or not, in this case, Pentoxyfilline was more than a placebo is in fact irrelevant.

These measurements are qualitative, in other words, lower, equivalent, or higher temperature. The implementation in 1989 was such that more precise recording was not possible.

## Examination of half the image

In 2012, the original Atari "NEOchrome" and "IMG" images can no longer be read on modern equipment. Therefore, the results are not reproducible. That is why they have been converted to "Mac pict" format. Just as with NEOchrome, this is a pure 4 bits image with 16 shades of grey. The image is identical to NEOchrome. The complete "pict" images have been covered by a black mask. This was done first on the contralateral side and then on the pain side so that the pain side and the reference side could be read successively. Adobe Photoshop Elements version 10.0 was used.

The 1989 image processing procedure was repeated in 2013 to analyse the reproducibility of the research and processing options, and to check the 1989 outcomes.

The excised sections with and without threshold values were repeated. The dimensions of the excised thresh are 35x45 pixels. Without thresh 90x45 pixels.

The pain sites indicated by the patient were covered by an image with NULL-values of 35x45 or 90x45 pixels. This selection was joined, copied and pasted in an identical NULL image. The new excised section contains exactly the desired amount of 1575, respectively 4050, pixels with the original values of the pain site. The procedure is identical for the reference side. In contrast to 1989, this image could have a maximum of 16 types of pixels valued at 16, 32, 48, 64…….255.

With "Adobe Photoshop Elements 10" the distribution of these pixel values is determined, resulting in a histogram and a calculated average value. But once again: the lighter the picture, the higher the average value, which can vary between 0 and 255.

All the images from 2012 and 2013 were saved as NEOchrome identical "pict" images. The results were processed using the PSPP statistics software, which is available as an open source at www.gnu.org, and the software "R, version 2.13.2.

## Results

### Results from 1989.

In 1989 it was difficult to determine where the limits were between, on the one hand, the degradation of the thermo-

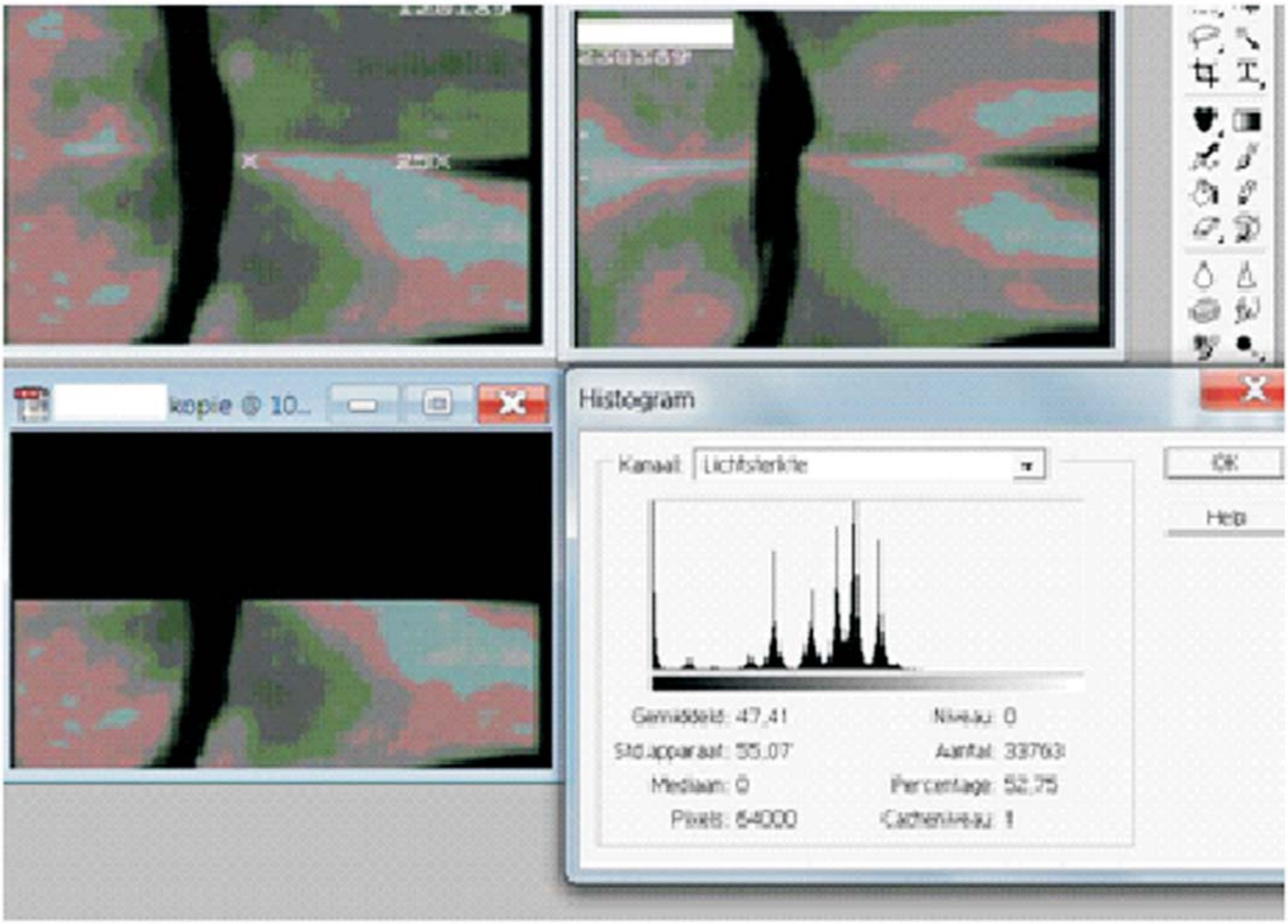



Figure 6. Examination of half the image

graphic image and remaining the same, and on the other hand, improvement and remaining the same.

That is why the images were also filtered with a threshold value: the pain site was black and the surrounding area was white. This procedure was also repeated in 2013.

Finally, the correlation between measurements and pain perception from 1989 were tested (table 1) The results found in 1989 were confirmed in 2012 and 2013 with the new images from 2012.

## Results 2012

In the total image, the temperature of the painful extremity (fig.6) increased after PTX significantly compared to the baseline settings. P=0.02.

In the reference extremity, there was no significant change of temperature, p=0.37 before and after PTX A significant difference, p<0.001 in increase of tem perature at the pain site compared the reference site was detected.

For the recalculated excised areas: The average value of the pain spot before PTX is significantly lower than the same spot contralateral. p < 0.001. After treatment, no significant temperature difference was detected between pain and reference sites. P=0.05,

The temperature at the pain sites increased after PTX significantly compared to baseline readings. The tem- perature difference between pain sites and re- ference sites increased after PTX significant compared to the baseline differences .P<0.001

Table 1
Relationship between change of pain sensation and temperature measured at pain sites

| Subjective<br>+: better<br>=: equal<br>-: worse | Temperature increase | | | Temperature unchanged | | | Temperature decrease | | |
|---|---|---|---|---|---|---|---|---|---|
| | + | = | - | + | = | - | + | = | - |
| Hypothermia | 39 | 3 | 1 | 2 | 1 | | 3 | 3 | 1 |
| Hyperthermia | 3 | 1 | | 1 | | | 4 | 1 | |
| Hypothermia all | 43 | | | 3 | | | 7 | | |
| Hyperthermia all | 4 | | | 1 | | | 5 | | |

## Results 2013

The correlation found between subjective pain and objective thermography were tested in 2013. Fig. 7 represents the data series as an example, on which the Spearman rank-order correlation coefficient is based; see row three of Table 2 (2013 Adobe threshold).

## Explanation of types of calculations

Cold spot is a temperature difference (Reference site-pain site) for intervention >0. Hot spot is a temperature difference (Reference site-pain site) for intervention <0. “px” is the mean temperature represented in a whole number from 0 to 255, using Adobe Elements 10 calibra- tions.

A: Absolute temperature change

“1” is Temperature decrease at the Cold spot or temperature increase at the Hot spot
“2” is Temperature unchanged (1.5%=±3 px)
“3” is temperature increase at the Cold spot/Temperature decrease at the Hot spot

B: Relative temperature change

“1”a is Temperature difference (reference site-pain site) prior to intervention - temperature difference after intervention < 0 at Cold spot
“1”b is Temperature difference (reference site-pain site) prior to intervention - temperature difference after intervention >0 at Hot spot

“2” is no temperature change: Temperature difference (reference site-pain site) prior to intervention - temperature difference after intervention :1.5%=± 3px

“3”a is Temperature difference (reference site-pain site) prior to intervention - temperature difference after intervention >0 at Cold spot
“3”b is Temperature difference (reference site-pain site) prior to intervention - temperature difference after intervention < 0 at Hot spot

## Discussion

The dynamic cooling method of Schubert et al. was not and is not generally applied (20). This is part of the reason why previous studies also used a continuous skin temperature measurement with thermistors. This proved that the skin, after the recommended period, had indeed reached a stable temperature. This is not expected to have an unfavourable affect on the measurement results.(21)

The results of 2012 resemble the results of 1988 very well despite the conversion made with original measure images. This conversion and the application of modern software cause a slight difference in the results, but they are consistent with each other.

It is expected that the data of the pain area produce even more intense results than those of the body part where that area is situated. This can be seen again in the strength of the statistic result.

The results from 2013 also indicate a relationship between objectively measured temperature differences and subjectively perceived pain changes. The table shows that the strongest results are found in the images with pixilation

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 3 | 3 | 3 | 3 |
| 3 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 2 | 3 | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | | |
| 3 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | |

Row 3 Table 1

Figure 7
represents the data series as an example..
Row 1 shows the series numbering 1-63 = number of 1989 measurements
Row 2 of Fig. 8 shows the recorded pain changes from 1989: 1= worsening 2=the same 3= improvement
Row 3 the consistent measurement value changes according to the definition:
1= temperature reduction at the pain site with initially cold pain site or temperature increase with initially warm pain site.
2= no change (change <=1.5% , which means: three points in the pixel value series 0-255) .
3= temperature increase at the pain site with initially cold pain site or temperature decrease with initially warm pain site.

Table 2

| Type of calculation | Study | N | Spearman rho | t | P Two-tailed |
|---|---|---|---|---|---|
| | | | | | |
| A | 2013 Adobe images | 61 | 0.5567 | 5.15 | <0.001 |
| B | 2013 Adobe images | 61 | 0.5263 | 4.75 | <0.001 |
| A | 2013 Adobe thresh | 61 | 0.497 | 4.4 | <0.001 |
| A | 1989 AIM images | 63 | 0.3328 | 2.76 | 0.007 |
| A | 1989 AIM thresh | 63 | 0.3159 | 2.6 | 0,011 |
| B | 1989 AIM thresh | 63 | 0.2755 | 2.24 | 0.028 |
| B | 2013 Adobe half-image threshold | 61 | -0.0238 | -0.18 | 0.857 |
| A | 2013 Adobe half images | 63 | 0.0042 | 0.03 | 0.976 |

The first column (Type of calculation) represents whether a situation improved, worsened or unchanged. The second column has the year, the software used and the type of image. The third column contains the number of research units (pain sites). The last three columns are self-explanatory.

from 1500 to 2300 and an assessment of the measured temperature changes of the pain sites in comparison with each other. A relative temperature change (see Explanation of Table 2) has results that are less strong. This also applies to the tests performed in 1988 with threshold values, possible due to information loss.

Modern techniques and a sharper imaging technique make the relationship between temperature change and pain perception more visible.

Both the distribution of the objective temperature change and the distribution of the subjective pain sensation are skewed to the left, which makes the estimation of the rank correlation somewhat harder. A research with a larger number of patients and/or with more variation on one of these measurement scales would be recommended to confirm the results

The results show that the findings can be reproduced sufficiently and can be carried out with modern hardware and software. The strength of the results indicates that the findings can be taken serious. The correlation of thermographic measure images and the subjective pain sensation suggest the possibility of a potential quantification of pain. That would not be surprising. A subjective factor such as sound perception can also be quantified.

Regarding a quantified sound perception, what must therefore be taken into consideration is that this study is suggestive of a correlation between a thermographic image and a subjective experience; however, a unique response in skin blood circulation has not been proven.

Therefore, factors other than pain and the medication used still have to be ruled out. The statistical method is also vulnerable because of the skewed distribution found. Subsequent research designs will have to take this into consideration.

Noteworthy is the observation that the temperature increased in cold spots and decreased in hot spots when the same pharmaceutical was used. That cannot be explained by a phosphodiesterase inhibitor. Possibly the inhibiting effect on TNFa, IL 6, IL1A, and IL1B. Viewed in this light, warm pain sites may have something to do with active processes.

Literature since 1988 also shows the fact that infrared thermography can have a function in diagnostics of pain complaints. Research after 1988 confirms the applicability of thermography in pain research (22,23,24). The sensitivity is high (100%) but the specificity in the static images is moderate (60%) (23), although with patello-femoral syndrome a sensitivity of 97% and a specificity of 90% is claimed.

In abdominal pain, contradictory results are found (25,26). With lower back pain, the results are contradictory as well (22,27). Hypothermia after minor injuries was concluded (28). Further study was advised as to a possible relation to reflex dystrophy (RDS) (28). In 1977, the year Bruehls criteria for CRPS were introduced, stress infrared thermography was found to be applicable in diagnosing CRPS1 with a sensitivity of 93% and a specificity of 89%. The positive predicting value is 90% and the negative predicting value is 94%. The value of infrared thermography with CRPS1 was confirmed in 2004 (29,30). For diagnostic purposes, dynamical infrared thermography produces better sensitivity and specificity than static thermography (31). Using tadalafil (32), a specific diesterase inhibitor in CRPS does not lead to measurable temperature changes.

The study supports thermal research from 1952. Non-visual recognizable sites of chronic pain can be made visible by non-contactual infrared thermography because they are situated in the infrared spectrum. Executing dynamic research is supported by recent research (24, 31).

Based on modern research, the sensitivity of infrared thermography on the pain images is high. Further research is needed to see if that is also the case for the observed cold spot pain zone.

Considering the measured effects of PTX there are indications that prostaglandins and TNF alpha can also play a role in the cold spots found (33,34). These should be investigated further.

To supplement the literature used in this study, recent research from 2008 to 2014 on connections between infrared thermography and chronic pain with human participants was searched. Pubmed search using the search terms: ((thermography and pain)) AND ("2008/01/01" [Date - Publication]:"3000" [Date - Publication]) AND (Human) returned 69 hits. Because this study addresses chronic pain without any known anatomical substrate, the search was expanded to: ((thermography and chronic pain)) AND ("2008/01/01" [Date - Publication] : "3000" [Date - Publication]) AND (Human).

This returned three articles, of which two had bilateral conditions. One met the criteria: one condition with reference of the symmetrical site heterolateral.(35). A second of the same group showed the same outcome. There is a correlation between pain and a thermographic image. Their outcome is not inconsistent with the results of this study. Diverse studies, mainly with herpes zoster as the condition, whereby the affected half of the body is compared with the other as reference.

There is no unanimous agreement about the results, although no correlation between pain and a thermographic image was found (36,37)

With regard to reproducibility, the original images from the study in 1989 were also recalculated with unilateral comparison of the pain side with the heterolateral side as reference. A correlation between pain and a thermographic image was found with this calculation (Table 1, row 7,8).

The comparison of 'half-images' is probably too precise when chronic pain is examined. It is also possible that the assumption both body halves responding identically to an intervention is wrong. (38)

## Conclusions

Most (>70%) chronic pain sites indicated by the patient and made visible by infrared thermography are cold in comparison with their surroundings.

After administering pentoxyphylline, the pain decreases and the temperature of the pain sites changes (cold becomes hot and hot becomes cold)

There is a correlation between change in temperature and change in pain sensation.

The results of the study of 1988-1989 have not been replicated in any latter study, although recent research in cold CRPS with administration of the specific diesterase inhibitor Tadalafil does not show a temperature change.

This study provides an indication, but is not proof, of the existence of a unique response of the skin blood circulation resulting from pain or the use of PTX.

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## Disclosure

There is no conflict of interest whatsoever.

### What is already known about this topic?

- Most pain sites are colder than their surroundings
- Pain is a subjective experience

### What does this study add?

- An instrument with the potential to assess chronic pain
- A different pharmacological approach to chronic pain than the usual one

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Address for correspondence
P.H.E. van der Veen
Onyx 13
1703 CD Heerhugowaard
The Netherlands
email: henk@chronic-pain-science.nl

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# Appendix

P. Henk E. van der Veen

After the first review, a thorough rearrangement of the material and a triple check of the archive material (including the electronic material) took place.

Three data files appeared that were not completely congruent with the last list that was used for the recheck procedure in 2013.

One is the original degas excision list that was the basis of the entire image processing in 1989. It was assumed that this list was lost. The significance of two other files was not clear.

The list used in 2013 for the recheck was tested against the original degas-list of 1989.

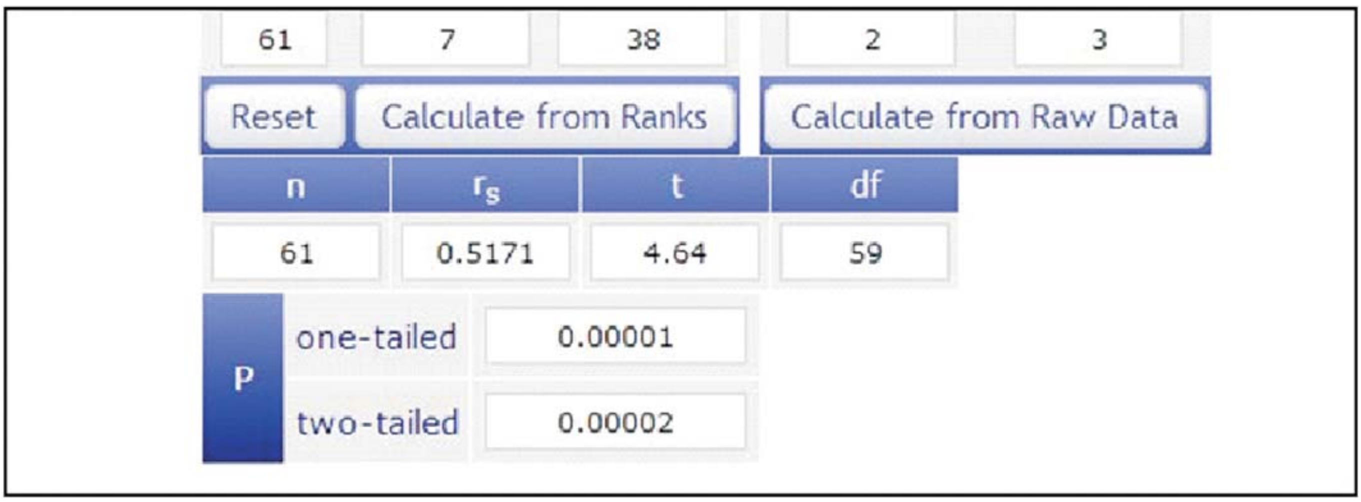
Eight abnormalities were found in the 2013 list compared with the degas-list: The same images were not used in the 2013 as were used in 1989. Most of them involved images that with dates two to four weeks later.

In all of these cases, the image processing of the 2013 image material was performed identically to that of 1989 in that combination.

This had no affect on the conclusion in six cases: worse, the same or better.

In one case, a measurement that was initially considered an improvement was recalculated as a worsening, and in another case, a worsening was recalculated as an improvement.

The new list obtained was statistically tested using the Spearman rank-order correlation coefficient. There is a minimal difference in statistical 'solidity'. The final conclusions of the study reported have not changed.



