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Dependency of diagnostic value on method of evaluation

Noise removal from Thermal Images

Thermal Imaging after a short period of vascular stasis

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The sensitivity of infrared imaging for diagnosing Raynaud´s phenomenon or Thoracic Outlet Syndrome is dependent on the method of temperature extraction from thermal images

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SUMMARY

The thermographic diagnosis of Raynaud´s phenomenon and of Thoracic Outlet Syndrome is based on temperature differences between the mean temperatures of regions of interest. A recent study comparing three different definitions of measurement area in thermal images from patients suspected of Raynaud´s phenomenon, found more cases when small instead of large areas of interest were used. Evaluation of thermograms from patients with suspected thoracic outlet syndrome revealed also more cases when small regions of interest have been defined. A clear description of the definition of regions of interest is necessary for the evaluation of the diagnostic accuracy of thermal imaging.

KEY WORDS: infrared imaging, Raynaud´s phenomenon, Thoracic Outlet Syndrome, diagnostic sensitivity, method of evluation

DIE DIAGNOSTISCHE SENSITIVITÄT DER INFRAROTTHERMOGRAPHIE FÜR DAS RAYNAUD PHÄNOMEN BZW, FÜR DAS THORACIC OUTLET SYNDROM HÄNGT VON DER ART DER TEMPERATURBESTIMMUNG IN DEN WÄREMBILDERN AB

Die thermographische Diagnose des Raynaudphänomens bzw. des Thoracic Outlet Syndroms beruht auf dem Unterschied der mittleren Temperatur von Messarealen. Eine rezente Studie verglich drei unterschiedlich definerte Messareale in Wärmebildern von Patienten mit Verdacht auf Raynaudphänomen und entdeckte mehr Fälle, wenn kleine an Stelle von großen Messarealen verwendet worden waren. Die Auswertung der Thermogrammme von Patienten mit der Verdachtsdiagnose Thoracic Outlet Syndrome fand ebenfalls mehr Fälle, wenn zur Auswertung kleine Messareale definiert worden waren. Für die Beurteilung des diagnostischen Wertes der Thermographie, ist eine klare Beschreibung der Messareale notwendig.

SCHLÜSSELWÖRTER: Infrarot-Thermographie, Raynaudphänomen, Thoracic Outlet Syndrom, diagnostische Sensitivität, Methode der Evaluierung

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Introduction

It was shown in previous papers [1-4] that the method of extracting temperatures from thermal images has an impact on temperature readings. The temperature of the ankle recorded at different distances with a infrared imager was lower in images taken at the long than the short distance [1].While the size of measurement varied between 121 pixel at the long distance and 1221 at the short distance, the mean temperature varied between 30.8 ± 0,6°C (distance: 100cm) and 29,9 ± 0,5 °C (distance. 250 cm). However, Maurer and Mayr reported nearly identical temperature values (32-65 ± 1.51°C versus 32.60 ± 1.54°C) in thermal images of knees recorded at distances of 50 cm and 150 cm [2]. Mayr compared also mean and maximum temperatures from a rectangular and a line shaped measurement area in thermal images recorded from knees [3]. Higher mean temperatures were obtained from the line shaped than the rectangular region of interest. In another study temperature readings from hands of different sizes in thermal images were compared and readouts were related to the size of the measurement area and also to the room temperature, represented by the background temperature in the images (4). Hand sizes were allocated to 5 classes, and background temperatures were assigned to 3 classes. Mean, standard deviation, 95% confidence interval and nonparametric tests were used for statistical analysis. Variation in the size of ROIs of 100 or more percent lead to significantly different temperature readings from these areas.

Other conditions than shape and size of measurement area contribute also to temperature readings from thermal imaging (5). Camera calibration, image capture, subject preparing, body positioning and image analysis have to be carefully taken into account, when accurate and precise temperature measurements are aimed im medical thermal imaging.

Recently, two studies were conducted to investigate the influence of definition of regions of interest on the diagnostic sensitivity of thermal images for Thoracic Outlet Syndrom(TOS) [6] and Raynaud´s Phenomenon [7], respectively.

Thoracic Outlet Syndrome

Numbness, weakness and sensation of swelling in one or both upper limbs may be caused by neurovascular entrapement at the thoracic outlet. Intermittent pain and paresthesia including the sensation of coldness usually follow the ulnar nerve distribution [8].In 1993 Schartelmüller and Ammer [9} established a protocol for thermal imaging in patients suspected of Thoracic Outlet Syndrome (TOS). With some modification [10] this protocol is routinely used since 1994 for the thermographically assisted diagnosis of Thoracic Outlet Syndrome. Temperature measurements were also applied as outcome measure in a clinical trial on the effectiveness of exercise therapy in patients with thoracic outlet syndrome [10]. Temperature readings from thermal images recorded from patients with thoracic outlet syndrome showed a high degree of inter- and intra-rater repeatability [11].