# Diagnostic value of infrared (IR) thermography for assessing diabetic foot in a dialysis patient - A case report

Takahiro Tamaki[1], Hideaki Ishikawa[2], Junichi Sakamoto[3]

Tokai Central Hospital of Japan Mutual Aid Association of Public School Teachers,
[1] Clinical Engineer, [2] Department of Nephrology, [3] Director of Hospital
4-6-2 Sohara Higashijima-cho, Kakamigahara, Gifu 504-8601, Japan

**SUMMARY**

**Diabetic foot ulcers (DFUs) are a common complication in patients with diabetes mellitus. Highly sensitive medical devices for diagnosing DFUs may therefore be helpful in clinical practice. We investigated whether Infrared (IR) thermography was useful for evaluating the efficacy of treatment in maintenance hemodialysis (MHD) patients with DFUs. IR thermography was used to assess the change in skin temperature during a hemodialysis session. Data on temperature were obtained from six different points on the soles of both feet of an 86-year-old man. We aimed to evaluate whether a polyacrylonitrile (PAN) dialysis membrane had merit as a treatment option in this patient.**

**As expected, the skin temperature of the sole of the foot increased significantly during the 4-hour dialysis session (0 min vs. 15 min, 27.0 ± 1.9 vs. 28.0 ± 1.6, p= 0.004; 0 min vs. 240 minutes, 27.0 ± 1.9 vs. 33.0 ± 0.4, p= 0.0004). The time series of thermographical images were also consistent with these statistical data.**

**We concluded that IR thermography may be useful for diagnosing and selecting suitable dialysis conditions for patients with DFUs. The measurements were non-invasive and to not harm our patients.**

**KEY WORDS: Diagnostic value, IR thermography, diabetic foot ulcers, dialysis patients.**

**DER DIAGNOSTISCHE WERT DER INFRAROTTHERMOGRAPHIE IN DER BEURTEILUNG DES DIABETISCHEN FUßES BEI EINEM DIALYSEPATIENTEN- EIN FALLBERICHT**

**Ulzerationen des diabetischen Fußes (DFUs) sind häufige Komplikationen von Patienten mit Diabetes mellitus. Hochempfindliche Medizingeräte für die Diagnose von DFUs könnten deshalb in der klinischen Praxis hilfreich sein. Wir untersuchten, ob die Wirksamkeit der Therapie bei chronischen Dialyse-Patienten mit DFUs mit Infrarotthermographie erhoben werden kann. Die Veränderung der Hauttemperatur während einer Hämodialyse-Behandlung wurde mittels Infrarotthermographie aufgezeichnet. Temperaturwerte wurden an sechs Punkten an den Fußsohlen eines 86 Jahre alten Manns gemessen. Ziel der Untersuchung war es zu klären, ob ein Polyacrylonitrile-Dialyse-Membran(PAN) ein vorteilhafte Therapieoption für diesen Patienten darstellt.**

**Wie erwartet, erhöhte sich die Hauttemperatur der Fußsohlen während der 4 Stunden dauernden Dialyse signifikant (0 min vs. 15 min, 27.0 ± 1.9 vs. 28.0 ± 1.6, p= 0.004; 0 min vs. 240 min, 27.0 ± 1.9 vs. 33.0 ± 0.4, p= 0.0004). Die Serie der Wärmebilder, die während dieses Zeitraum aufgenommen worden waren, stimmten mit den statistischen Daten überein.**

**Wir schließen, dass der Einsatz der Infrarotthermographie für die Diagnose und Auswahl von geeigneten Dialysebedingungen für Patienten mit DFUs hilfreich sein kann. Die Messungen sind nicht-invasiv und belästigen die Patienten nicht.**

**SCHLÜSSELWÖRTER: Diagnostischer Wert, Infrarotthermographie, diabetischer Fuß, Dialyse-Patient.**

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## Introduction

Approximately, 300,000 patients currently receive dialysis treatment in Japan[1], with the cause of renal failure in nearly 40% of these patients being diabetic nephropathy. It is therefore an urgent issue for health care providers to improve clinical practice and prevent progression of this disease in Japan[2].

Dialysis patients with diabetes mellitus commonly have complications, such as retinopathy and neuropathy. Diabetic foot ulcers (DFUs) are also a serious comorbidity[3]. It is well documented that DFUs contribute to increased mortality in these patients [4], and therefore need to be treated adequately. We recognized that a number of our dialysis patients with DFUs suffered from coldness, numbness, or pain in their feet. Although we observed that these symptoms were clearly associated with the severity of the DFUs, it proved considerably more difficult to provide suitable therapy against immeasurable subjective symptoms. In other words, we currently do not have sufficient clinical evidence for reducing the risk of DFUs such as recommended skin temperature. Therefore, quantitative analysis of a symptom such as coldness could be helpful for physicians to consider better management of DFUs.

To date, infrared (IR) thermography has become available as a medical procedure in hospitals[5]. It is a non-contact and non-invasive measurement that maps the surface temperature of an object in a remote manner. Medical IR thermography is used currently to study blood flow, detect breast cancer, and evaluate the diabetic foot[6,7]. In this study we attempted to measure the skin temperature of a dialysis patient's feet during a dialysis session by using IR thermography to evaluate whether dialysis conditions had an impact on skin temperature. The aim of this investigation was to investigate whether IR thermography had diagnostic value in the field of dialysis therapy. The following is a case report to evaluate this possibility.

## Methods

We investigated an 86-year-old patient with DFUs who had received hemodialysis for approximately 10 years. Prior to the start of this study, the dialysis membrane was changed from polysulfone to polyacrylonitrile (PAN) after informed consent was obtained from the patient. We used a PAN/AN69 membrane, H 12 (Gambro, Japan). We speculated that the PAN/AN69 membrane could contribute to better management of the DFUs in this patient. The detailed reason for this possibility is reviewed in the "Discussion" section. We assessed whether our therapeutic strategy was effective and selected a reliable method such as IR- thermography to evaluate treatment. We considered that IR-thermo graphy would be suitable for our patient because it is a non-invasive procedure.

We used a medical thermography system named Infra-Eye 3000 (Nihon Kohden Co. Ltd, Japan; Fujitu Tokki System Ltd, Japan), which is used in hospitals in Japan. Skin temperature was calculated simultaneously using the computer software in that system.

The measurement conditions were as follows: room temperature approximately 25° C, acetate-free citrate dialysate (Carbostar ®, Ajinomoto Pharmaceuticals Co. Ltd., Japan), dialysate temperature 36.0°C, dialysate flow 500 mL/min, and blood flow rate 200 mL/min. The body temperature of the patient ranged between 35.5 to 36.5°C. Electric carpet with a temperature of approximately 30°C was placed under the patient's legs.

The distance from the patient's foot to the thermography unit was 60 cm. The temperature was measured at six different points of the soles of both feet during the 4 hour hemodialysis session. Detailed information of the measurement points is described in Figure 1. We compared the mean temperature at the measurement points at 0, 15, 30, 60, 180, and 240 minutes during the dialysis session. The series of measurements were repeated three times. With the exception of the patient's body temperature the conditions of the experiment were fixed during the observations.

Representative data of the measurements are shown in the Results section. Statistical analysis was performed using Stat View software version 5.0 for Windows. One-way ANOVA was used to evaluate the change in surface skin temperature of the patient. The data were expressed as mean ± standard deviation, with $P < 0.05$ considered statistically significant.

## Results

Pictures of the patient's feet are shown in Figure 1. We detected a slight worsening in skin color of the tiptoe in both feet and a skin ulcer in the right leg. These findings indicated that the patient had a diabetic foot ulcer. We also noticed that the skin temperature was markedly lower on palpation. The thermography results are shown in Figure 2, with the photographs arranged in chronological order from A to F (A start of dialysis session, B 15 min, C 30 min, D 60 min, E 180 min, and F 240 min at end of the session). The letters and squares in each picture represent points where temperature was measured repeatedly. We were also able to detect a higher temperature zone in the area adjacent to the electronic carpet. Figure 3 shows the foot sole temperatures of a healthy middle-aged man. Comparison of this photo with photo A in Figure 2 shows that skin temperature was lower in the patient.

Statistical analysis of the changes in mean temperature at the six measuring points showed the temperature increased gradually from the centre to the periphery in both feet (Figs 2, 4). The improvement in skin surface temperature during the dialysis sessions was statistically significant ($P < 0.0001$).

Clinical monitoring showed the number of skin ulcers in the patient's feet reduced after the dialysis membrane was changed as described in the Methods section. We also found that subjective symptoms of the patients such as coldness, pain, fatigue, and skin conditions in the feet improved following the change in dialysis membrane.

## Discussion

Several reports have been published on the diagnostic value of IR thermography in the diabetic foot and neuropathy [5-8]. In contrast, there has been only limited research on the efficacy of IR thermography as a clinical procedure in dialysis patients [9]. In this case study we showed that IR thermography was useful for assessing improvements in skin temperature gradients during a dialysis session.

As far as we are aware, this is the first study of its kind and the results are novel.

Our results raise two major clinical points. First, foot sole skin temperature in dialysis patients with DFUs may be considerably lower than normal (Figure 2). Because it is likely the DFUs will be worsened by this condition, physicians should be encouraged to pay greater attention to improving foot temperature in daily clinical practice. Second, the skin temperature of both feet improved significantly in our patient during dialysis therapy. This finding indicates further research is warranted on whether dialysis conditions such as choice of dialysis membrane, dialysate type and temperature, duration of dialysis session, and rate of blood flow may affect the peripheral circulation in dialysis patients. Several studies have reported that cytokines such as interleukin-1 (IL-1), IL-2, and tumor necrosis factor (TNF) are produced in the peripheral blood of maintenance hemodialysis patients[10-12]. This immunological response may be caused by contact between the blood and dialysate or dialysis membrane. The amount of these cytokines produced may be influenced by factors such as the dialysate condition, endotoxin contamination, and membrane structure. As described in the Methods section, we selected a PAN/AN69 membrane with the aim of improving management of DFUs in this patient[13,14]. According to previous research, generation of bradykinin (BK) was detected with this membrane[15]. It is also well known

Figure 1.
Photos of the patient's feet. We observed that the skin color of both tiptoes was slightly worsened.
The arrow in the right panel shows a diabetic foot ulcer.

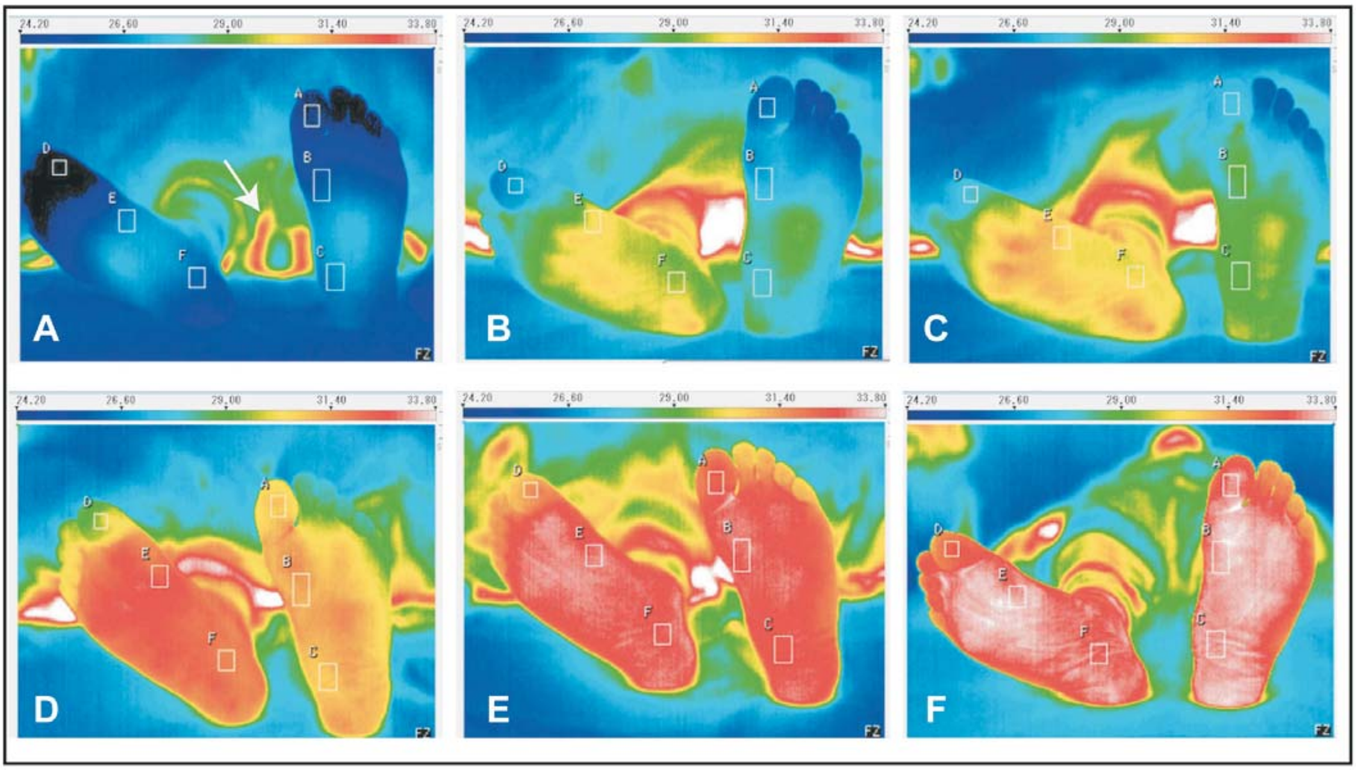


Figure 2.
The results of IR thermography arranged in chronological order.
Photo A was obtained at the start of the dialysis session (0 min), B at 15 min, C at 30 min, D at 60 min, E at 180 min, and F at the end of therapy (240 min). The letters and squares shown in each panel represent the points where skin temperature was measured and calculated (A to C were on the left foot sole and D to F were on the right foot).

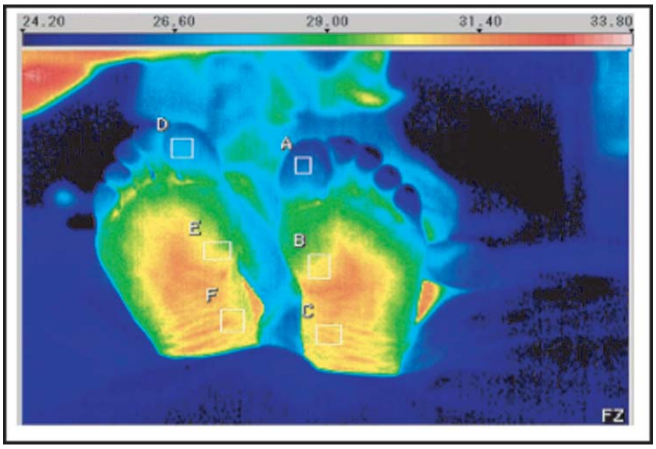


Figure 3.
This image was a obtained from a heathy volunteer and was used as reference data in the study.

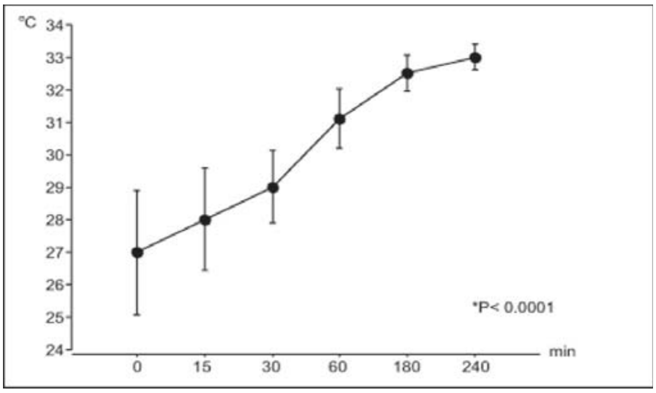


Figure. 4.
The increase in foot sole skin temperature during the dialysis session. The data shown are representative of three independent observations.
The error bars represent the standard deviation of mean temperature of the six measurement points shown in Figure 2 (A to F).

that the effect of BK may be mediated by nitric oxide (NO), a factor responsible for vascular smooth muscle relaxation. Taken together, these results indicate BK may be considered as a kind of vasodilator[15]. We hypothesized that our finding of increased skin temperatures was possibly induced by improved blood flow in peripheral tissues, or more precisely, as a result of vasodilation of peripheral blood vessels in the patient's feet. As mentioned in the Results section, we confirmed that disease control against DFUs in patients may be refined by careful observation of the patient's symptoms for several months. Taken together, our results suggest that the PAN/AN69 membrane has advantages in the treatment of DFUs in dialysis patients. While it is necessary to consider the adverse effects of using PAN/AN69 membranes such as allergic reactions during hemodialysis [16,17], our case report suggests these membranes may also have beneficial effects [13]. This possibility is worth considering and warrants further investigation.

Our study had several limitations. First, it was a case report and therefore the results may not be applicable to other dialysis patients. A larger study to assess the therapeutic efficacy of PAN/AN69 membranes with the aid of IR-thermography is therefore necessary in the future. Second, although we postulated that the increase in skin temperature in the feet might be mediated by BK production, we did not directly measure BK concentrations in the blood. Third, the patient routinely used an electric carpet during dialysis sessions, with the temperature of both the carpet and dialysate maintained lower than the patient's body temperature. We confirmed that the body temperature did not change significantly before or after each dialysis session investigated. We consider these findings indicate that the improvement in skin temperature was mediated only in the peripheral regions, in this case, the patient's feet. We therefore concluded that we could exclude the possibility of these characteristics improving foot skin temperature.

In conclusion, although our study had several limitations, we demonstrated that IR thermography had diagnostic value and could provide important clinical information in dialysis patients with DFUs. Although there are no established criteria for skin temperature levels to determine the pathophysiology of DFUs, we consider that quantitative analysis of skin temperature of dialysis patients' feet using IR thermography adds new insights on clinical guidelines such as " adequate or recommended management of foot skin temperature for dialysis patients with DFUs". Accumulation of knowledge and experience of the IR thermography test will also contribute to refining clinical practice in the field of dialysis therapy.

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The authors have no relevant financial interests to declare.

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*Address fro Correspondence*

Junichi Sakamoto, MD, PhD, FACS
Director, Tokai Central Hospital
4-6-2 Sohara Higashijima-cho, Kakamigahara, 504-8601, Japan
e-mail: sakamjun@med.nagoya-u.ac.jp

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Military Institute of Medicine, Warsaw, Poland

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**Conference venue:**
Hotel "HYRNY"
Zakopane, Pilsudskiego str 20

**Chair** of the Organizing and Scientific Committee
Prof. Anna Jung MD,PhD

## Programme

### Saturday, April 5th 2014

### 09:00 - 11:00 Session I

*Chairmen*: Prof. Francis Ring, Prof. Kurt Ammer

1. Ring F. (UK)
   Infrared Imaging in Diabetes: an overview. (
2. Ammer K. (Austria)
   The value of thermography in back pain patients
3. Viter VI, Vavilov AYu, Urakov AL, Chirkov SV. (Russia)
   Infrared thermometry for assessing the onset of mechanical trauma that resulted in bruises or abrasion in living persons
4. Cholewka A. -(Poland)
   The usage of thermovision in photodynamic therapy.

### 11:20 - 13:00 Session II

*Chairmen:* Prof. Anna Jung, Dr. Kevin Howell

1. Rustecki B, Rustecka A, Kalicki B, Kwasiborski P, Ring F, Truszczynski A, Jung A. (Poland).
   Comparison of core temperature measured at the esophagus with infrared thermographic temperature monitoring in patients undergoing general anesthesia
2. Mozanski M, Rustecki B, Kalicki B, Jung A. (Poland)
   Evaluation of paravertebral blocks for mastectomy in an high risk patient by means of infrared imaging - a case report

3. Strakowska M, Wiecek B, De Mey G. (Poland)
   Thermal modeling of a tissue for cold stress and medical screening applications.
4. Soiher MG, Soiher MI, Urakov AL, Reshetnikov AP, Kopylov MV, Fischer EL.(Russia)
   Local facial temperature can be used to identify the salivary glands, mimic and masticatory muscles

## 14:30 - 16:00 Session III

*Chairmen:* Prof. Adriana Nica, Prof. Boguslaw Wiecek

1. Mróz J, Kalicki B, Lipinska-Opalka A, Krawczyk A, Jung A, Zuber J, Zaganczyk B. (Poland)
   Application of thermography in the diagnosis and treatment monitoring of the Complex Regional Pain Syndrome type I.
2. Kalicki B, Mróz J, Iwaniszczuk A, Krawczyk A, Lipinska-Opalka A, Rustecki B, Murawski P, Zuber J, Jung A. (Poland) - Thermographic imaging in selected physiotherapeutic treatments.
3. Urakov AL, Urakova NA. (Russia)
   Temperature of the site of injection in subjects with suspected " Injection's disease"
4. Kasatkin AA, Reshetnikov AP. (Russia)
   Assesment method of irritating effects intravenous catheter using infrared thermography.
5. Dima V, Demetrian M, Dima C, Nica A (Romania)
   The use of infrared thermography in neonatology

## 16:45 - 17:00 Training course

Chairman: Prof. Antoni Nowakowski, Doc. Boleslaw Kalicki

1. Krawczyk A. (Poland)
   The usage of thermovision in examination of electromagnetic structures.
2. Wiecek B, Strakowski R. (Poland)
   Design of medical bolometer thermal cameras with prolonged time of uninterrupted operation
3. Firm presentation.

## 17:00 - 18:30 EAT committee meeting

## Sunday, April 6th 2014

## 09:00 - 11:00 Session IV

Chairman: Prof. Manuel Sillero-Quintana , Dr n.med. Janusz Zuber

1. Cholewka A. (Poland)
   The usage of thermovision in capacity tests of athletes.
2. Sillero-Quintana M, Fernandez Jaen T, Fernandez-Cuevas I, Gomez-Carmona PM, Arnaiz J, Perez MD, Guillen P. (Spain) - Infrared Thermography as a support tool for screening and early diagnosis of sport injuries.
3. Adamczyk JG, Boguszewski D, Siewierski M, Bialoszewski D. (Poland)
   Non-invasive evaluation of lactate level in capillary blood during post-exercise recovery.
4. Boguszewski D, Adamczyk JG, Janicka M, Mrozek N, Piejko K, Bialoszewski D. (Poland)
   Applying of thermovision in the estimation of the influence of the sports massage on selected physiological parameters of upper limbs.
5. Nowakowski A. - (Poland)
   IR - Descriptors in quantitative evaluation of wound healing.

# Abstracts

## INFRARED IMAGING IN DIABETES: AN OVERVIEW

E.F.J.Ring, P. Plassmann

Medical Imaging Research Unit, Treforest Campus,
University of South Wales, Pontypridd. CF37 1DL UK

This paper reviews some of the studies documented to evaluate the potential role of thermal imaging in the assessment of effects of Diabetes Mellitus DM on the temperature of the extremities. One of the first in 1967 was Branemark et al. in Sweden who noted abnormal thermal patterns in the hands and feet of 16 young diabetics (mean age 28 yrs.), some of whom did not have vascular complications. The mean duration of the disease was 13 years. They concluded that thermography was a suitable method for further studies of the extremities in these patients [1].

In 1988 RP Clarke et al in London investigated tissue damage to the feet in diabetic patients with thermography and pedobarography to study the areas of maximum pressure on the plantar feet during weight bearing. They found asymmetry in several cases, and noted that increased temperature could be a warning sign of future deterioration.[2]

In 1998 JR Harding et al Newport UK investigated diabetic foot ulcers and osteomyelitis. They found that 21 patients with confirmed osteomyelitis all had positive changes in thermography of the ankle and foot. The thermograms were negative in 23 of 28 patients who did not have osteomyelitis.[3]

Makoto O et al. in Japan (2013) also studied thermography as a screening tool for osteomyelitis in DM patients, diagnosed by MRI. They found a positive predictive value PV of thermography to be 100% and a negative PV of 71% . [4]

In 2000, Fujiwara et al in Japan used a cold stress with one toe in water at 0oC for 10 seconds and studied the thermal recovery of the foot. There were 61 patients and 16 controls in this study. They noted a high proportion of DM. patients had a slower recovery to baseline than the controls.[5]. In l2002, K.Ammer et al studies the thermograms of the feet in 76 patients with type II DM. They investigated the distribution of skin temperature, but found no correlation with the severity of f skin changes or acquired skeletal deformities..[6]

In 2006 M. Bahara et al. in the UK found mean skin temperatures were lower in DM patients than controls measured at the forehead, palm of the hands knees and tibiae. They found that as HbA(1c) increased, so skin temperature decreased, concluding that thermography may be of value in early detection of the disease. They postulated that temperature decrease may be due to decreased basal metabolic rate and high insulin resistance. [7]

In 2007 Lavery's group in Texas USA conducted a 15 month multicentred randomised trial on 173 DM patients who had a history of diabetic foot ulceration. [8] The patients were issued with an infrared thermometer and required to measure 6 sites on the foot every day. If temperature differences of more than 2.2°C (4°F) were found, they were to contact the nurse and reduce activity until temperatures normalised. Two forms of therapy were used, and those with the enhanced therapy had fewer ulcers than those with the standard therapy, being more than four times more likely to develop ulcers than those with the enhanced treatment.

This concept was furthered in a non thermographic study by Constantijn Hazenberg in the Netherlands who used a photographic foot imaging device as a telemonitoring tool for home use on patients at high risk of ulceration. All referred for treatment of ulcers in early stages were succes- fully treated.[9] In all studies the overall aim is of early prediction of ulcer formation, which when established can result in very slow healing and reduced quality of life.[10]

A group research project has now been funded in the UK National Health Service involving the National Physical Laboratory, The Glamorgan Research Unit and clinical centres in London and Newcastle. This is at the early experimental stage of constructing a thermographic system spe- cifically for the feet, pro -bably to be used at family health centres for regular monitoring of patients in a multi centred trial.

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## THE VALUE OF THERMOGRAPHY IN BACK PAIN PATIENTS

Kurt Ammer [1,2]

[1]Medical Imaging Research Unit, Treforest Campus,
University of South Wales, Pontypridd. CF37 1DL UK
[2]Institut für Rheumatologie der Kurstadt Baden, Baden, Austria

This paper is an update of a narrative review on thermo- graphy in spinal disorders- published in 2010 [1]. After providing definitions of low back pain with a focus on differentiation between specific and the predominant non-specific form of back pain, new research results are reported mainly in the field of radiculopathies and non-specific low back pain.

A study from South Korea defined in patients with unilateral lumbar radiculopathy and healthy, non symptomatic controls, 30 regions of interest (RoI) on the back and the lower extremity and compared the mean temperatures of these regions bilaterally [2]. An abnormal temperature distribution pattern was diagnosed if the mean temperature in at least one of the 30 RoIs was lower or higher than the temperature in the respective RoI of healthy control subjects in the magnitude of mean temperature plus 2 standard deviations. 97% of the patients showed abnormal temperature difference in at least one of the 30 ROIs, and 79% showed hypothermia on the involved side. Neither pain severity nor other physical or electrophysiological findings were related to the thermographic findings.

A study conducted in Olomuc, Czech Republic, investigated the occurrence of post-sympathectomy dysfunction after anterior and lateral lumbar inter- body fusion procedures [3]. The authors found coincidence between temperature differences on the lower extremity and symptoms of sympathetic injuries in 17/28 patients (true negative 10/28 and true positive 7/28), the rate of false positive was 8/28 and false negative thermograms were found in 3/28 patients. A sensitivity of 50% and a specificity of 70% of thermo- graphy for symptoms of sympathetic post-sympathectomy dysfunction can be calculated.

Chiropractors from Canada compared the skin temperature of the lumbar region between subjects with and without chronic low back [4]. The authors reported lower paraspinal temperatures in low back pain patients than in healthy controls. Temperature increased after therapeutic spinal manipulation at all spinal levels and irrespective of the treated side.

Gabrhel et coworkers published a large retrospective study on thermographic findings in the pelvic-femoral- region [5]. A diagnostic accuracy of hot spots for painful trigger points with sensitivity of 91% and specificity of 55% was reported. The authors related also the temperature difference recorded in the gluteal region with the range of motion of the hip joint and found higher diagnostic accuracy for temperature differences measured in the distal than the proximal part of gluteal region. 50 out of 62 patients with restricted joint play of the sacroiliacal joint presented with thermal asymmetry and increased temperature above the affected sacroiliacal joint was obvious in 36/62 cases.

A recent evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy stated, that "*There is an insufficient evidence to make a recommendation for or against the use of thermal quantitative sensory testing or liquid crystal thermography in the diagnosis of lumbar disc herniation with radiculopathy*" [6]. This statement is in line with the conclusion achieved in the literature review of 2010: the thermo- graphic body of knowledge in spinal disorders is incomplete and more high quality studies are needed before thermal imaging can be recommended as diagnostic method or as outcome measure for back pain.

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## INFRARED THERMOMETRY FOR ASSESSING THE ONSET OF MECHANICAL TRAUMA THAT RESULTED IN BRUISES OR ABRASIONS IN LIVING PERSONS

V.I.Viter[1,2], A.Yu.Vavilov[1,2], A.L.Urakov[1], S.V.Chirkov[1]

[1]Izhevsk State Medical Academy, Izhevsk, Russia

[2]Bureau ForensicMerdicine of the Udmurt Republic, Izhevsk, Russia

INTRODUCTION: The technique of infrared thermometry can be used in forensic medical examinations of recently injured subjects. Objective information of the temperature in both the injured and the non-injured body regions of investigated person can be obtained. Temperature reactions caused by damage, dependent on gender and age of the injured subject, the region exposed to injury and the extent of the damaged tissue can be determined. Soft tissue injuries caused by external forces in violent actions are accompanied by formation of bruises and skin grazes. Infrared based temperature data are used as a diagnostic tests in victims of violence at the bureau for forensic medicine in Russia. A number of mathematical expressions was developed, and their scientific and practical novelty, was confirmed by two patents for inventions of Russia [3,4].

METHODS: Research was conducted in 219 injured subjects referred to forensic medical examination at the Bureau of Forensic Medicine of the Udmurt Republic (Izhevsk, Russia) in 2009-2012. Infrared investigations of the injured subjects was performed with the thermal camera ThermoTracer TH9100XX (NEC, USA) [1, 2]. The obtained data were processed using the

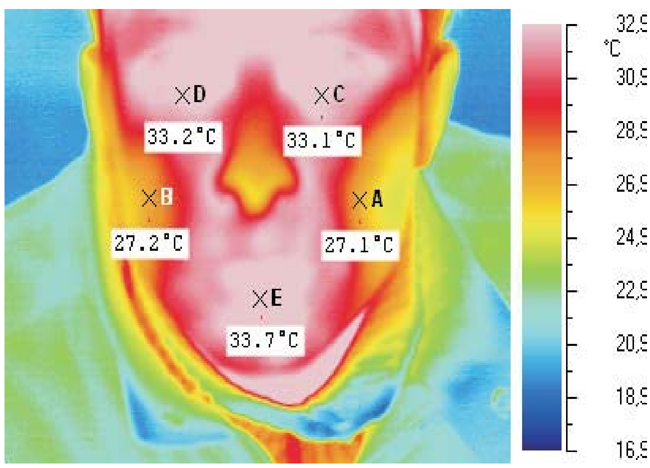


Figure 1 - A 20 years old man fell down on the street , 26 hours prior to the investigation.
No temperature changes were detected as minor injury induced temperature changes last only for 12 hours

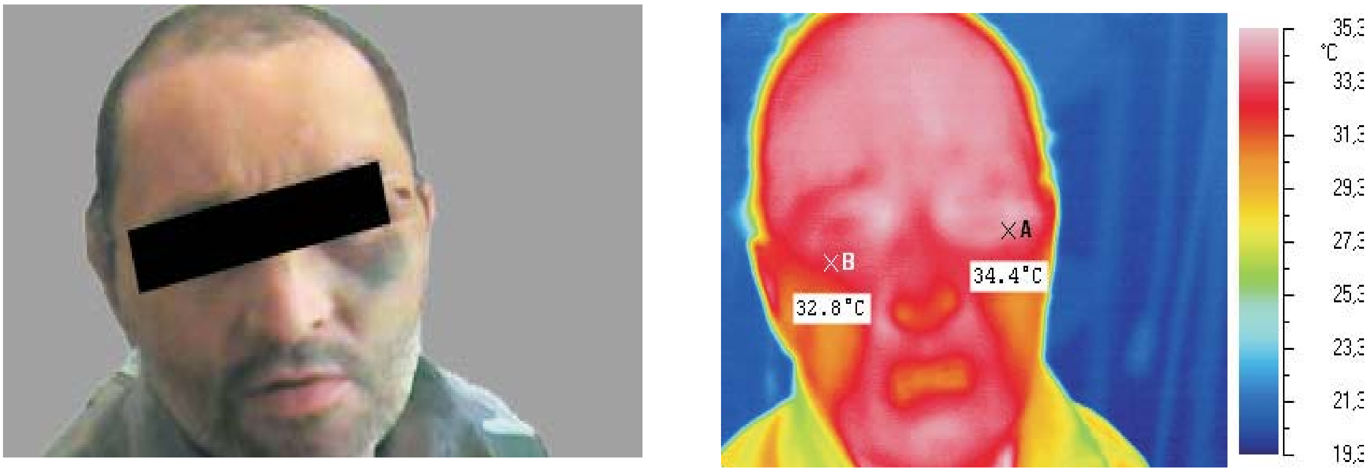


Figure2 - A 48 years old manreceived two consecutive punches towards the left eye, 29 hours prior to thermography
Clinical status: Below the left eye there is triangular shaped bruise, 8×4 cm of crimson-blue colour with slight edema. At the outer corner of the left eyebrow was a graze, 1,5×0,6 cm, beneath a small, tender, brownish crust. He complaint of pain at the site of injuries.


Figure 3 - Male patient, 34 years. Received a punch towards the left orbita 32 hours prior to thermographic investigation. Asymmetry of the face caused by edema of the left cheek, a bruise at the lower edge of the left orbit of dark-violet colour, 4×6 cm in size
Temperature asymmetry and discrepancy between the center of damage and the location of maximum temperature

software Thermo graphy Explorer and Image Processor. The study was approved by the Ethics committee at Izhevsk State Medical Academy and complied with the Declaration of Helsinki. All patients gave oral informed consent.

RESULTS: It is generally established that the distribution of temperatures is highly symmetric in people not exposed to injury (Fig. 1). However, injuries such as bruises and grazes can be detected by disturbed symmetry of temperature distribution. Higher temperatures are detected at the site of the tissue damage. In some cases, the maximum temperature of the injured site coincided with the geometrical centre of damage (Fig. 2).

In some patients, most of the heat was observed below the injury, possibly caused by edema production in soft tissues. In this regard, the area with the maximum temperature, which is below the site of injury is compared with the contralateral side. (Fig. 3)

The magnitude of temperature differences depends on the body region, the area of damage, gender and age of the injured subject. Nevertheless, the most significant parameter in forensic medical examination was the accurate identification of dynamics temperature. This was achieved by a number of mathematical expressions describing the change (decrease) of temperature difference values in the post-traumatic period. The course of temperature for a period of 24 to 120 hours is described by the exponential function. The magnitude of temperature differences depends on the body region, the area of damage, gender and age of the injured subject. Nevertheless, the most significant parameter in forensic medical examination was the accurate identification of dynamics temperature. This was achieved by a number of mathematical expressions describing the change (decrease) of temperature difference values in the post-traumatic period. The course of temperature for a period of 24 to 120 hours is described by the exponential function.

The mathematical calculation of the onset of trauma, based on infrared thermometric data of injuries, can be performed with the following equation

$$T=A-B\times Dt+C\times S-D\times Age;$$

where T - onset of a trauma in hours; Dt -temperature difference in degrees Celsius; S - area of damage of $cm^2$; Age - age of the victim, in full years; A, B, C, D - the coefficients depend on the type of injury (bruise, graze) and its localizations.

Agreement between the real and the estimated time of injury was tested with the method of mean error and its 95% confidence interval. Critical evaluation of the developed mathematical equations completely confirmed their accuracy. This recommended this method to be used for examination in the Bureau of forensic medicine in Russia in order to confirm of experts opinion on the onset of trauma resulting in bruises and grazes in injured subjects.

CONCLUSION: Studying temperature features of injuries such as bruises and grazes has a high impact in the practice of forensic medicine and generated new scientific knowledge, allows a better definition of the onset of injuries by improving the accuracy and objectivity of forensic medical examinations.

The scientific and practical novelty was confirmed with two patents for inventions of Russia.

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## COMPARISON OF CORE TEMPERATURE MEASURED AT THE ESOPHAGUS WITH INFRARED THERMOGRAPHIC TEMPERATURE MONITORING IN PATIENTS UNDERGOING GENERAL ANESTHESIA

Bartosz Rustecki[1], Agnieszka Rustecka[2], Boleslaw Kalicki[2], Francis Ring[3], Przemyslaw Kwasiborski[4], Andrzej Truszczynski[1], Anna Jung[2]

[1] Klinika Anestezjologii i Intensywnej Terapii

[2]Klinika Pediatrii, Nefrologii i Alergologii Dzieciecej
Military Institute of Warsaw,. Szaserów st. 128

[3]Medical Imaging Research Group University of Glamorgan, UK

[4] Zaklad Biofizyki i Fizjologii Czlowieka WUM, Chalubinskiego 5

Patients under general anesthesia are endangered of cooling. All anesthetics disturb the function of thermoregulation centre and delay its reaction to cooling. Without a heat preserving treatment, all patients undergoing general anesthesia are endangered of decreasing their core temperature.

Post-surgery cooling has a negative impact on patients comfort and increases the perioperative risk, affecting mostly elderly patients under prolonged surgical procedures. Humans without clothing cool down quickly in an environmental temperature below the threshold of thermal comfort temperature. Patients under general anesthesia cool down quicker and reach the equilibration with environment temperature even later. Therefore, temperature should be monitored during all major surgery procedures. The temperature measured with an esophageal probe is the most preferable and accurate measurement of core temperature, but due to many reasons is not widely used and cannot performed in procedures of regional anesthesia techniques. Temperature monitoring by means of an infrared camera might be an interesting alternative for temperature monitoring during general anesthesia.

In prevention of cooling under anesthesia for general surgery, all patients receive warm i.v. fluids. A special measure to limit perioperative cooling is the usage of special mattress which can be heated beneath the patient placed on the operation table.

This study was designed to investigate whether core temperature can be monitored in a non-invasive way during general anesthesia by an infrared camera while examining the effectiveness of heated mattresses in prevention of perioperative cooling

After obtaining informed consent for participation in the study, patients over 50 years old, under 30 BMI, planed for general anesthesia in major surgical procedures with a predicted duration over 2 hours were included. Patients were randomized into two groups: group 1 did not receive additional warming during general anesthesia. In group 2 patients were warmed by mattresses with a surface temperature set to 39°C

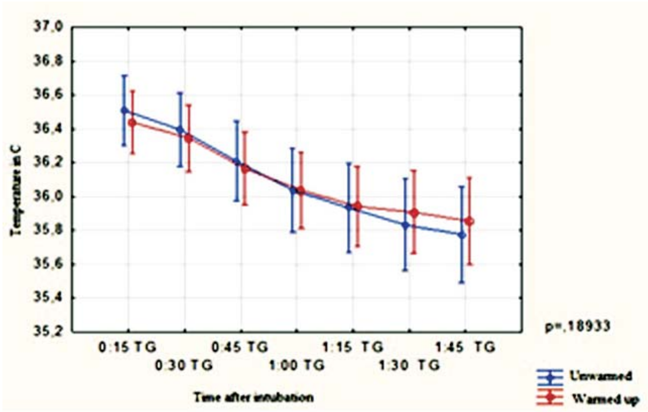


Figure 1
Changes of deep temperature measured in esophagus during anesthesia in time

Every 15 min infrared images of the patients face were recorded. Core temperature measured with an esophageal probe, and the surface temperature of mattress were registered. Data from infrared images were afterwards analyzed.

52 patients were included, 23 in group 1 (without warming) and 29 in group 2 which received preventive intervention against perioperative cooling. Groups did not statistically differ with respect to age, weight, height, BMI or baseline core temperature.

Esophageal measured core temperature showed in both groups a similar trend of temperature decrease until 90 minutes after intubation, from 36.49±0.46ºC to 35.79±0.64ºC in the first group, and from 36.45±0.47ºC to 35.95±0.58ºC in the second group, respectively. Afterwards patients from both groups continued to cool down, but patients from the warmed group decreased their core temperature group slower than subject of the

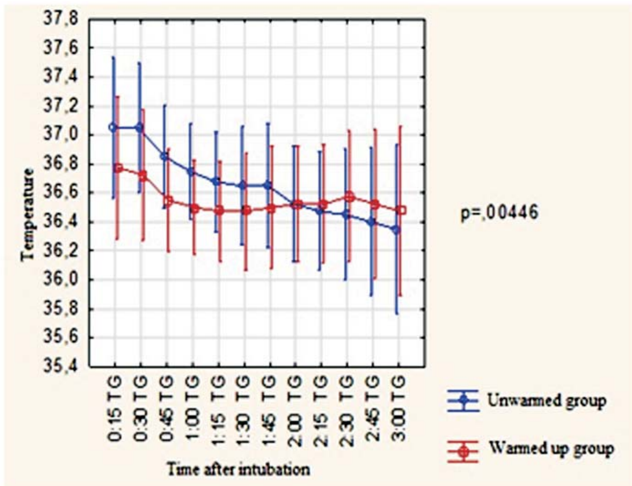


Figure 2
Changes of deep temperature measured in esophagus during anesthesia over time.e

non-warmed group. There were no statistical difference between groups in 1 hour 45 minutes check (p=0,189) (Diagram 1). After 3 hours of anesthesia, a significant difference was evident with p=0,004, with less cooling effect in the warmed group (n=4, in each group) (Diagram 2).The number of patients undergoing prolonged procedures was too small for performing any meaningful statistical analysis.

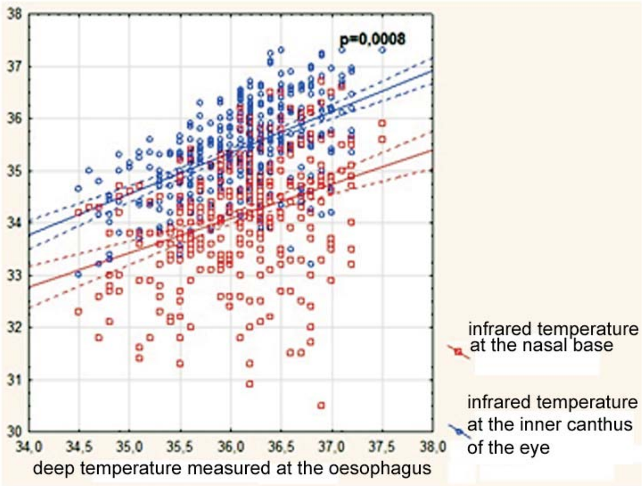


Figure 3
Result of linear regression analysis for association between deep temperature measured in esophagus and infrared markings received in both ways. P value reflects degree of Real differences between obtained correlation coefficients.