About 1000 subjects underwent routinely this investigation, since thermal imaging was included in the diagnostic pathway for TOS. A temperature difference of 0.5 or more degrees between index and little finger in at least two provocative arm positions is regarded to be diagnostic. However, the definition of regions of interest may be time consuming, particularly in cases when the contrast between cold finger tips and the image background is low.

An alternative method based on the mean temperature value of a line over the finger of interest was used for the re-evaluation of thermal images of 210 cases (156 females, 64 males) retrieved from the database of our Thermography Unit were quantitatively re-evaluated [12]. In 115 image series did not show pathological findings and have been classified as normal (55 on the left hand side, 60 on the right hand side). Definite TOS affecting the little finger was detected in 49 left hands and 44 right hands, a definite cold index finger was observed in 6 hands (3 right and 3 left hand side) only. 02 image series showed temperature changes that indicated a probable TOS on the little finger (48 left hand, 54 right hand). A possible TOS (little finger) was seen in 80 hands (42 left hand, 38 right hand). The remaining cases were 9 times classified as probably TOS (index) and as possible TOS (index) in 15 other cases. There was no significant difference in age between the different classes of TOS, with the exception that patients with probable or definite cold index finger at the right hand side had a higher age as subjects without symptoms or with TOS symptoms at the little finger.At the right hand, males had also less definite and probable TOS symptoms at the little fingers than females.

The aim of the following study was the direct comparison of the diagnostic outcome using either the established area based or the alternatively line related temperature measurements for evaluation.

Methods

25 series of thermal images from patients who were tested for thermal symptoms caused by TOS were retrieved from the database of our Thermography Unit. Each series consisted of eight images which have been recorded with an AGEMA 870 Infrared Scanner.

The first image "*At Rest*" was recorded with the subject standing and the arm hanging freely, the palm pointing towards the camera. The head of the subject was in normal position and he breathed normally. The second image "*Hands Up*" was taken with the shoulder abducted in ninety degrees, the hand pointed upwards, the palm towards the camera, the head in the normal position and normal breathing. Next the "*Hyperabduction Test*" was imaged with maximum abduction in the shoulder joint, the elbow flexed ninety degrees with the forearm pointing upwards, breath was hold in full inspiration and he head turned to the investigated side. The final image recorded a "*Modified Adson's Manoever*" while holding the breath in full inspiration and turning the head away from the investigated side, the arm is slightly moved backwards and sidewards.

The retrieved AGEMA images have been stored in CATS-format and were converted to the image format of the software package CTHERM. Further image analysis was performed with the statistics tool of CTHERM:

For the established evaluation, regions of interest were defined over the index and little finger of both hands in the following way: A polygonal measurement area was defined around the finger. The outline of this region of interest crossed the hand at the base of the finger and the background temperature was increased to the level of the isotherm surrounding the finger. The mean temperature and the number of pixels of the measurement area were recorded. (figure 1)

For the alternative evaluation a line was aligned to the base and the tip of the finger investigated. The mean temperature and the number of pixels of the line were recorded. The temperature difference between index and little finger was calculated for each method of evaluation.

Based on this temperature difference the following classification was made: a pathological temperature difference in one position was named "possible TOS", pathological findings in two positions were regarded as a "probable TOS" and pathological temperature readings in three or four arm position was classified as "definite TOS". In addition, TOS cases were labeled with "index" or "little finger" with respect to the colder finger. Table 1 shows the evaluation of the image series of Figure 1

Further statistical analysis was performed with the software package SPSS 10, after the temperature readings from the measurement areas in all positions have been computed into one file resulting in a sample of 100 values, of which the reliability coefficient alpha and the average interclass correlation were determined. The recorded values from the regions of interest were compared by the Student-T test between the original and the alternative method of evaluation. The level for significant differences was set for 2-tailed p=0.05.

Results

Thermal image series from 25 patients (24 females, 1 male) with median age of 45 (range 23 to 66) years were re-evaluated. Analysis of the temperature readings from each measurement area by the Kolomogorov-Smirnov-Test indicated a distribution of values that was not significantly different from a normal distribution (2-tailed p-values between 0.06 and 0.32). Therefore, further analysis with the Student-T-Test was appropriate.