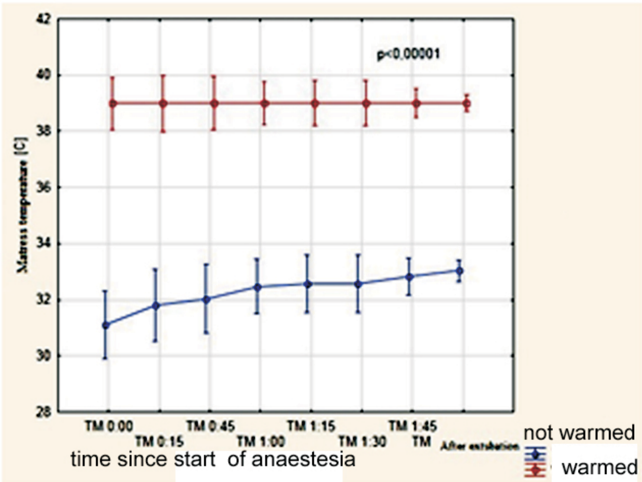


Figure 4
Changes of mattress temperatures in groups over time

Infrared images were analysed with two different measurement areas. Firstly, the average temperature from to regions of interest placed at the inner canthus of both eyes was calculated. This measurement showed a similar temperature drop in both groups: from 35.78±0.86ºC obtained immediately after intubation to 35.18±0.85ºC 90 minutes after intubation in group 1, and from 35.53±0.93 ºC to 35.26±0.74 ºC in group 2.

The second measurement were taken from at the base of the nose and obtained significantly lower temperatures. 34.23±1.16 ºC and 34.01±1.1 ºC in group 1, and, 33.89±1.37 ºC and 34±1.06 ºC in group 2, respectively. No trend of patients´ cooling was observed with that measurement area.

We obtained a high correlation between the esophageally measured core temperature and the infrared based temperature at the inner canthus of the eye count and only a small correlation between core temperature and the temperature of nasal base. Linear regression analysis showed a higher relevance of the correlation with the temperature of the inner canthus than the temperature at the nasal base (p=00008). This findings support the possibility of monitoring temperature with infrared technology during anesthesia. The proposed monitoring procedure will benefit from improved camera technology and software based synchronization of temperature measurements with the performance of anesthetic machines.

There were no statistically important differences in heat loss between patients in the warmed and non-warmed group, although less cooling was observed after 90 minutes in warmed patients. Only in prolonged procedures patients might obviously benefit from using heated mattresses. Despite that, other measures must be taken to prevent patients cooling during anesthesia.

## EVALUATION OF PARAVERTEBRAL BLOCKS FOR MASTECTOMY IN AN HIGH RISK PATIENT BY MEANS OF INFRARED IMAGING - A CASE REPORT

Marcin Mozanki[1], Bartosz Rustecki[1], Boleslaw Kalicki[2], Anna Jung[2]

[1] Klinika Anestezjologii i Intensywnej Terapii.
[2]Klinika Pediatrii, Nefrologii i Alergologii Dzieciecej,
Military Institute of Warsaw, St. Szaserów 128

Thoracic paravertebral block is the technique of injecting local anesthetic adjacent to the thoracic vertebra close to where the spinal nerves emerge from the intervertebral foramina. It is effective in treating acute and chronic pain of unilateral origin from the chest and abdomen. This technique is followed by pain relief with preservation of pulmonary function and hemodynamic stability.

66 year old woman (156 cm, 80 kg, BMI 32) with chronic right heart failure, hypertension and obesity, on chronic oxygen therapy was presented for elective mastectomy due to breast cancer. She suffered from severe COPD and also bullous emphysema. FVC 1.59 l; FEV1 0.55 l; FEV1%FVC 34.6.

The paravertebral block was performed using the multi-shot percutaneous technique at Th3, Th4, Th5 and Th6. This technique causes very good pain relief and also excellent preservation of pulmonary function and stable hemodynamics as well. There is only a short list of adverse effects and possible complications. In addition to nerve blocks, deep sedation was used. For confirmation of sufficient analgesia, temperature changes were monitored using a FLIR i7 infrared camera. Infrared images were recorded 20 and 30 minutes after initiating the nerve blocks. Infrared based temperature readings indicated a rise of tempera-

Table1.
Mean infrared temperature readings

| Marked segment | Time 0 | Ä Time 0-+20 | Time + 20 | Ä Time +20-+30 | Time + 30 |
|---|---|---|---|---|---|
| seg Th2 | 33,1 | 1,3 | 34,4 | 1,1 | 35,5 |
| seg Th2-3 | 34,1 | 1,1 | 35,2 | 0,1 | 35,3 |
| seg Th3-4 | 33,3 | 1,2 | 34,5 | 0 | 34,5 |
| seg Th4 | 32,6 | 0,8 | 33,4 | 1,4 | 34,8 |
| seg Th5 | 33,2 | 0,7 | 33,9 | 0,4 | 34,3 |

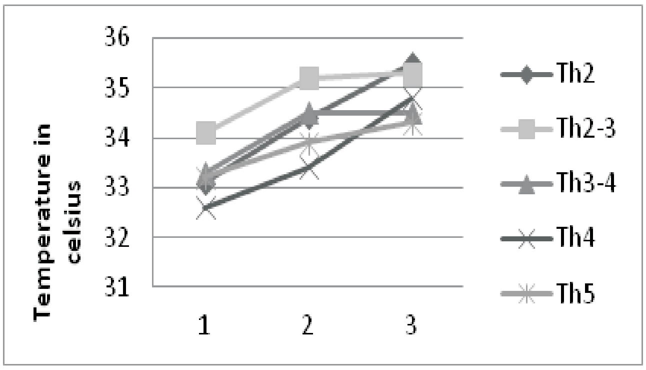


Figure 1.
Temperature changes in check points. 1 - before blockade, 2- 20 minutes after blockade, 3 - 30 minutes after blockade

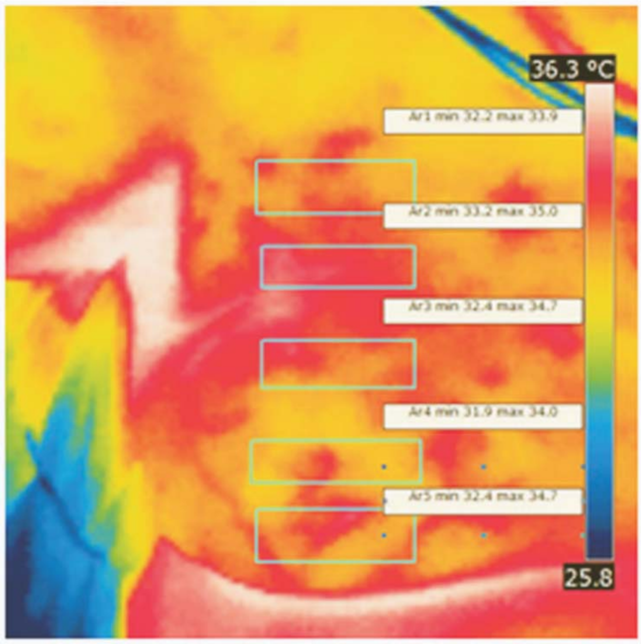


Figure 2.
Infrared image recorded before paravertebral blockade.

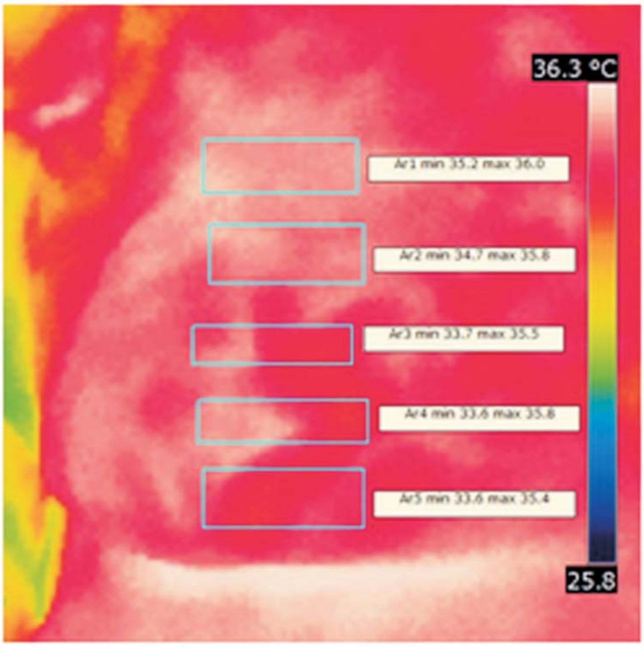


Figure 3.
Infrared image recorded e30 minutes after paravertebral blockade..

ture in each level of nerve blocks 20 minutes after injection. Later infrared temperature readings showed a further increase of temperature in the region of interest confirming the block of the sympathetic nervous system and indirectly a sufficient amount of analgesia. Temperature changes are shown in Table 1 and Figure 1. Example infrared pictures are in Figures 2 and 3. There were no hemodynamic and pulmonary complications postoperatively.

Paravertebral block in combination with sedation creates excellent conditions for breast surgery procedures. Additional temperature monitoring performed with infrared camera may indicate a sufficient range of analgesia needed to perform surgery. A stable, undisturbed cardiovascular system and good, preserved pulmonary function recommends this method as excellent for high risk patients. Low complication rate is an additional advantage.

## LOCAL FACIAL TEMPERATURE CAN BE USED TO IDENTIFY THE SALIVARY GLANDS, MIMIC AND MASTICATORY MUSCLES

M.G.Soiher[1], M.I.Soiher[1], A.L.Urakov[2], A.P.Reshetnikov[2], M.V.Kopylov[1], E.L.Fischer

[1]Institute of Biotechnology and Interdisciplinary Dentistry, Moscow, Russia
[2]Izhevsk State Medical Academy, Izhevsk, Russia

INTRODUCTION: Currently, the standard diagnostic procedures in dentistry do not include an assessment of the dynamics of the local skin temperature of the face before and after application of provocative stimuli such as the input of warm water into the oral cavity and/or chewing rough food [4,5]. However, available data suggest that the infrared thermographic examination of the extremities can predict the clinical outcome in cardiovascular disease, ischemia and hypoxia [1, 6, 9]. Other research findings had shown that the installation of warm solutions of drugs into the subcutaneous fat or elastic intravascular catheters inside of subcutaneous veins is followed by characteristic variation dynamics of local temperature of the overlying skin. These skin temperature changes might be regarded as a diagnostic symptom of inflammatory infiltrates in subcutaneous tissue and veins [2, 7, 8,]. In this regard, analysis of the dynamics of local facial temperatures during and after provocative tests may assist in identification of symptoms caused by diseases located in the oral cavity. In particular, in the skin in the area of the projection of the teeth, bones, joints, muscles and salivary glands may present with high temperature in conditions of local inflammation, cancer, or high functional activity. Such a diagnostic approach may become a new safe method considering thermal conductivity, heat production and tissue structure of the face and head in diagnostic decisions.

METHODS: In 10 adult healthy volunteers aged 20 to 29 years; the skin temperature of cheeks was investigated before, during and for 30 minutes after application of two provocative tests. Firstly, 15 - 20 ml of warm water at the temperature of +40 ± 1°C were installed into the oral cavity and secondly the participants chewed for 30 seconds a handful of shelled almond nuts. 20 patients at the age of 19 to 70 years with a diagnosis of "bruxism" (10 people) and "focal dystonia the muscles of the face" (10 people) were also investigated. Dynamics of the facial skin temperature was recorded with the thermal imager TH91XX (NEC, USA) at an ambient air temperature 24± 0.5°C. The temperature window of the infrared camera was set to the range of 26 -37° C [3, 7, 8]. Surface electromyography (EMG) was used for monitoring the bioelectric potentials of facial muscles.

Botulinum toxin "A" (Lantox®) has been injected in the masseter or temporal muscles. Medication was administered into the chewing muscles by intramuscular injections through the skin and/or through the mucous membrane of the oral cavity at a dose of 30 - 50 units at the right and left side of the face. In temporal muscles, medication was administered by intramuscular injections through the skin at a dose of 15 to 20 units in each muscle parts, resulting in a cumulated total dose of 100 units of Lantox. Muscle target for injection were selected on the basis of high tension identified by light palpation, increased electro-physiological activity in the surface EMG, and local hyperthermia on the skin in the area of projection of the muscles visible on infrared images.

All patients declared informed consent and received their injections on an outpatient basis in treatment room of the hospital.

RESULTS: Prior to the provocation test, skin temperature of the cheeks is lower than the temperature of adjacent areas of the face, with exception of the nose. The temperature of the skin on the right or left half of the face is the same. After chewing a handful of shelled almonds, facial skin temperature of healthy volunteers started to rise, reaching the highest values within 10 minutes. In 7 volunteers who chewed nuts evenly at both halves of the denture, the skin temperature in the area of the projection of the masticatory muscles, increased by 1.3 ± 0,4°(p ? 0.05, n = 14) equally on both sides of the face and the skin temperature of adjacent regions also increased, but only by 0.35 ± 0,1°C (p ? 0.05, n = 14). In 3 volunteers who chewed nuts only at the right or left half of the denture, the skin temperature of the cheek also increased, but predominately on one side of the face, leading to asymmetric distribution of facial temperature. Local hyperthermia of the skin was located in the area of projection of the muscles involved in chewing (figure 1).

In patients admitted to the hospital with complaints of pain on the right and/or left side of the face, local hyperthermia is detected on their right and/or left side of the face. Local hyperthermia in the projection of muscles are associated with high tension in these muscles. Inpatients with bruxism, the skin temperature in the projection area of the masticatory muscles exceeds the temperature recorded in the respective skin areas of healthy volunteers by 0.40 ± 0.09 ° C (p ≤0.05). Chewing nuts causes increase of skin temperature in all of these patients, regardless of the site of pain. In patients with facial pain on one side, the temperature of the skin overlying the chewing muscles and the adjacent regions increased in the non- painful part of the face on the average by 0,65 ± 0.15 and 0.50 ± 0.15 ° C (P ≤ 0.05, n= 20) respectively. The temperature rise on the painful side was 1.30 ± 0.30 ° C above the masticatory muscles and 0.40 ± 0.15 ° C in regions adjacent to the muscles (p ≤ 0,05,). Injection of Botulinum toxin into "abnormal" facial muscle reduces the amplitude of bioelectric potentials, the magnitude of the relative hyperthermia, stiffness and soreness of muscles and normalizes the chewing function. 3 days after application of Lantox, the local hyperthermia in the area of the projection of "abnormal" of muscles was reduced by 0.44 ± 0.03 ° C (p ≤ 0,05, n = 10) in these patients.

The introduction of water at a temperature of 40 ± 1° C for 3 minutes into the oral cavity, promoted the development of local hyperthermic zone on the skin of the cheeks in the area of projection of the salivary glands. These areas cheek on both cheeks are of oval shape , and its temperature exceeds the temperature of the adjacent regions in average by 0.9 ± 0.2°C (p ≤ of 0.05, n = 15) (figure 2).

Monitoring the thermal radiation from the skin of the cheeks by infrared thermography in normal conditions and after at installation of warm water into the mouth, is a promising technique for identify diagnostic patterns of temperature distribution in cheeks, in particular for identification of salivary glands. Infrared thermography of the face can also optimize the diagnosis and treatment of hypertonic masticatory muscles when patients are presented with myogenic pain of the face in dental practice.

CONCLUSION: It was shown that surface electromyography indicates increased electrophysiological activity, and infrared thermography of the facial skin allows to detect increased skin temperature in the area of projection of high tensioned muscles. It was found that injection of botulinum toxin A in a dose of 15 - 20 or 30 - 50 units steps (respectively) into temporal or chewing muscles of high tension, reduced effectively myogenic facial pain, muscular tension and increased electrophysiological activity, local hyperthermia ofthe skin in the field of muscle projection, bruxism, focal dystonia of muscles and normalizes the act of chewing food.

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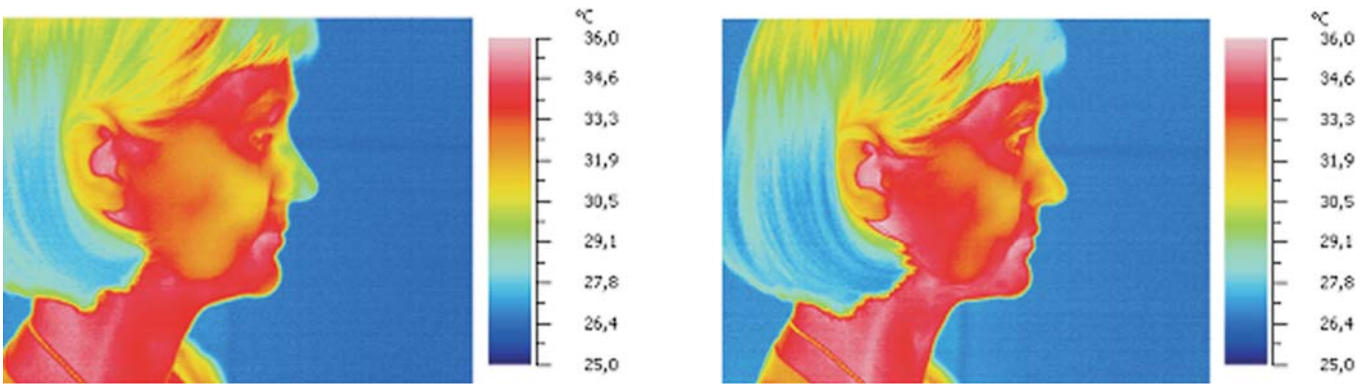


Figure 1.
Infrared thermal image, right side of the face, healthy girl, . recorded before (A) and 10 minutes after chewing (B)food at a temperature of +24 ± 0.5° C

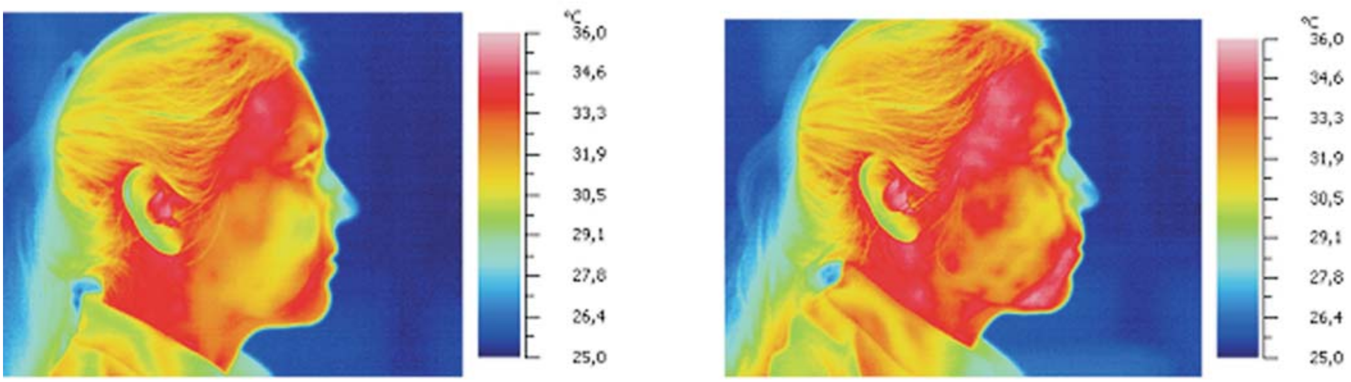


Figure 2.
Infrared thermal image, right side of the face, healthy girls, recoded before (A) and 3 minutes after 20 ml drinking water (B) at a temperature of 40° C

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## APPLICATION OF THERMOGRAPHY FOR DIAGNOSIS AND TREATMENT MONITORING OF THE COMPLEX REGIONAL PAIN SYNDROME TYPE I (CRPS I)

J. Mróz[1], B. Kalicki[2], A. Lipinska-Opakla[2], A. Krawczyk[3,4], A. Jung[2], J. Zuber[2], B. Zaganczyk[2]

[1] Klinika Rehabilitacji Wojskowego Instytutu Medycznego w Warszawie Kierownik Kliniki: cz.p.o. dr n. med. Józef Mróz
[2] Klinika Pediatrii Nefrologii i Alergologii Dziecicenj Wojskowego Instytutu Medycznego w Warszawie Kierownik Kliniki: prof. dr hab. n. med. Anna Jung
[3] Politechnika Czsteochowska Wydzial Elektryczny
[4] Wojskowy Instytut Higieny i Epidemiologii

Complex regional pain syndrome is one of the most poorly understood and frequently misdiagnosed entities in clinical practice. It was previously called algodystrophy, post-traumatic pain syndrome (PTPS), causalgia, or reflex sympathetic dystrophy (RSD). The CRPS is characterized by severe pain of the distal part of limb, oedema, vasomotor dysfunction and impaired efficiency. These symptoms occur after trauma, less common after thoracic surgeries, myocardial infarction, stroke, peripheral nerve injury and seldom in the course of venous or arterial thrombosis. Whilst these symptoms are restricted to the innervation area of the injured nerve in CRPS type II (formerly called causalgia), CRPS type I develops independently from injuries in the peripheral nerve supply.

Pathomechanism of the disease is unclear, but the most important factor of its pathogenesis seems to be a disorder of the autonomic nervous system. Limb pain and swellings, in the typical cases, are accompanied by vasomotor disturbances, restricted mobility, increased sensitivity to pressure and temperature changes. The course of the disease can be divided into 3 periods: I acute period, II dystrophic period, III atrophic period. Apart from the vasomotor form, we can distinguish paralytic form (after a stroke) and toxic (drug-induced). The majority of patients has emotional instability, hyper-reactivity and a tendency to anxiety and depression. Imaging studies are useful in the diagnosis. The effectiveness of treatment depends on the period in which the diagnosis is made. The sooner patients are treated, the better the outcomes. Analgesics and sympatholytics are used for therapy. Good effects are obtained from decongestants, anti-inflammatory medication and treatment that stimulates bone calcification and also after the application of an alternating magnetic field of low frequency, low-energy laser, whirlpool limbs massage and exercise therapy for the affected limb.

We present a case of 42 year old man with algodystrophic syndrome, which was diagnosed in the advanced second stage of the disease. Pharmacological treatment and physiotherapy had been used for 3 months and led to a significant improvement, which is well documented d by the thermographic examination.

## THERMOGRAPHIC IMAGING IN SELECTED PHYSIOTHERAPEUTIC TREATMENTS

B. Kalicki[1], J. Mróz[2], A. Iwaniszczuk[2], A. Krawczyk[5,6,] A. Lipinska- Opalka[1], B. Rustecki[3], P. Murawski[4], J. Zuber[1], A. Jung[1]

[1]Klinika Pediatrii Nefrologii i Alergologii Dzieciceej WIM,
[2]Klinika Rehabilitacji WIM,
[3]Klinika Anestezjologi i Intensywnej Terapii WIM,
[4]Oddzia? Teleinformatyki WIM,
[5]Politechnika Czsteochowska, 6WIHiE

MAGNETOTHERAPY use the magnetic component of electromagnetic fields at frequency 10 - 100 Hz with the magnetic field intensity in the range of 0.1 mT - 20 mT. The most frequent used device is a solenoid, sometimes flat applicators are used. The therapeutic indications are focused on non-abrasive and painless treatment, contracture resolving through muscle relaxation, analgesic, anti-inflammatory and drainage effect to enhance repair in superficial, and even deep tissue layers.

LASER BIOSTIMULATION is caused by a laser beam of low energy on the human tissue in order to energize living systems. Laser therapy may stimulate the regeneration of bone, blood, lining cells of blood vessels, cartilage, nerve, and muscle. Moreover, it has been documented to enhance the quality of healed tissue. Well-proved effects of Laser therapy are tissue regeneration, reduction of Inflammation, analgesia, enhanced Immune function.

The OBJECTIVE of this paper was to evaluate the thermal effects induced by magnetic field or laser therapy by means of an infrared thermographic camera.

MATERIAL AND METHOD: Five volunteers were examined with infrared camera FLIR T640 according to standard protocol. Two volunteers exposed their hands to magnetotherapy, three other volunteers were stimulated with low energetic laser at the elbow joint. Prior to and after therapy, the skin temperature of the hands and of the elbow were measured. The temperature effect in the body region treated was analysed in relation to the treatment applied.

RESULTS: The histograms of temperatures at examined areas are presented before and after stimulations. Temperature changes within the examined areas became obvious after exposure to magnetic fields and laser beams, respectively.

CONCLUSIONS: 1. EMF with the field intensity between 0.2 mT to 20 mT evoke different thermic effects. It was observed that EMF, particularly those of higher intensity, can cause remarkable changes of skin temperature. Besides heat production as cause of temperature increase, plus and minus deviations of skin temperature might be due to direct modifications of receptors controlling the microcirculation which lead either to vasoconstriction or vasodilatation.

2. It is assumed that the laser beam used for biostimulation is athermal. However, the thermographic examination showed an increase in temperature at the site where the laser beam was ap-

plied. The laser energy causes an increase of temperature because the thermoregulation system is not able to counteract and dissipate the heat within the short treatment period of 2-5 minutes.

## TEMPERATURE OF THE SITE OF INJECTION IN SUBJECTS WITH SUSPECTED “INJECTION'S DISEASE"

A.L.Urakov, N.A.Urakova

Izhevsk State Medical Academy, Izhevsk, Russia

INTRODUCTION: For long time, processes of local injuries caused by injection of medicaments leading to infiltrative damage of the skin, subcutaneous fat and other tissues have not been studied, although tissue necrosis and subsequent development of a purulent abscess as the most severe unwanted outcome of this procedure are well known. It was believed that they are not a direct consequences of injections. Such an understanding of the pathogenesis of the disease interfere with the practice of the late detection of affected patients who sought medical help in the final stage of the disease, after necrosis has become infected and transformed into a festering sore that justify hospitalization of patients in the department of purulent surgery. A correct understanding of the etiology of diseases supported the common opinion about the high quality of solutions for injections. Therefore, the cause of the development of necrosis and an abscess at the injection site was considered as an infection due to violation of standards of asepsis and antisepsis during administration of injectable drugs [2,3,6,7].

We found that the main cause of the disease is soaking of tissue with blood and/or solutions for injection, especially those that contain drugs in concentrations of more than 10% [4,5]. In 2013 we described for the first time etiology, pathogenesis, course of disease, outcomes and measures for prevention and treatment of this pathology and received the authority to call it "Injection's disease" or "Urakov's disease" [8,9]. Injection's disease is characterized by the emergence of local inflammation of the skin, subcutaneous fat, skeletal muscles and other soft tissues, which had been punctured by injection needles and infiltrated with saturated solutions of medicaments. Subjective symptoms of this disease are local tenderness and hardness of tissues that were pierced with needles and soaked with saturated drug solutions. Objective symptoms of injection's diseases are puncture wounds, coloured spots on the skin in the areas of puncture, inflammatory infiltration and hardening of soft tissues beneath the lesion.

The threat of injection's disease persists because needles cause regularly an interstitial hemorrhage, and pharmaceutical companies continue in production of medicinal products with irritating action. Under these conditions, early detection of the onset of injection's disease is an important task and this problem can be solved with the help of IR-thermography of the skin at the injection site [1,3,7].

METHODS: Temperature and condition of the injection at the buttocks, hips, arms and abdomen were studied in 300 adult patients of both sexes in 5 hospitals of the city of Izhevsk in 2012 and 2013. In 10 piglets of both sexes the abdominal region was investigated in the same way. Evaluation was performed visually by eye, by using the ultrasound device Aloka SSD-900 (Japan) and by Thermo Tracer TH9100XX (Nec, USA) before, during and after the injection of drugs with respect to their osmotic activity that were determined with cryoscopy method using the Osmomat-030 RS (Anselma Industries, Austria).

RESULTS: It was observed that intracutaneous, hypodermic, intramuscular and other interstitial injections of all drug solutions with a temperature of 24 ± 0.5 C, cause short-term decrease in temperature at the injection site, where the temperature drops by a few degrees. Local hypothermia is preserved for 1 - 5 minutes, the duration, the magnitude and the extension of the local hypothermia is directly dependent on the volume of the injected solution. Thus, the area of drug infiltration can easily be visualized with the help of thermal imager. Within few minutes, the temperature of the injection site recovers to baseline readings.

There are 2 options for the dynamics of local temperature. In the one case, the temperature of the injection site remains at the original level. Such a stable temperature after injection indicates a high level of security of the injected drug and the absence of irritation, inflammation, cauterizing or necrotizing actions. As a rule of thumb, solutions of medicaments are secure when their total concentration of the ingredients is below 1%, or 2%, as they are hypo-osmotic or iso-osmotic (respectively). Such medicinal solutions do not irritate or inflame the tissue at the site of injection.

In the other case, the temperature at the injection site starts to rise and within 1 - 2 minutes, the temperature in the centre of the infiltrated area exceeds the baseline value by several degrees. The emergence of central hyperthermia at the injection site indicates a low level of local security of the injected drug that confers irritating, or denaturing (cauterizing) actions causing inflammation, tissue necrosis and abscess formation. We proved that medicinal solutions conduct a high level of local aggressiveness when their total concentration of the ingredients is more than 5% (in case of metal salts) or more than 10% (in case of carbohydrates and similar organic compounds) because they are hyper-osmotic (hypertonic). Therefore, solutions of any medications with total concentration above 10%, are followed by local changes of the affected tissue, similar to the local action of 10% sodium chloride, i.e. having a dehydration effect.

Despite this, specialists of pharmaco-therapeutic committees do not link the total concentration of dissolved ingredients with the osmotic activity of solutions and do not include osmotic activity in the legitimate list of monitor indicators for the quality of medicinal fluids. In this regard, pharmaceutical companies produce medicinal solutions with a total of concentration of 10% (Sol. Calcium Glukonate), 30% (Sol. Sulfacetamide Sodium), 40% (Sol. Glucose), 50% (Sol. Sodium Metamizol) and even 76% (Sol. Urographin) and list all drugs regardless of the pharmacological action in one combined group -the group of hypertonic deyhydrating solutions.

Thus, the VALUE of TOTAL CONCENTRATION and OSMOTIC ACTIVITY of the medicinal solutions is an important factor of their local action.

Our experience shows that the local pharmaceutical aggressiveness of some medicaments may be caused by other factors (for example, excessively high acidity, concentration of alcohols, aldehydes, Ca2+ or K+, and others). However, the existence of a local hyperemia at the injection site is a universal indicator of aggressiveness (local toxicity) of drugs.

Monitoring the local temperature at the site of intracutaneous, subcutaneous and even intramuscular injection using the IR-thermography for 10 minutes after injection, provide information about the dynamics of the local temperature, ensuring accurate and timely assessment of the state of tissue at the injection site, and assist the identification of inflammation in local tissues after a short period or long period after the injection (figures 1 and 2). In fact, local hyperthermia, hyperemia, swelling, and soreness develops at the injection site 6 - 8 minutes after injection of irritant or cauterizing drugs. As shown in the illustration figures, IR thermography provides means for identifying of local temperature increase over the site of inflammation located in the skin or subcutaneous fat, and also in skeletal muscles after intramuscular injection.

CONCLUSION: It was shown that normally the temperature of the tissue at the injection site of a safe drug may decrease for a short period, but then returns to baseline readings. Medicaments

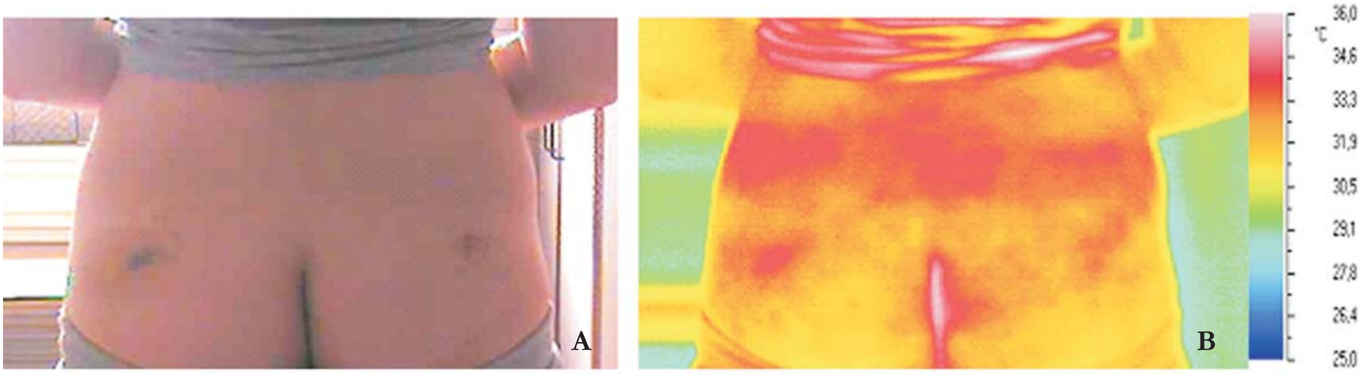


Figure 1.
Gluteal region patient C., 28 years (department of gynecology) 48 hours after 7 days i/m injections every 12 hours 3.8 ml 30% Ceftriaxone (Ceftriaxone sodium for Injection 1g, lidocaine hydrochloride 1% 3.5 ml - CSPC Ouyi Pharmaceutical Co. Ltd, PRC, year of manufacture - 2013, series [1] 659130168). Injections were made using a syringe volume 5 ml mark «Luer» (manufacturer Tianjin Medic Medical Equipment Co. Ltd, China) and needles injecting 22Gõ11/2 (needle thickness of 0.7 mm and a length 38 mm). A - visible image B – the IR-image.

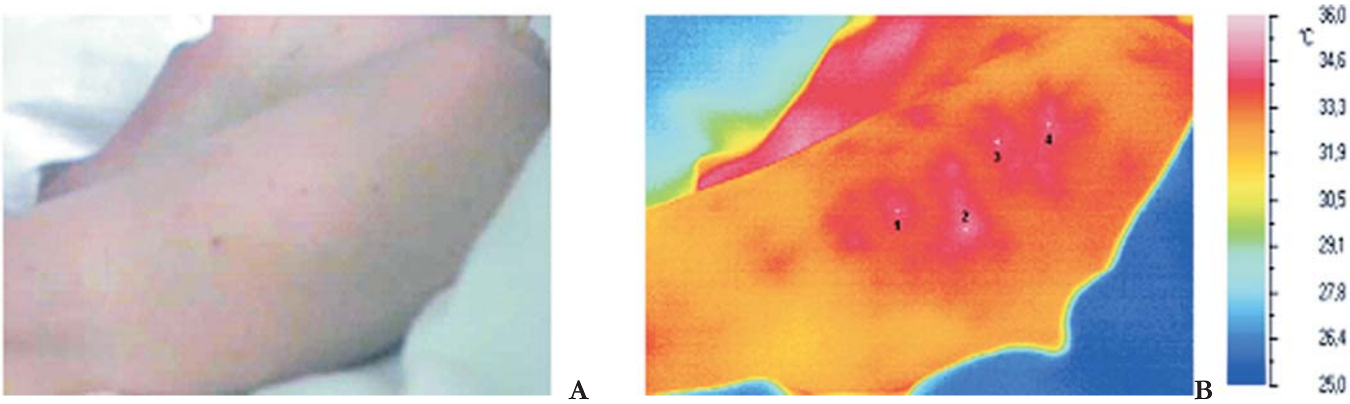


Figure 2.
The left shoulder of the patient D., 46 years after the 4 intramuscular injection of 1 ml solution Ketorol® (Ketorolac Tromethamine 30 mg/ml, Solution for injection 1 ml. Dr. Reddys Lab. Ltd. Year of manufacture - 2012, Series ? A2674) every 6 hours. Injections were made using a syringe volume 5 ml mark "Luer" (manufacturer Tianjin Medic Medical Equipment Co. Ltd, China) and needles injecting 22G?11/2 (needle thickness of 0.7 mm and a length 38 mm). A - visible image B - IR-image

with irritant or cauterizing action, cause a long-lasting local hyperthermia. Monitoring the local temperature at the injection site by IR-thermography has a high predictive value for the diagnosis and treatment of injection's disease.

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## ASSESSING THE IRRITATING EFFECT OF INTRAVENOUS CATHETERS BY INFRARED THERMOGRAPHY

A.A.Kasatkin[1] , A.P.Reshetnikov[1,2]

[1] Izhevsk State Medical Academy, Izhevsk, Russia

[2] Dental clinic "ReSto", Izhevsk, Russia

INTRODUCTION: Catheterization of patient's peripheral veins may be accompanied by local complications such as venous thrombosis and phlebitis (1). Modern technology of venous catheterization and standardised monitoring of the area of catheterization do not prevent complications totally (2). To prevent the development of these complications manufacturers of catheters recommended to remove catheters within 48 - 72 hours after installation (3).

We hypothesized that one of the causes of local phlebitis may be a response to irritation of the endothelium of the vein due to prolonged contact with the intravascular catheter. Experimental findings in pigs indicated the presence of irritant properties of intravascular catheters, which was accompanied by the development of local hyperthermia on the skin surface in the projection of the catheter set (4).

In this regard, we propose thermographic monitoring of the catheterization site for the assessment of irritating effects of intravascular catheters, installed in superficial veins of hospital patients.

METHODS: Observations were conducted in 100 patients of anesthesiology department of Izhevsk Clinical Hospital (Izhevsk, Russia) and Dental Clinic "ReSto" (Izhevsk, Russia) in 2009-2012. The area of vein catheterization was investigated by infrared images recorded with a ThermoTracer TH9100XX (NEC, USA). The obtained data were processed with the software Thermography Explorer and Image Processor The study was approved by the Ethics committee at Izhevsk State Medical Academy and complied with the Declaration of Helsinki. All patients gave informed consent.

We investigated the dynamics of temperature based on infrared radiation from the patient's skin overlying the superficial veins, before and after installation of the catheter into the vein. The region of interest was defined by an area of the skin extending from the site of puncture over the total catheter´s length.

RESULTS: In normal skin, the temperature in the area of catheterization ranged from 29,4 to 35,2 °C, and the temperature gradient between the puncture site at the skin and the projection of the tip of the intravascular catheter did not exceed 0,4 º C.

The emergence of a permanent local hyperthermia of the skin in projection of tip of the intravascular catheter indicates local inflammation of the venous wall. In this condition, the temperature gradient between the puncture site at the skin and the projection of the tip of intravascular catheter were in the range 0.5-1.1 º C. Local increase in skin temperature overlying the tip of the intravenous catheter was accompanied by local pain in 56% of patients, and local hyperemia of the skin in 10% of patients. This may indicate a high sensitivity of infrared thermography in detecting early signs of damage and inflammation of the vascular wall. It should be noted that the appearance of local hyperthermia was recorded within the first 24 hours after catheterization in patients in whom catheters have been installed in the area of moving elbow, wrist and ankle joints (Fig. 1). In patients with immobilized limbs, in which intravenous catheters have been established, local hyperemia did not develop within 24 hours. Thus, the installation of intravascular catheters in the subcutaneousl veins overlying moving joints may increase the likelihood of catheter induced damage of the endothelium, regardless of the polymer material of the catheter.

The results of these studies confirm our assumption that intravascular catheters may irritate the endothelium of veins and cause phlebitis.

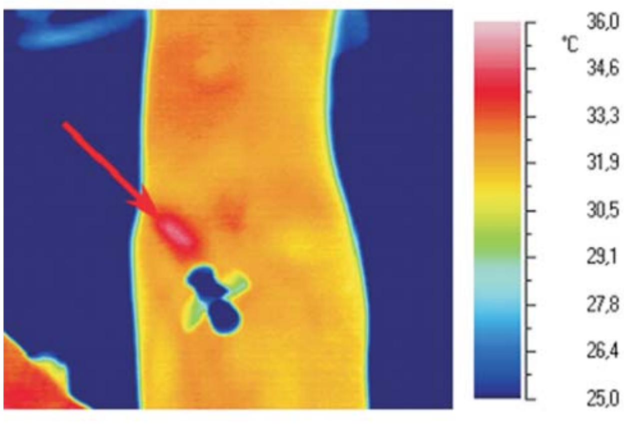


Figure 1
Infrared image of the left forearm of patient P., at age 32, made 1 hour after vein catheterization (arrow marks the local hyperthermia of skin in projection of intravascular tip of catheter).

The results obtained, allowed us to develop methods to improve the efficiency and safety of intravenous injection of drugs and vein catheterization, and also provide a method to monitor the irritant effect of intravascular catheters (5, 6, 7).

CONCLUSION: This study supports the value of temperature measurement in the assessment of irritating effects of intravenous catheter used in hospitals. The emergence of a permanent local hyperthermia of the skin in projection of the intravenous catheter indicates the presence of irritant properties of the catheter.

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5.Urakov AL., Urakova NA., Urakova TV. Method of subcutaneous veins imaging in infrared radiation spectrum range according to A.A.Kasatkin. Patent 2389429 RU, 2009.