Figure. 1.
Series of thermal images of a subject withthermographically definite TOS at the right hand side and possible TOS left hand side. The red and blue areas represent the standard method of evaluation, the yellow and and green lines habe been used for the alterna-

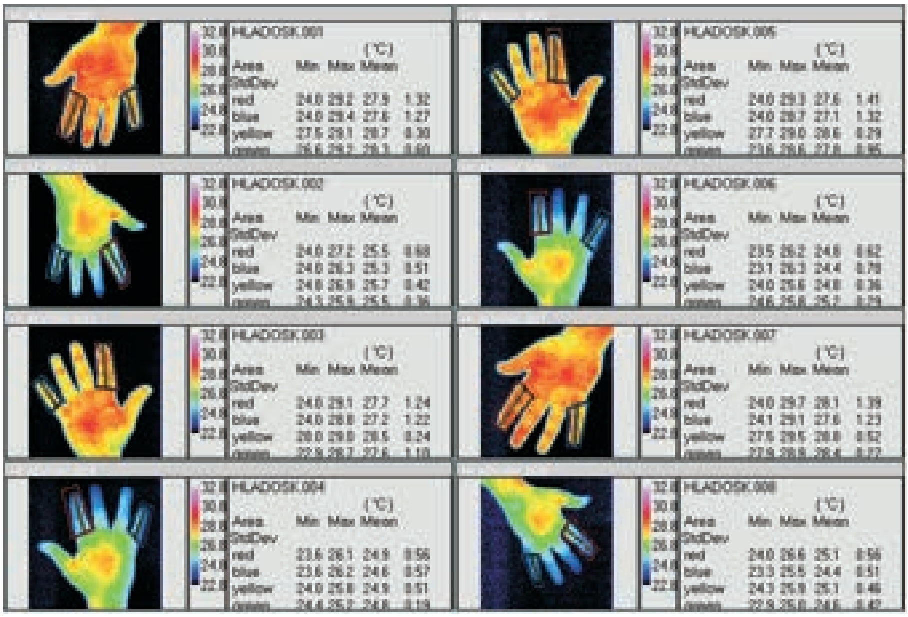


Table 1
Classification of the images in figure 1,based on temperature differences between index and little finger

	Right hand ?t index-little finger	Left hand ?t index-little finger
At rest:standard	normal (<0.5°)	normal (<0.5°)
At rest:alternative	normal (<0.5°)	normal (<0.5°)
Hands up: standard	pathological (>0.5)	normal (<0.5°)
Hands up: alternative	pathological(>0.5)	normal (<0.5°)
Hyperabduction:standard	pathological (>0.5)	normal (<0.5°))
Hyperabduction:alternative	pathological(>0.5)	normal (<0.5°)
Adson: standard	pathological (>0.5)	pathological (>0.5)
Adson: alternative	normal (<0.5°)	pathological(>0.5)

Table 2
Measurements at both hands

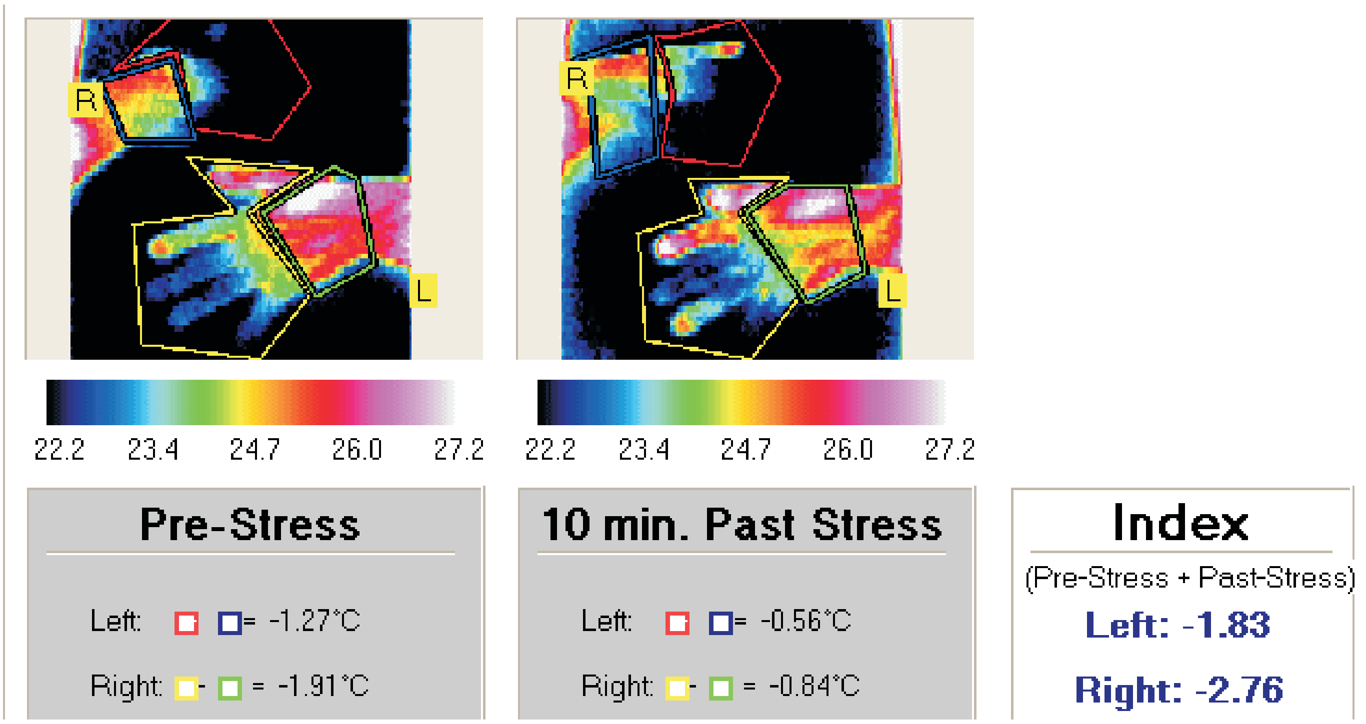
right hand	Standard method		Alternative method	
	Mean ± standard deviation	95 % confidence interval	Mean ± standard deviation	95 % confidence interval
Index	27.18 ± 1.89	26.81 to 27.56	27.46 ±1.99	27.01 to 27.86
Little finger	26.88± 2.00	26.48 to 27.28	27.13 ± 2.12	26.71 to 27.56
Difference index minus little finger	0.30 ± 0.32	0.24 to 0.37	0.33 ± 0.40	0.25 to 0.41
left hand	Standard method		Alternative method	
	Mean ± standard deviation	95 % confidence interval	Mean ± standard deviation	95 % confidence interval
Index	27.04 ± 1.98	26.64 to 27.43	27.24 ±1.99	26.83 to 27.65
Little finger	26.81 ± 2.00	26.41 to 27.20	27.07 ± 2.13	26.64 to 27.49
Difference index minus little finger	0.23 ± 0.38	0.15 to 0.31	0.17 ± 0.40	0.05 to 0.28

Table 3
Diagnostic outcome of standard and alternative evaluation

Evaluation right hand side	No TOS	Possible TOS	Probable TOS	Definite TOS
Standard method	14	3	3	5
Alternative method	10	4	3	8

Evaluation left hand side	No TOS	Possible TOS	Probable TOS	Definite TOS
Standard method	10	3	7	5
Alternative method	7	8	4	6

Figure .2
Example of cold stress tool of CTHERM that generates the Thermal Index



The size of of the measurement area of the alternative method of evaluation was about 10% of the region of interest used with the original method. Interclass correlation coefficients between temperature readings obtained from the standard and the alternative method of evaluation were 0.887 for the temperature difference index minus little finger at the right hand side, and 0.794 for the left hand side.

Higher temperature values were obtained from the smaller regions of interest resulting in wider confidence interval of temperature differences between index and little finger. Table 2 shows mean values of area and line measurements at both hands based on the computed 100 measurements.

The allocation to classes of TOS was significantly different between the two methods of evaluation (Chi-square Test, 2-tailed-p= 0.01). A higher number and more severe cases of TOS were detected with the alternative than with the original method of evaluation. (Table 3)

Raynaud´s Phenomenon

Raynaud´s phenomenon is characterised by colour changes of the fingers and of toes, occasionally . Pallor or white fingers is caused by arterial vasoconstriction, blue fingers or Cynosis is due to venous congestion and Rubor or redness of fingers is the result of reactive hyperemia. White fingers are often accompanied by low skin temperature and thermal imaging was used already in the nineteenseventies for the diagnosis of Raynaud`s phenomenon [15-17].

Immersion of hands in water of 20°C is a well accepted cold challenge test for the thermographic diagnosis of Raynaud's phenomenon [18] However, a standard for evaluation of temperature changes is not yet established. Francis Ring has proposed a Thermal Index by combining the temperature gradients from the dorsum to the fingers prior and past the cold challenge [19]. Others determined the gradient of single fingers [20] or used the slope of the rewarming curve.[21,22].