6.Urakov AL., Urakova NA., Urakova TV. et al. Method for ulnar vein catheterisation and multiple-dose intravenous drug introduction. Patent 2387465 RU, 2010.

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## THE USE OF INFRARED THERMOGRAPHY IN NEONATOLOGY

Vlad Dima,, Mihaela Demetrian, Clara Dima, Adriana-Sarah Nica

SCOG Filantropia Bucuresti, INRMFB Clinica III Bucuresti

INTRODUCTION: Infrared thermography is an alternative for measuring the body temperature of neonates without touching or disturbing them. This technique may replace the conventional means of measuring the body temperature. It works by measuring the thermal radiation from the body's surface.

OBJECTIVE: Promoting this noninvasive method of measuring the body's temperature. Due to this method we can eliminate the discomfort generated by sticking and detaching temperature sensors to the skin, thus preventing the dermatitis generated by adhesive tape.

MATERIALS AND METHODOLOGY: We used an infrared digital camera for measuring the body temperature of 45 neonates in the first hour of life.

RESULTS: Arms, ties and buttocks tend to change their temperature according to the room's temperature. The skin on the abdomen has a more stable temperature that does not change so easely.

CONCLUSIONS: The infrared digital cameras are easy to use, precise and can measure very rapidly the neonates' body temperature without touching them, in perfect consistency with the minimal stimulation protocol specific to the NICU

## THE USAGE OF THERMOVISION IN EXAMINATION OF ELECTROMAGNETIC STRUCTURES

Andrzej Krawczyk

Czestochowa University of Technology, Electrical Engineering Department. Military Institute of Hygiene and Epidemiology,Warsaw

Electromagnetic Field (EMF) is a natural source of heat in all solid materials, conducting, ferromagnetic and dielectric. The mechanisms of a heat generation are different depending on the materials:

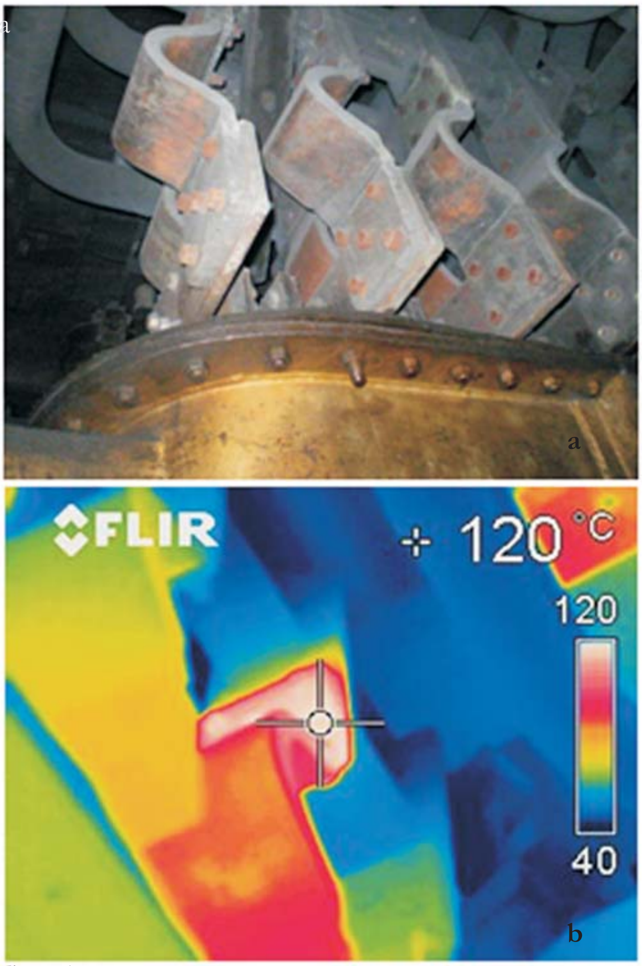


Figure 1
Electric connections of bus-bars supplying the arc furnaces:
a) bus-bars, b) thermograms

- in the conducting materials heat is generated due to current flow, according to Ohm's law (Joule's heat),
- in the magnetic materials heat is generated due to movement of domains and the phenomenon of hysteresis,
- " in dielectric materials heat is generated due to polarisation of electric dipoles.

Recently, remote thermography technologies have been used to determine the temperature distribution. The temperature distribution is very helpful in the designing process of electrical machines and electric power systems

As an example of the thermographic examination, the temperature distribution on the surfaces of bus-bars which supply the electric arc furnaces. The temperature distribution is presented in Fig.1.

## INFRARED THERMOGRAPHY AS A SUPPORT TOOL FOR SCREENING AND EARLY DIAGNOSIS OF SPORT INJURIES

Manuel Sillero-Quintana[1], Tomás Fernández Jaén[2], Ismael Fernández-Cuevas[3], Pedro M. Gomez-Carmona[3], Javier Arnáiz[1], María-Dolores Pérez[1], Pedro Guillén[2]

[1] Sports Department. Physical Activity and Sports Faculty. Technical University of Madrid (UPM), Madrid, Spain
[2] CEMTRO Clinic, Madrid, Spain.
[3] PEMAGROUP, Madrid, Spain.

There are sufficient means to reliably diagnose sport injuries and to specify the lesion produced; however, they are not real-time, low-cost, harmless and easy-to-use as screening method in emergency trauma services. This work tries to establish the ability of infrared thermography (IRT) to discriminate injuries and its applicability in emergency trauma scenarios.

The sample consisted of 202 patients of the Emergency Unit at the CEMTRO clinic in Madrid (108 males and 94 females). Average and maximal skin temperatures (Tsk) from the injured and the contralateral non-injured region of interest (ROI) were collected from a thermogram recorded with a T335 FLIR infrared camera, and the results contrasted with the diagnosis of the emergency unit practitioner.

The Tsk differences between the injured and the uninjured area ( Tsk) were significant ($p<0.05$) for both average ( Tsk=+0.5°C) and maximum ( Tsk=+0.6°C) temperatures. These side-to-side Tsk data agreed with the thresholds of asymmetry established in previous studies. The results analysed with respect to injured ROI, type of injury, medical diagnosis of the practitioner and evolution time of the injury, showed a good specificity of IRT for detecting injuries. The influence of the usage of ice and anti-inflammatory creams on Tsk results was analysed in some cases selected from the general study.

Results indicate that thermography is a valid tool to determinate the existence of an injury. When a high resolution infrared imager is used and an appropriate protocol is followed, IRT might become a valuable tool which provides the practitioner with additional information for correct identification of sport injuries.

## NON-INVASIVE EVALUATION OF LACTATE LEVEL IN CAPILLARY BLOOD DURING POST-EXERCISE RECOVERY

Jakub Grzegorz Adamczyk[1,2,] Dariusz Boguszewski[2], Marcin Siewierski[1],

[1]. Rehabilitation De-partment, Physiotherapy Division, Warsaw Medical University, Poland
[2]Theory of Sport De-partment, Józef Pilsudski University of Physical Education in Warsaw, Poland

INTRODUCTION. Changes in body temperature and in the blood lactate concentration are typical reactions of an organism to work load. The aim of this work was to investigate the relationship between the temperature of the lower extremities and the blood lactate concentration as possible method of assessment of the magnitude of work load induced by physiotherapeutic interventions.

MATERIAL AND METHODS. Sixteen non-training male subjects participated in the test (average age: 22.3 ±1.6 years). They performed maximum-height jumps from a fully knee-bent position for one minute. Their body temperature was measured by infrared thermal imaging and blood lactate concentration was determined at the beginning and throughout a 30-minute recovery.

RESULTS. An analysis of isotherms showed a strong relationship between the temperature of the anterior surface (AS) and posterior surface (PS) of the lower extremities ($r=0.83$; $p<0.05$). Immediately after the exercise, the temperature of the lower limbs decreased on average by 1.44°C ($p<0.001$) and returned almost to baseline values during the recovery period. There was a significant negative correlation ($r= -0.29$; $p<0.05$) between the temperature of lower limbs and the blood lactate concentration, both for AS ($r= -0.22$; $p<0.05$) and PS ($r= -0.23$; $p<0.05$).

CONCLUSIONS. 1. The results show that a maximum anaerobic effort is accompanied by a substantial drop of the temperature on surface of engaged muscles and the magnitude of post-exercise drop of temperature is proportional to the blood lactate concentration. 2. A physiotherapist can be useful member of coaching staff.

## IR-DESCRIPTORS IN QUANTITATIVE EVALUATION OF WOUND HEALING

Nowakowski A.*, Moderhak M. *, Kaczmarek M.*, Siondalski P.**

*Politechnika Gdanska, Katedra Inzynierii Biomedycznej
antowak@biomed.eti.pg.gda.pl
** Katedra i Klinika Kardiochirurgii i Chirurgii Naczyniowej GUMed

The aim of this presentation is to analyze the possibility of using the recently elaborated infrared imaging procedure called Active Dynamic Thermography (ADT) for quantitative diagnostis and evaluation of wound healing processes in cardiosurgery. Classical thermal features and novel descriptors are compared from the point of view of objective, quantitative estimation of wound state. Temporal properties of thermal transients are proposed for the objective quantitative description of the healing process. Algorithms enabling the evaluation of surgical wound healing process are discussed in terms of possible implementation of the method into clinical practice.

# Meetings

## $11^{th}$-$12^{th}$ June 2014

MeMeA2014 - $9^{th}$ edition of IEEE International Symposium on Medical Measurement and Applications in Lisbon, Portugal

Special session on
"Developments and Applications of Thermography"

Organizers:
Joaquim Gabriel, Faculty of Engineering,University of Porto, Portugal, jgabriel@fe.up.pt
Ricardo Vardasca, Faculty of Engineering, University of Porto, Portugal, ricardo.vardasca@fe.up.pt

Http://memea2014.ieee-ims.org,

## $7^{th}$-$11^{th}$ July 2014

12th Quantitative InfraRed Thermography Conference, QIRT 2014 in Bordeaux, France

### PROGRAMME

*Keynote 1*: Alain Arneodo,
Wavelet-based multifractal analysis of dynamic infrared thermograms and X-ray mammograms to assist in early breast cancer diagnosis

*Keynote 2*: Francis Ring,
Pioneering Progress in Infrared Imaging for Medicine

*Keynote 3:* Gerd Busse,
Lockin-Thermography: Principles, NDE-applications and trends

*Keynote 4:* François Simoens and Olivier Gravrand,
Imaging technology developments at Leti, and focus on cooled and uncooled infrared detectors

*Keynote 5:* V. Vavilov,
Thermal NDT ? Historical milestones, state-of-the-art and trends

### BIOMEDICAL APPLICATIONS

*BIO 1 Tuesday 8th July, 11:00-12:20*

Multifractal analysis of skin temperature fluctuations of women breasts with and without tumor
by E. Gerasimova, B. Audit, S.-G. Roux, A. Khalil, F. Argoul, O. Naimark, A. Arneodo and O. Gileva

Integration of thermographic data with the 3D object model
by M. Kaczmarek

Infrared thermography-based integrated approach aimed at objective evaluation of systemic vascular reactivity in humans
by B. G. Vainer and V. V. Morozov

Proposals to standardize results in human thermography.
by M. Sillero-Quintana, J. Arnaiz-Lastras, P.M. Gómez-Carmona and I. Fernández-Cuevas

*BIO 2 Tuesday 8th July, 16:15-17:55*
(IRT applied to skin)

Study of a possible detection of abnormalities under skin tissue by infrared thermography
by H. Trabelsi, N. Elkadri and E. Sediki

Comparison of image analysis methods in skin temperature measurements during physical exercise
by D. Formenti, A. Trecroci, M. Gargano, G. Alberti, and N. Ludwig

A preliminary study on the relationship between energy expenditure and skin temperature in swimming
by A. Seixas, T. Gonjo, R. Vardasca, J. Gabriel, R. Fernandes and J.P. Vilas-Boas

Thermal skin pattern of diabetic children
by F. J. González, E. S. Kolosovas-Machuca, E. Galván-Sánchez, B. Moncada and A. Di Carlo

*BIO 3 Wednesday 9th July 16:15-17:55*
(Analysis techniques)

Modelling and Correction of Influences on Surface Temperature Measurements using infrared thermography for animal health and welfare assessments
by T. Landgraf, St. Zipser, M. Stewart, S. Dowling, A.L. Schaefer

A correlational analysis of human cognitive activity using Infrared Thermography of the supraorbital region, frontal EEG and self-report of core affective state.
by S.D.Jenkins, R.D.H.Brown

Dynamics of skin temperature of the knee during physical exercise measured by infrared thermography
by V. Svaic, B. Jurinjak, D. Zupanic and A. Bolaric

Lock-in thermography versus dye penetration testing and SEM for in vitro adaptation of smart dental restorative materials (giomers) to the walls of the cavity
by M. Streza, D. Dadarlat, I. Hodisan, C. Prejmerean and C. Boue

A Template Based Method for Normalizing Thermal Images of the Human Body
by R. Vardasca, J. Gabriel, C. D. Jones, P. Plassmann and E. F. J. Ring

*BIO 4 Thursday,10th July, 11:00-12:20*

System and software for thermal image screening in medicine using thermal inverse modeling
by M. Strakowska, M. Strzelecki, B. Wiecek, G. De Mey

Towards a Medical Imaging Standard Capture and Analysis Software
by R. Vardasca, P. Plassmann, J. Gabriel and E. F. J. Ring

A proposal of a standard rainbow false color scale for thermal medical images
by R. Vardasca and J. Gabriel

Rapid vs. delayed infrared responses after ischemia reveal recruitment of different
by By K. Chang, M. Antalek, M. Seidel, T. Darlington, A. Ikeda, S. Yoon, H. Ackerman, A. M. Gorbach

*BIO 5 Thursday,10th July 14:45-15:45*
(IRT cardio applications)

Problems of cardiosurgery wound healing evaluation
by A. Nowakowski, P. Siondalski, M. Moderhak, M. Kaczmarek and L. Jaworski

Infrared thermography as applied to the studies of cardiovascular system in rats
by B. G. Vainer, V. I. Baranov and E. G. Vergunov

Thermography-based blood perfusion imaging in hands: spectral amplification and time shift
by A.A. Sagaidachnyi, D.A. Usanov, A.V. Skripal, A.V. Fomin

*BIO 6 Friday, 11th July 11:00-12:20* (Analysis)

Infrared thermography as an objective technique for evaluation of patch tests results
by M. Szwedo, B. Tomaka, J. Targosz, K. Targosz, B. Jasiewicz-Honkisz

Local temperature head of fetus during final period of birth
by A. Urakov, N. Urakova

Infrared Imaging for Real-Time Noncontact Respiration Monitoring
Abdulkadir Hamidu Alkali, Reza Saatchi, Heather Elphick, Derek Burke

## CALIBRATION AND METROLOGY

*CM1 Wednesday 9th July,11:00-12:20 (technics)*

3D Thermal Imaging: Fusion of Thermography and Depth Cameras
by J. Rangel and S. Soldan

Mapping non-destructive testing data on the 3D geometry of objects with complex shapes
by S. Soldan, D. Ouellet, P.Hedayati, H. Bendada, D. Laurendeau, A. Kroll

Quantitative Infrared Thermography on Carbon Stripper-Foils under Swift Heavy Ion Irradiation
by K. Kupka, M. Tomut, C. Hubert, R. Danjoux, and C. Trautmann

Qualitative diagnostics of wind-turbine blades inspection using active thermography
by M. Szwedo and P. Hellstein

*CM2 M Wednesday 9th July, 14:45-15:45 (special measurement)*

Scanning infrared microscope with a high spatial resolution
by V.M. Bazovkin, I.V. Mzhelskiy and V.G. Polovinkin

Evaluation in a controlled environment of a low-cost IR sensor for indoor thermal comfort measurement
by G.M. Revel, M. Arnesano and F. Pietroni

Investigation of separate adsorbent particles under adsorption-desorption conditions with the use of infrared thermography and computer simulation
by B.G.Vainer, A.B.Ayupov and M.S.Melgunov

*CM3 Thursday,10th July, 14:45-15:45 (properties characterisation)*

Emissivity evaluation of Ultra Short Pulse Laser Textured steel surfaces
by J. Wullink, C. Delicaat, F. D. van den Berg, M. Groenendijk and J. van Tienhoven

Experimental facility dedicated to high temperatures thermophysical properties measurement: validation of the temperature measurement by multispectral method
by L. Dejaeghere, T. Pierre, M. Carin and P. le Masson

Determination of anisotropic properties of carbon fiber composites for civil engineering applications using infrared thermography with periodic excitation
by L. Ibos, J. Dumoulin and V. Feuillet

*CM4 Friday, 11th July;08:50-10:30 (state of art)*

Development of a shutterless calibration process for microbolometer-based infrared measurement systems
by A. Tempelhahn, H. Budzier, V. Krause and G. Gerlach

Temperature monitoring on a plasmatron experiment by pyroreflectometry
by R. Gilblas, T. Sentenac, D. Hernandez, O. Chazot, and Y.Le Maoult

Increasing performances on blackbodies to extend their temperature range
by Catherine Barrat, Sébastien Violleau

IR thermography on misaligned tiles in Tore Supra Tokamak : MTF knowledge help to solve sharp temperature profile
by F. Rigollet, J. L. Gardarein, Y. Corre and J. Gaspar

Performance tests of thermal imaging systems to assess their suitability for quantitative temperature measurement
by A. Whittam, R. Simpson and H. McEvoy

## CIVIL ENGINEERING & BUILDINGS

*CEB1 Wednesday 9th July, 09:30-10:30(Application 1)*

Quantitative analysis and image processing techniques of large-scale industrialsize fire tests using infrared thermography
by J. de Vries

Soundness assessment of structural timber elements in traditional timber dwellings: the combined use of quantitative IR thermograhy and ultrasonic testing
by A. Kandemir-Yücel, A. Tavukçuoglu, E. N. Caner-Saltik

Detection of reinforcement bars in concrete slab by infrared thermography and microwaves excitation
by F. Brachelet, S. Keo, D. Defer and F. Breaban

*CEB2 Thursday, 10th July, 114:45-15:45 (Application 2)*

Laboratory thermal transmittance assessments of homogeneous building elements using infrared thermography
by I. Simões, N. Simões, A. Tadeu, J. Riachos

Influence of environmental parameters on the thermographic analysis of the building envelope
by S. Van De Vijver, M. Steeman, N. Van Den Bossche, K. Carbonez, A. Janssens

Dynamic heating control by infrared thermography of prepreg thermoplastic CFRP designed for reinforced concrete strengthening
by L-D. Théroux, J. Dumoulin and J.L. Manceau

*CEB3 J Thursday, 10th July, 16:15-17:55 (bonding)*

Active and passive thermography evaluations of bonding defects in adhered ceramic tiling: experimental assessment
by J. Laranjeira, N. Simões, I. Simões, A. Tadeu and C. Serra

Active thermography evaluation of bonding defects in adhered ceramic tiling: thermal stimulation conditions and data analysis methods assessment
by N. Simões, J. Laranjeira, I. Simões, A. Tadeu and C. Serra

Characterization of density variations of historic timber structure by thermal methods
by O. Carpentier, E. Antczak, F. Brachelet, D. Defer, T. Descamps and L. Van Parys

Inspection of bonding areas between two metallic plates with flash method and two temperature analyses
by T. Vogt Wu, C. Pradere, J.L. Dauvergne, J.C. Batsale, D. Balageas

Square pulse heating infrared thermography and shearography applied simultaneously on CFRP tissue bonded to reinforced concrete
by L-D. Théroux, J. Dumoulin and X. Maldague

*CEB4 Friday 11th July, 08:50-10:30 (in-situ measurement)*

Aerial oblique thermographic imagery for the generation of building 3D models to complement Geographic Information Systems
by S. Lagüela, L. DíazVilariño, D. Roca, J. Armesto

Gasteizmografia.com : Thermographic map of the Vitoria-Gasteiz facades
by Iker Gómez Iborra, Itziar Gorosabel

Simulation of 3D heat diffusion in multilayered construction systems for active IRT data analysis
by C. Serra, A.Tadeu, N. Simões, I. Simões

Civil engineering structure daily monitored through IR Thermography and environmental measurement
by A. Criniere, J. Dumoulin, L. Perez and F. Bourquin

Innovative technique for the implementation of three dimensional indoor temperature measurements using infrared thermography
by P.A. Fokaides, S.A. Kalogirou

FLUID DYNAMICS & ENERGETIC

FDE 1 Wednesday 9th July, 9:30-11:00 (heat transfer and exchanger)

Infrared Thermography to Study Endwall Cooling and Heat Transfer in Turbine Stator Vane Passages Using the Auxiliary Wall Method
by H. Werschnik, T. Ostrowski, G. Schmid, H.-P. Schiffer

Determination of local heat-transfer coefficient distribution on a vortex enhanced finned-tube heat exchanger fin using infrared thermography
by Daniel Bougeard and Serge Russeil

Inverse identification of unsteady heat transfer coefficient using infrared thermography in a fin an tube heat exchanger assembly
by Mohammed Mobtil, Daniel Bougeard

*FDE 2 Thursday 10th July, 9:30-11:00 (control and check)*

Investigation of the quality and performance of organic solar cells by thermographic imaging
by R. Öttking, R. Rösch, M. Seeland, B. Muhsin, K.-R. Eberhard, D. Fluhr and H. Hoppe

Tracking a moving boundary layer transition front in supersonic flow using infrared thermography
by Rogier Giepman, Ferry Schrijer and Bas van Oudheusden

Differential Infrared Thermography of Gasoline Direct Injection
by H. Golzke, P. Leick and A. Dreizler

*FDE 3 Friday 11th July, 08:50-10:30 (application IR in fluid)*

The effect of heating time on heat transfer rate measurement
By LI Ming, Yang Yanguang, Luo Wanqing, LI Zhi-hui

Gas temperature imaging using the heated grid technique with adaptive background correction
by M. Ehrensperger, J.P. Kunsch and T. Rösgen

Experimental study of evaporation of a static liquid plug inside a heated dry capillary tube
by Vyas Srinivasan, Balkrishna Mehta and Sameer Khandekar

IR thermography investigation on roughness induced transition in high-speed flows
by F. Avallone, F.F.J. Schrijer and G. Cardone

IR Experimental investigation on twin synthetic impinging jets heat transfer behaviour
by C.S. Greco, A. Ianiro and G. Cardone

IMAGE & DATA PROCESSING

IDP 1 Tuesday 8th July, 9:30-11:00 (estimation)

Fast estimation of the phase diagram of a binary system using infrared thermography
by R. Cadoret, E. Palomo del Barrio, J. Daranlot

Quantitative application of pulse phase thermography to determine material parameters
by B. Stotter, K.H. Gresslehner, G. Mayr, G. Hendorfer and J. Sekelja

Infrared tomography: towards a novel methodology to investigate the volumetric radiative properties of heterogeneous materials by B. Rousseau, Y. Favennec, S. Guevelou, F. Dubot, D. R. Rousse

*IDP 2 Tuesday 8th July, 14:00-15:40*
*(defect detection)*

Thermal non-destructive testing: Localization of hidden defects
by S. Hatefipour, J. Ahlberg, J. Wren, A. Runnemalm

Defect detection strategies in Nickel Superalloys welds using active thermography
by E. Fernández, A. Beizama, A. García de la Yedra, A. Echeverria, P. Broberg, A. Runnemalm

Early defect diagnosis in installed PV modules exploiting spatio-temporal information from thermal images
by S.Rogotis, D.Ioannidis, A. Tsolakis, D.Tzovaras

Lock-In thermography for the wide area detection of paint degradation on RAAF AP3-C Aircraft
by R. Jones, M. Lo, M. Dorman, A. Bowler, D. Roles, S. A. Wade

Ultrasonic and optical stimulation in IR thermographic NDT of impact damage in carbon composites
by V. Vavilov, W. ?widerski and D. Derusova

*IDP 3 Wednesday 9th July, 11:00-12:20*
*(defect detection)*

Towards automatic defect detection in carbon fiber composites using active thermography
by R. Usamentiaga, P. Venegas, J. Guerediaga and L. Vega

A defect detection approach in thermal images
by P. Hedayati Vahid, S. Hesabi, X. Maldague, and D. Laurendeau

Evaluation of frescoes detachments by partial least square thermography
by P. Bison, A. Bortolin, G. Cadelano, G. Ferrarini, F. Lopez and X. Maldague

Multimodal fusion system for NDT and Metrology
by M. Akhloufi and B. Verney

*IDP 4 Wednesday 9th July, 16:10-17:50*
*(numerical processing)*

Finite element optimization by pulsed thermography with adaptive response surfaces
by J. Peeters, G. Steenackers, B. Ribbens, G. Arroud, J. Dirckx

Towards longwave infrared tunable filters for multispectral thermal imaging applications
by K. K. M. B. D. Silva, H. Mao, and L. Faraone

Preprocessing of temperature measurement by IR techniques using POD truncated basis for heat source estimation
by N. Ranc, A. Blanche, D. Ryckelynck and A. Chrysochoos

Background Thermal Compensation by Filtering (BTCF) for Contrast Enhancement of Thermographic Sequences
by Andrés D. Restrepo G. and Humberto Loaiza C.

Automatic generation of façade textures from terrestrial thermal infrared image sequences
by L. Hoegner and U. Stilla

*IDP 5 Thursday 10th July, 11:00-12:20*
*(experimental applications)*

Experimental analysis of heterogeneous nucleation in undercooled melts by infrared thermography
by M. Duquesne, A. Godin, E. Palomo del Barrio and J. Daranlot

Analysis of crystal growth kinetics of meta-stable phases in undercooled melts by infrared thermography
by A. Godin, M. Duquesne and E. Palomo del Barrio

Weld pool surfaces temperature measurement from polarization state of thermal emission
by Nicolas Coniglio, Alexandre Mathieu, Olivier Aubreton and Christophe Stolz

A fusion method with robustness analysis for infrared weak small target enhancement based on NSCT
by Q. Zhang and X. Maldague

*IDP 6 Thursday 10th July, 16:10-17:50*
*(quality control)*

Calorimetric analysis of coarse-grained polycrystalline aluminum by IRT and DIC
by L. Li, J.-M. Muracciole, L. Sabatier, L. Waltz and B. Wattrisse

Thermal Imaging for Monitoring Rolling Element Bearings
by R. Schulz, S. Verstockt, J. Vermeiren, M. Loccufier, K. Stockman and S. Van Hoecke

Development of infrared and visible endoscope as the safety diagnostic for steady-state operation of Wendelstein 7-X
by M. W. Jakubowski, C. Biedermann, R. König, A. Lorenz, T. S. Pedersen, A. Rodatos and the Wendelstein 7-X team

Texte Fatigue limit evaluation of martensitic steels with thermal methods
by U. Galietti, D. Palumbo, R. De Finis and F. Ancona

RITA - Robotized Inspection by Thermography and Advanced processing for the inspection of aeronautical components
by C. Ibarra-Castanedo, P. Servais, A. Ziadi, M. Klein and X. Maldague

*IDP 7 Friday 11th July, 11:00-12:20 (developed method)*

New concept for higher accuracy in measuring position to be implemented with the existing prototype automated thermography end-effector utilising an industrial robot and laser system by S. Dutta, T. Schmidt

Development of standards for flash thermography and lock-in thermography
by C. Maierhofer, P. Myrach, H. Steinfurth, M. Reischel, M. Röllig

Temporal resampling of time-varying infrared images sequences
by R. Montanini, T. Scimone, S. De Caro and A. Testa

Active infrared maging for 3D control of multi-layer transparent objects
by O.Aubreton, A. Bajard, B. Verney. M. Belckacemi, F. Truchetet

## INDUCTION THERMOGRAPHY & VIBROTHERMOGRAPHY

*ITVT Tuesday 8th July, 09:30-10:30*

Highly-efficient and noncontact vibro-thermography via local defect resonance
by I. Solodov, M. Rahammer and G. Busse

Scanning induction thermography (SIT) on damaged carbon-fiber reinforced plastics (CFRP) Components
by Renil Thomas, M. N. Libin, Krishnan Balasubramanian

Induction thermography as an alternative to conventional NDT methods for forged parts
by P. Bouteille, G. Legros

## INDUSTRIAL APPLICATIONS

*IA 1 Tuesday 8th July, 09:30-10:30 (Surface Characterization)*

Surface crack detection using infrared thermography and ultraviolet excitation
by A. Runnemalm, P. Broberg

Thermal behavior of the mold surface in HPDC process by infrared thermography and comparison with simulation
by S. Tavakoli, I. Ranc and D. Wagner

Phase lock-in thermography for thermal diffusivity measurement and layer surface characterization
by S. Pham Tu Quoc, G. Cheymol, A. Semerok

*IA 2 Wednesday 9th July, 09:30-10:30 (Engine Characterization)*

Losses determination in induction motors using infrared thermography techniques
by E.C. Bortoni, R.A. Yamachita, J.M.C. Guimarães and M.C.C. Santos

Combustion characterization of hybrid catalytic fuelled with methane and hydrogen mixtures
by C. Allouis, S. Cimino

Identification and mapping of early thermoacoustic phenomena in gas turbine test rig
by C. Allouis, A. Ferrante

*IA 3 Thursday 10th July, 09:30-10:30 (IRT Examinations)*

A Simple and Practical Device to Make Feasible the Practical Examinations for Certification in Thermography
By Laerte dos Santos, Alisson M. Lemos and Marco A. AbiRamia jr.

Finite Element Thermal Analysis of Surface Cold Spots Observed during Infrared Video Imaging of a Moving Hot Steel Skelp
by J. Barry Wiskel, J. Prescott and H. Henein

Condition Assessment of Electrical Connections Utilizing Infrared Thermography
by G.B. McIntosh

*IA 4 Friday 11th July, 11:00-12:20 (Materials Characterization)*

Application of infrared technology for the control of aeronautical composite components subjected to bending load tests
by P. Venegas, I. Sáez de Ocáriz, L. Vega, J. Gueredíaga

Heat Conductance Determination using Infrared Thermography
by Jean-Marie Buchlin, Mathieu Delsipé, Philippe Planquart, Michel Renard

Thermoelastic investigation of a hydraulic plastic valve undergoing a time dependant internal pressure variation
by A. Salerno and F. Pezzani

Coupling infrared thermography and acoustic emission for damage study in CFRPcomposites
by V. Munoz Cuartas, M. Perrin, M.-L. Pastor, H. Welemane, A. Cantarel and M. Karama

## IR - SIGNATURE & RECOGNITION

*IRS Wednesday 9th July, 14:45-15:45*

Time Resolved Multispectral Imaging
by F. Marcotte, Ph. Lagueux

Development and validation of a numerical tool for the simulation of the temperature field and infrared radiance rendering in an urban scene
by N. Lalanne, J.-C. Krapez, C. Le Niliot and X. Briottet

## MICROSCALE APPLICATIONS

*MA Thursday 10th July, 16:15-17-55*

The infrared measurements of damages of laser-processed carbon fiber reinforced plastics
by M. Muramatsu, Y. Harada, T. Suzuki and H. Niino

Quantitative kinetics and enthalpy measurements of bi phasic underflow chemical reactions by InfraRed Thermography
by M. Romano, C. Pradere, J. Toutain, C.Hany, J.C. Batsale

Synchronous use of FPA-based infrared thermography and fast ellipsometry for high-sensitive investigation of the adsorption-desorption processes rapidly progressing on solid surfaces
by B. G. Vainer, A. A. Guzev, K. P. Mogilnikov, S. I. Romanov, V. A. Shvets

Signal imposing system of micro-scale thermal imaging applied to un-cooled infrared cameras
by J. Morikawa, E. Hayakawa and T. Hashimoto

Thermal measurements of integrated inductors in CMOS technology and simple 1D analytical model of heat conduction
by I. Papagiannopoulos, M. Kaluza, B. Wiecek, A. Hatzopoulos, V. Chatziathanasiou and G. De Mey

## MONITORING & MAINTENANCE

MM Tuesday 8th July, 11:00-12:20

Online beam monitoring on targets at an ion beamline by infrared thermography
By M. Tomut, C. Hubert, K.Kupka, D. Severin, M. Bender and C.Trautmann

Thermal Nondestructive Control of an Aircraft Trellis Welding
by A. Eddazi and S. Belattar

Method of determination of sky thermal radiation and sky temperature with the use of long- wave IR camera measurement results
by T. Kruczek

Air curtain temperature measurement in an open refrigerated display cabinet by IR Thermography
by S. Marinetti*, A. Rossetti* and S. Minetto*

## NDE

*NDE1 Tuesday 8th July, 14:00-15-40*

Infrared thermography for non-destructive evaluation of thermoplastic composites
by S. Boccardi, G.M. Carlomagno, C. Meola, G. Simeoli and P. Russo

Comparison of IR Thermography and Reflectance-Enhanced Photoluminescence for early Quantitative Diagnostic of Thermal Barrier Coatings Spallation
by E. Copin, T. Sentenac, Y. Le Maoult, P. Lours

LEDs for thermographic NDT: status and chances
by Mathias Ziegler, Henrik Steinfurth, Mathias Röllig, Philipp Myrach, and Christiane Maierhofer

Infrared tomography: towards a novel methodology to investigate the volumetric radiative properties of heterogeneous materials
by B. Rousseau, Y. Favennec, S. Guevelou, F. Dubot, D. R. Rousse

Detecting hidden defects from real data
by P.Bison, M.Ceseri, F.Clarelli and G.Inglese

*NDE2 Wednesday 9th July, 16:15-17-55*

Temporal analysis for implicit compensation of local variations of emission coefficient applied for laser induced crack checking
by G. Traxler, P. Thanner, G. Mahler

Titre Vertical cracks characterization and resolution from lock-invi brothermography
by A. Castelo, A. Mendioroz, R. Celorrio, and A. Salazar

Titre flying-spot lock-in thermography and its application to thickness measurement and crack detection
by U. Netzelmann

Thermography for Characterisation of Deformation Process in Stainless Steels
by B.Venkatraman, M.Menaka and Baldev Raj

Mechanical and infrared thermography analysis of shape memory polymer - focus on thermoelastic effect
by J. Délémontez, M.Tagglione

*NDE3 Thursday 10th July, 9:30-10 :30*

Fiber orientation measurement in cylindrical carbon reinforced parts
by H. Fernandes and X. Maldague

Defect Depth Detectability in Austenitic Stainless Steel by Lock in Thermography
by M.Menaka and B.Venkatraman and Baldev Raj

Thermal effect of local defect resonance in ultrasonically excited shearography and thermography
by N. Gulnizkij, I. Solodov, M. Rahammer and G. Busse

NDE3 Thursday 10th July, 11:00-12:20 (modelling)

Analytic model for pulsed thermography of subsurface defects
by P. Broberg

Development of a discontinuous finite element method to characterize vertical cracks using lock-in thermography
by R. Celorrio, A.J. Omella, N.W. Pech-May, A. Mendioroz, A. Oleaga and A. Salazar

A model for the depth effect on the reconstruction of defect geometry triangular by pulsed thermography
by A.Elhassnaoui, S. Sahnoun

TAn analytical model and parametric analysis of ultrasound-excited infrared thermography
by Xingwang Guo

## NDE APPLIED TO COMPOSITE STRUCTURES

*NDEC1 Tuesday 8th July, 16:10-17:30*

Composite characterization using infrared inspection technologies
by David G. Moore

Investigation of multiple cracking in glass/epoxy 2D woven composites by vibrothermography
by G. Bai, B. Lamboul, J.-M. Roche, S. Baste

Wide-area impact damage evaluation with sonic infrared imaging NDE in advanced composite structures
by X. Han, Justin M. Ar-Rasheed, D. Zhang, A. Lubowicki, L. Favro, and G. Newaz

Active infrared sensing of impact damage in carbon fibre reinforced polymer
by Tong Kuan Chuah, Liping Zhao and Shaochun Ye

*NDEC2 Wednesday 9th July, 14:45-15:45*

Inspection of Pseudo Kissing-bond Defects in Composite Laminate with Infrared sensing
by L. Zhao and W. Guo

Thermal characterization of composite materials exposed to fire: quantitative comparison between classic and infrared-nondestructive methods
by C. Justo-María, S. Sánchez, J. Meléndez, F. López, M.E. Rabanal and F.J. López del Cerro

Infrared thermography to monitor composites under bending tests
by S. Boccardi, G.M. Carlomagno, C. Bonavolontà, M. Valentino, and C. Meola

## THERMOMECHANICS

*Tuesday 8th July, 11:00-12:20*

Study of strain localization and energy dissipation in metals based on infrared thermography
by O.A. Plekhov, A. Fedorova, A. Kostina and I. Panteleev

Development of the measurement system for determination of dissipation rate near the fatigue crack tip
by A.Prokhorov, A. Vshivkov, A. Iziumova, ?. Plekhov, J.C. Batsale

Mechanical and infrared thermography analysis of shape memory polymer - focus on thermoelastic effect
by M. Staszczak, E. A. Pieczyska, M. Maj, K. Kowalczyk-Gajewska, M. Cristea, L. Urba?ski, H. Tobushi and S. Hayashi

Experimental study by full field measurement techniques of the stress gradients effect under fretting, fretting-fatigue and notch fatigue
by A-R. Moustafa, B. Berthel, E. Charkaluk, S. Fouvry

## THERMOGRAPHIC SIGNAL RECONSTRUCTION (TSR)

*TSR1 Tuesday 8th July, 14:00-15:40 (Method developments)*

Characterization of Full-Range Time Evolution in Active Thermography
by S. Shepard, M. Frendberg and Y. Hou

Approaches to Data Reduction, Visualization and Analysis in Thermographic Signal Reconstruction
by S. Shepard

Images of TSR coefficients: A simple way for rapid and efficient defect detection
by J.-M. Roche, F.-H. Leroy, D.L. Balageas

Common tools for quantitative pulse and step-heating thermography - Part II: experimental validation
by J.-M. Roche, D.L. Balageas

Comparative study of Thermographic Signal Reconstruction and Partial Least Squares Thermography for detection and evaluation of subsurface defects
by F.López, V.P. Nicolau, C. Ibarra-Castanedo,X. Maldague and S. Sfarra

*TSR 2 Wednesday 9th July, 11:00-12:20 (Application)*

Detection and characterization of composite real-life damage by the TSR-polynomial coefficients RGB-projection technique
by J.-M. Roche, D.L. Balageas

Defect depth determination in a CFRP structure using TSR technique
by B. Oswald-Tranta, A.Maier, R. Schledjewski

Thermal diffusivity measurements of porous CFRP specimens with different number of plies using pulsed thermography in transmission and reflection mode
by G. Mayr, B. Plank, J. Gruber, J. Sekelja and G. Hendorfer

Reconstruction of thermal signals in infrared images reveals sub-cutaneous vasculature and thermogenicity
by Wei-Min Liu, Ken Chang, Stephen Yoon, and Alexander M. Gorbach

## STUDENT AWARD

*SA Tuesday 8th July, 16:10-17:30*

Characterization of temperature and strain fields during cyclic laser shocks
by A. Charbal, D. Farcage, F. Hild, M. Poncelet, S. Roux and L. Vincent

Simultaneous front and rear faces flash characterization method for thin cylindrical multilayered composites
by L. Duquesne, C. Lorrette, C. Pradere, G. L. Vignoles and J-C. Batsale

Multiscale analysis of thermography imaging dynamic for sol-gel coating discrimination
by S. Mezghani, E. Perrin, J.L Bodnar, B. Cauwe, V. Vrabie

Analogous of Wien's law for the optimal wavelengths selection in bi-spectral method used for temperature measurement of surfaces exhibiting non-uniform emissivity, and general methodology for the multi-spectral method
by C. Rodiet, B. Rémy and A. Degiovanni

## 14th- 16th July 2014

10th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics in Orlando, Florida,

*Venue*: Hyatt Regency Grand Cypress Hotel, USA, One Grand Cypress Blvd, Orlando, Florida, FL32836

*Purpose:* The conference is broad in scope and provides a forum for specialists in heat transfer, fluid mechanics and thermo- dynamics from all corners of the globe to present the latest progress and developments in the field. The broad scope brings together a wide range of research areas from narrow funda- mental work to import applications such as in the broad fields of energy, manufacturing, biomedical, processes, production, education, instrumentation and control, MEMS, etc. This will not only allow the dissemination of the state of the art, but it will serve as a catalyst for discussions on future directions and priorities in these areas. The additional purpose of this conference is to initiate collaboration in research.
I*nformation:* http://edas.info/web/hefat2014/home.html

## 25th July 2014
## 1st Seminar of Medical Infrared Thermography London

In association with **UCL**, the **European Association of Thermology** and the **Royal Free Hospital**

Supported by Instrotech and FLIR Systems

*Venue:* Institute of Immunity and Transplantation, Royal Free Hospital, London NW3 2QG

*Date*: Friday, 25th July 2014, 10 am - 1 pm

The seminar is free to attend, but numbers are strictly limited. To reserve a delegate place or submit an abstract (maximum 100 words) contact the organiser Dr. Kevin Howell (Microvascular Diagnostics, Royal Free Hospital) at k.howell@ucl.ac.uk

PowerPoint presentations to be submitted via email by 21st July. Please contact the organiser if you wish to bring your own media for presentation on the day.

A light lunch will be provided at the end of the seminar. Please inform the organiser of any special dietary requirements.

For programme updates and further information during spring 2014:

Follow us on Twitter: **@MIRT_London**

Follow and like our Facebook page:

**www.facebook.com/MIRTLondon**

## 11th-12th August 2014

International Conference on Heat Transfer and Fluid Flow (HTFF'14) in Prague, Czech Republic

*Information*: info@HTFFconference.com

## 13th - 14th September 2014

Kinesiology and Thermography, in Epe, the Netherlands

The course given by Prof. Dr. med. Marcos Brioschi, Brazil

Sign Up before 10th August.

*Information:*
Irma Wensink
De Leegte 16, 8162 BZ Epe, The Netherlands

email: irma@thermografie-centrum.nl
www.thermografie-centrum.nl

## September 15th, 2014

The use of Thermography in Rheumatology.

The course given by Prof. Dr. med. Marcos Brioschi, Brazil

Sign Up before 10th August.

*Information:*
Irma Wensink
De Leegte 16, 8162 BZ Epe, The Netherlands

email: irma@thermografie-centrum.nl
www.thermografie-centrum.nl

## 20th -21st September 2014

AAT Annual Scientific Session in Grenville, South Carolina

The AAT Annual Meeting will be held at the Bon Secours St. Francis Hospital campus.

A Pre-Meeting Physicians Member Certification Course will be held on September 19th, 2014

PROGRAMME

*General Sessions: Saturday, September 20, 2014*

08:00am - Registration

08:30am - *Welcoming Remarks*
Jeffrey Lefko, Greenville, SC,
Executive Director, American Academy of Thermology

8:35-9:15 *Keynote Address:* Historical Overview of AAT and the Use of Thermal Imaging for RSD and Neuromusculoskeletal Testing
Joseph Uricchio, MD, Florida,
Past President, American Academy of Thermology

9:15am - *Session 1: Basic Science, Clinical Conditions, AAT Guidelines & Indications*

9:15-9:45am Role of Cold Stress testing in Thermography
Dr. Robert Schwartz, MD, Greenville, SC,
President of American Academy of Thermology

9:45-10:15am Status Update on the Practice and Use of Thermography
Dr. Philip Getson, DO, Marlton, NJ,
Vice President, American Academy of Thermology

10:15-10:45 am AAT Veterinarian Thermography Guidelines Improves Reliability of Thermography in Veterinary Imaging Diagnostics
Dr. Tracy Turner, DVM, Elk River, MN,
Board Member, American Academy of Thermology

Q&A/ Discussion

10:45am - Break

11:15am - *Session 2: Panel Discussion: Recruiting A Medical Director For Thermography Technicians*

11:15-11:40am Nuances Of The Multiple Site Model
Nina Rea, Atlanta Georgia,
Member, AAT Education Committee

11:40-12:05pm Strengths Of The Single Office Setting
Jan Crawford, RN, Rockford, Illinois,
Chair, AAT Technicians Subcommittee

12:05-12:15pm Insight Into The Doctor's Point of View
Dr. Robert Schwartz, MD, Greenville, SC,
President of American Academy of Thermology

Q&A/ Discussion

12:30pm - Lunch (provided)

1:30pm - *Session 3: Panel Discussion: Influence of Thermographic Cameras and Equipment on Thermographic Studies*

1:30-2:00pm Understanding the Factors Which Influence Quality of Thermograms- Emissivity, Environment, Range, Focus, and Techniques
Mr. Gary Lux, Cold Mountain Infrared, Black Mountain, NC, LLC

2:00-2:20pm How Different Imaging Studies Influence the Diagnostic Accuracy of Breast Cancer
Raghava Bhaskaran, MD, Atlanta, Georgia

2:20-2:45pm Integration of Musculoskeletal Thermography into an Existing Autononomic Testing Program
Dr. Tashof Bernton, MD, Denver, CO,
Board Member, American Academy of Thermology

2:45-3:10pm Recent International Developments in Thermo graphy
Bryan O'Young, MD, New York, NY,
Secretary, AAT Board of Directors

Q&A/ Discussion

3:20pm - Break

3:40pm - *Session 4: Panel Discussion: Hot Topics In Thermal Research Issues and Challenges*

3:40-3:50pm Thermal Imaging and Estrogen Dominance: Are We On The Same Page?
Dr. Robert Schwartz, MD, Greenville, SC,
President of American Academy of Thermology

3:50 -4:10pm Thermal Imaging and Estrogen Dominance: How I Read It
Dr. Philip Getson, DO, Marlton, NJ, Vice President,
American Academy of Thermology

4:10-4:30pm Thermal Imaging and Estrogen Dominance: How I Read It
Bruce Rind, MD, Washington, DC,
Member AAT Website Committee

4:30-4:45pm Issues and Challenges for Research and Education in Medical Thermography
James Melton, MHA, Cary, NC,
Member, AAT Board of Directors

Q&A/ Discussion

5:00pm - Annual Scientific Session Wrap Up and Remarks

5:30pm - Session Ends

Shuttle back to Hilton Hotel

6:30- 7:30pm - Meet and Mingle Reception with the Leadership at the Hilton Hotel

Presentation of AAT 2014 Achievement Award

*Committee Meetings: Sunday September 21st, 2014*

07:30am - Shuttle from Hilton Hotel

- 08:00am - Committee Meetings
  (Committee members and other attendees):
  Membership Committee including:
  - Sub Committee on Complimentary Alternative Medicine (CAM) and Allied Health
  - Sub Committee on Technicians/Technologists. Devices and Equipment Committe
- Journal/Newsletter
- Website Committee
- Education Committee
- Advocacy Committee

09:15am - General Session (all in attendance)

10:15am - General Session Ends

10:30am - Shuttle returns to Hilton Hotel

10:15am - Board of Directors Meeting (board members only)

1pm - Board of Directors Meeting Ends

Further information on registration, travel and hotels at the AAT-Website: https://aathermology.org

## 26th-28th September 2014
## ThermoMed International 2014

60th Anniversary of the German Society of Thermography and Regulation Medicine, in Langen near Frankfurt

Website: www.thermomed2014.org

Please send all abstract in parallel to reinhold.berz@gmx.de and to sauer@hsauer.de

**European Association of Thermology** **Physical Activity and Sports Faculty (INEF).U.P.M.**

# XIII European Association of Thermology Congress


## Thermology n Medicine:
## Clinical Thermometry and Thermal imaging

# CALL FOR PAPERS

The EAT and the Faculty of Physical Activity and Sports Sciences (INEF) have the pleasure of inviting you to participate in the XX EAT Congress in Madrid between the 3rd and 5th of September, 2015.

The target of this Congress is integrating professionals and researchers from different fields who are working daily with medical thermography, introducing the latest advances in infrared technology and the new applications arising from them.

The Congress will appeal not only to end-users of medical thermography but also to researchers and developers. The congress will focus on free communications and posters in the areas of Human Applications, Animal Applications, and Engineering.

We look forward to seeing you in Madrid in September 2015..

Manuel Sillero Quintana
Chairman of the Organizer committee.

James Mercer
President of the EAT.

## VENUE

The congress will take place at the Physical Activity and Sport Sciences Faculty (INEF Madrid) which belongs to the Technical University of Madrid (UPM) located in the University City of Madrid. It has an auditorium with 600 places and two conference rooms with seating for 140 and 120 persons and are fully equipped with modern audio-visual facilities.

## COMMITTEES

Manuel Sillero-Quintana (SPA). Congress Chairman

### ORGANIZING COMMITTEE

Prof. Dr. Kurt Ammer (AUT)

Prof. Dr. Kevin Howell (GBR)

Prof. Dr. Anna Jung (POL)

Prof. Dr. James Mercer (NOR)

Prof. Dr. Francis Ring (GBR)

Dr. Ricardo Vardasca (POR)

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Prof. Dr. Pedro J. Benito (SPA)

Prof. Dr. Joao Carlos Bouzas (BRA)

Prof. Dr. Javier Calderón (SPA)

Dr. Ismael Fernández-Cuevas (SPA)

Prof. Dr. Ignacio Refoyo Román (SPA)

Dr. Pedro M. Gómez (SPA)

Mr. Sergio Piñonosa (SPA)

Prof. Dr. Antonio Rivero (SPA)

### EAT SCIENTIFIC BOARD (preliminary list)

Prof. Dr. Kurt Ammer (AUT)

Prof. Dr. Imre Benkö (HUN)

Dr. Marcos Brioschi (BRA)

Dr. Timothy Conwell (USA)

Dr. Ismael Fernández-Cuevas (SPA)

Dr. Joaquim Gabriel (POR)

Dr. Kevin Howell (UK)

Prof. Dr. Anna Jung (POL)

Prof. Dr. Arcangelo Merla (ITA)

Prof. James Mercer (NOR)

Prof. Dr. Adriana Nica (ROM)

Prof Dr David Pascoe (USA)

Prof. Dr. Francis Ring (UK)

Dr. Ricardo Vardasca (POR)

Prof Hisashi Usuki (JPN)

## KEY DATES

The draft of the scientific program can be found in the web page of the EAT

The scientific committee will receive submission for abstracts for free communications and posters in the areas of "Biomedical Applications", "Animal Applications" and "Technical Applications". Abstracts will be submitted only on-line; the link will be published in due time.

**Note**: The authors of best communications will be invited to publish an extended version of the works in Thermology International.

- 10th October 2014. Opening of abstract submission and registration.
- 30th January 2015. Abstract submission deadline.
- 27th March 2015. Acceptance notification to authors.
- 17th April. End of Early bird registration.

IMPORTANT:
The registrations will be done only on-line. The link will be published in due time.

| | Early Registration (Until 17-4-15) | Late Registration (Until 31-7-15) | Last-minute Registration (After 31-7-15) |
|---|---|---|---|
| **EAT MEMBER** | 300.-€ | 360.- € | 400.- € |
| **Non EAT member** (1) | 350.-€ | 410.- € | 450.- € |
| **1-day registration** (2) | 125.- € | 150.- € | 170.- € |
| **Student** (3) | 150.- € | 200.- € | 240.- € |
| **Accompanying person** (4) | 200.- € | 260.- € | 300.- € |

(1)Annual EAT fee = 50 € (including one year subscription to the journal Thermology International). To get information about how to apply to the EAT as ordinary or extraordinary member, visit http://www.europeanthermology.com (membership).

(2)1-day registration will include registration pack and coffee breaks and lunch of the day. Gala Dinner not included.

(3)A certificate with ECTS credits will be provided by U.P.M. Gala Dinner not included.

(4)Accompanying person registration will include 2 one-day excursions (9:00 - 16:00) with lunch (3rd and 5th of September) and Gala Dinner.

## TRAVEL INFORMATION

Madrid-Barajas Airport is a large international and domestic airport with frequent direct flights from many international destinations. There is a train service directly from Terminal 4 (T4) to Príncipie Pío Station (35 minutes, about 2.50 €), where the official hotel is located. There are also metro and buses from the Airport to the city center (40-50 minutes, about 5-6 Euros). A taxi from the Airport could be another option but a little bit more expensive. In 2014 the fixed fee for a taxi from the Airport to any place in the centre of Madrid is 30€).

The radial structure high-speed train (AVE), regional trains and buses allow travel to Madrid from the most important cities of Spain. Furthermore, Madrid has an excellent underground system, a frequent bus network and many reasonably priced taxis for local transportation. We encourage our attendees to use the public transport. It will be provided a 10 ticket bonus in the Reception of the Hotel to all the attendants with a 3-days registration.

## ACCOMODATION

Hotels in Madrid are quite full in early September. For this reason, the organizers of the EAT Congress have reserved 100 rooms for participants at the Hotel Florida Norte****, which will be the official hotel of the congress. The special fees for the attendants are:

- 35.35 € (incl. 10% VAT) per person in double bed room including breakfast (buffet).
- 59.35 € (incl. 10% VAT) single room including breakfast (buffet).

The Florida Norte Hotel is about a 25 minutes walk or a 5-10 minute bus ride to the venue. The city centre is a 10 minute walk from the hotel.

VERY IMPORTANT. In the registration form the participants have to indicate whether or not the will stay in the Hotel Florida Norte (organizers will inform to the Hotel). If they choose to use the Hotel Florida Norte, they have to reserve the hotel themselves writing and email to reservas.florida@celuisma.com. Alternatively the hotel can be booked on-line at http://www.celuisma.com/en.

NOTE: If you indicate in the booking form that you are an attendant of the EAT Congress you will be charged the special congress rate and NOT the fee indicated on their website.

# XIII EAT CONGRESS. 3rd to 5th September 2015, Madrid

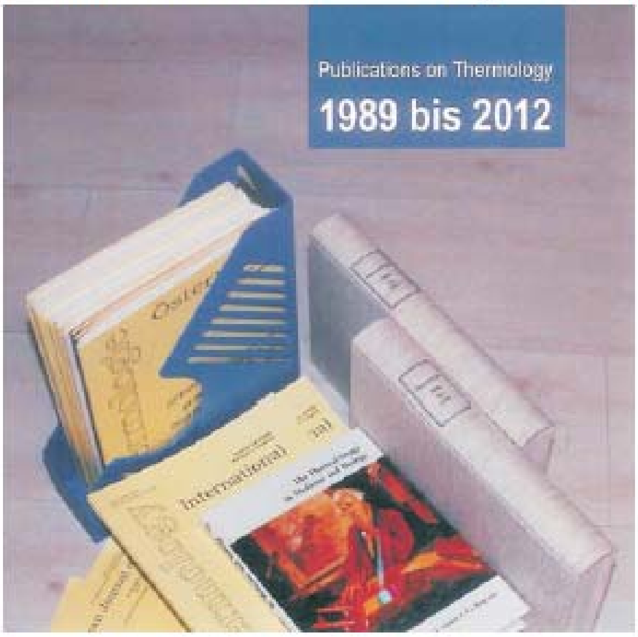
## Thermology in Medicine: Clinical Thermometry and Thermal imaging

## PROGRAMME

| | **Wednesday, 2-9-15** | **Thursday, 3-9-15** | **Friday, 4-9-15** | **Saturday, 5-9-15** |
|---|---|---|---|---|
| 8:30 | PRE-CONGRESS COURSE<br>**To be decided yet.** | Late Registrations (INEF) | Late Registrations (INEF) | Late Registrations (INEF) |
| 9:00 | | Morning Session 1-1 Technical Apps. | Morning Session 2-1 Biomedical Apps. (Sports) | Morning Session 3-1 Biomedical Apps. |
| 9:30 | | | | |
| 10:00 | | | | |
| 10:30 | | | | |
| 11:00 | | Coffee Break | Coffee Break | Coffee Break |
| 11:30 | | Morning Session 1-2 Technical Apps. | Morning Session 2-2 Biomedical Apps. | Morning Session 3-2 Biomedical Apps. |
| 12:00 | | | | |
| 12:30 | | | | |
| 13:00 | | | | |
| 13:30 | | Lunch (INEF) | Lunch (INEF) | Lunch (INEF) |
| 14:00 | | | | |
| 14:30 | | Afternoon Session 1-1 Technical Apps. | | Closing Ceremony and EAT Awards |
| 15:00 | | | | |
| 15:30 | | | VISIT TO TOLEDO AND GALA DINNER (*) | |
| 16:00 | | Coffee Break | | |
| 16:30 | | Afternoon Session 1-2 Animal Apps. | | |
| 17:00 | | | | |
| 17:30 | | | | |
| 18:00 | | EAT General Assembly | | |
| 18:30 | Late Registration and Accreditation at the Hotel Florida Norte | | | |
| 19:00 | | | | |
| 19:30 | | | | |
| 20:00 | | | | |
| 20:30 | | | | |
| 21:00 | | | | |
| 21:30 | | | | |
| 22:00 | | | | |
| 22:30 | | | | |
| 23:00 | | | | |

(*) Note.- The bus will depart from the Florida Norte Hotel. Takes about 60 minutes to Toledo (motorway). The visit will be from 16:30 or 17:00 to 20:00 and the dinner from 20:00 to 22:00 arriving 23:00 to the hotel.

# Publications on Thermology 1989 to 2012 - An electronic archive DVD



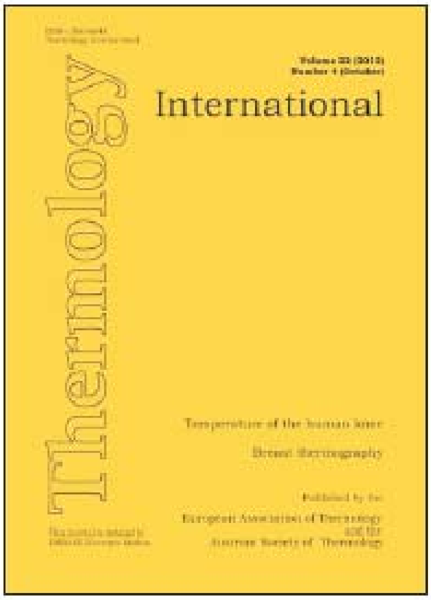

This data compilation contains all issues of

Thermologie Österreich
May 1991 to April 1997

European Journal of Thermology
July 1997to October 1998

Thermology international
January 1998 to October 2012



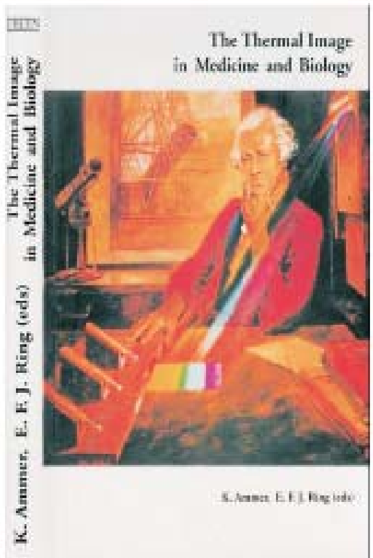


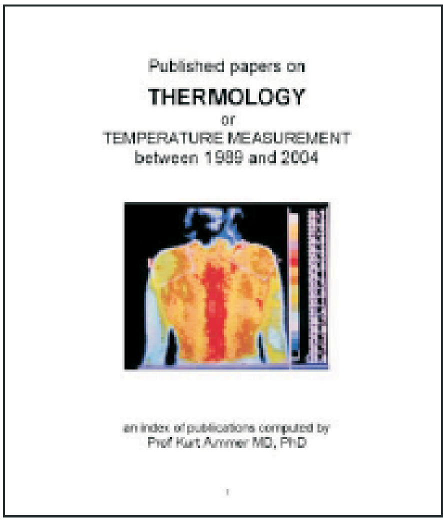

Plus

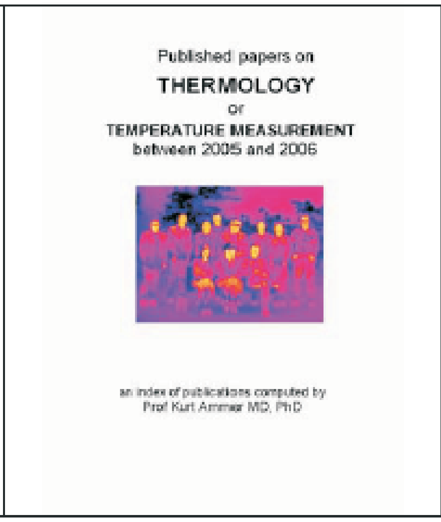
## The Thermal Image in Medicine and Biology

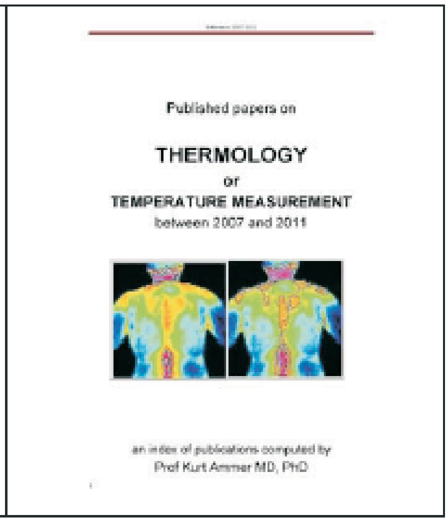
edited by K.Ammer and E.F.J Ring

Uhlen Verlag, Wien (1995)






Plus

Published Papers on Thermology and Temperature Measurement

Volume 1: 1989 to 2004

Volume 2: 2005 to 2006

Volume 3: 2007 to 2011

Plus

Proceedings of the First Thermological Symposium of the Austrian Society of Thermology

Thermographie, evozierte Potentiale, edited by O.Rathkolb and K.Ammer

Plus

Proceedings of the Second Thermological Symposium of the Austrian Society of Thermology

Kontaktthermometrie und Thermographie, edited by K.Ammer and O.Rathkolb

Plus

THERMOGRAPHIE 90 - Eine computergestützte Literatursuche by K.Ammer

## The prize for the DVD is 100.- Euro (mailing costs included)

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or machyl@uhlen.at

Orders by fax: to +43 1 480 54 23 will also be accepted.

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