Methods

Three methods of evaluation of temperature readings from thermal images were compared in hands of 26 subjects after thermal images have been recorded in the following way. After acclimatization for 15 minutes to a room temperature of 24 degrees, the hands were positioned on a table, and images in the dorsal view for both hands were recorded. Then the hands, covered with plastic gloves, were fully immersed for 1 minute in water of 20°C. Immediately after taking off the gloves, and at in interval of 10 minutes 3 other thermal images were captured.

The cold stress test- tool of the software package C-Therm was used for the calculation of Ring's Thermal-Index. Ring originally [19] excluded the thumb from the region of interest due to the fact that the thumb is rarely affected by Raynaud´s phenomenon which was confirmed in a recently published paper [23). However, we included all fingers in the distal measurement area (Figure 2.)

Briefly, the thermal index was calculated in the following way. In the image prior to the cold challenge the distal region of interest (R0I 1)including the thumb and all long fingers was defined by the statiistics tool of CTHERM. Next the ROI 2 was defined from the wrist to the metacarpal (MCP) joints. The programme automatically calculates mean temperatures of the mesurement fields. This procedure was repeated for the images 10 and 20 minutes after the cold challenge. Finally. two images of interest are imported into the cold stress tool of CTHerm, where the temperature difference between distal and proximal ROI is automatically calculated and the Thermal Index is generated by summing up the temperature differences in the earlier and the later image.

Alternatively areas over single fingers were defined and gradients of single fingers were calculated by substracting the mean temperature of the dorsum from the mean temperature of finger areas (FG1=finger gradient 1). (Figure 3). Combining the mean FG1 prior and post cold challenge resulted in Thermal index area (TIa).

Temperature gradients for single fingers were determined in the following way (Figure 3): Spot temperatures were measured on the tip and over the mid of metacarpal bone of each finger. Gradients were calculated by subtracting the metacarpal temperature from the temperature of the finger tip (FG2=finger gradient 2). The mean value of the temperature gradients of all fingers of the right and the left hand were calculated.

An alternative Thermal Index gradient (TI) was calculated by summing up mean temperature gradients of fingers in the images of interest i.e. the comparison of the image prior

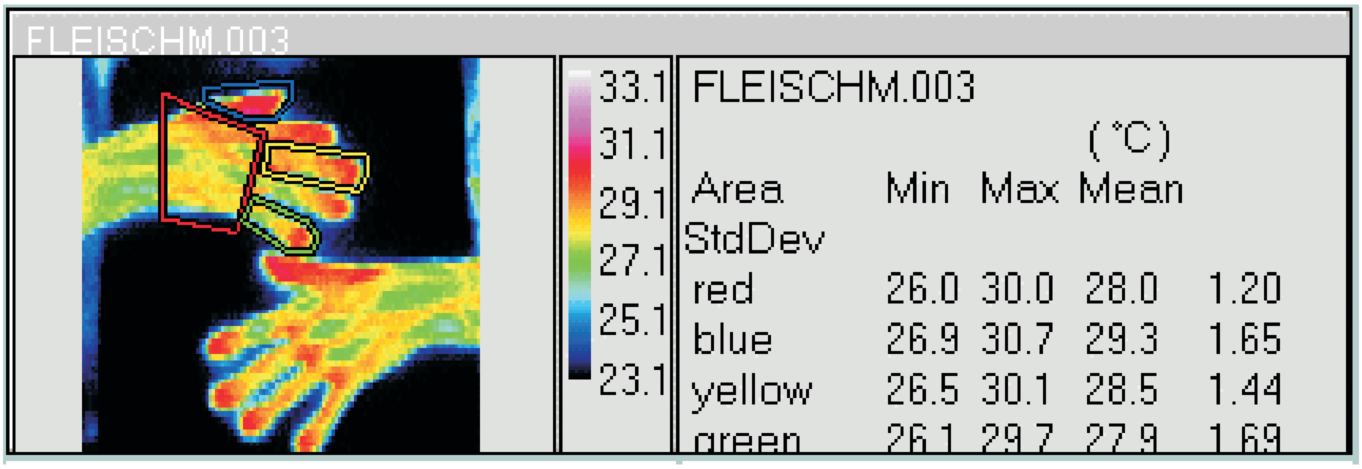


Figure. 3
Combination of a measurement area over the dorsal hand with measurement area over each finger

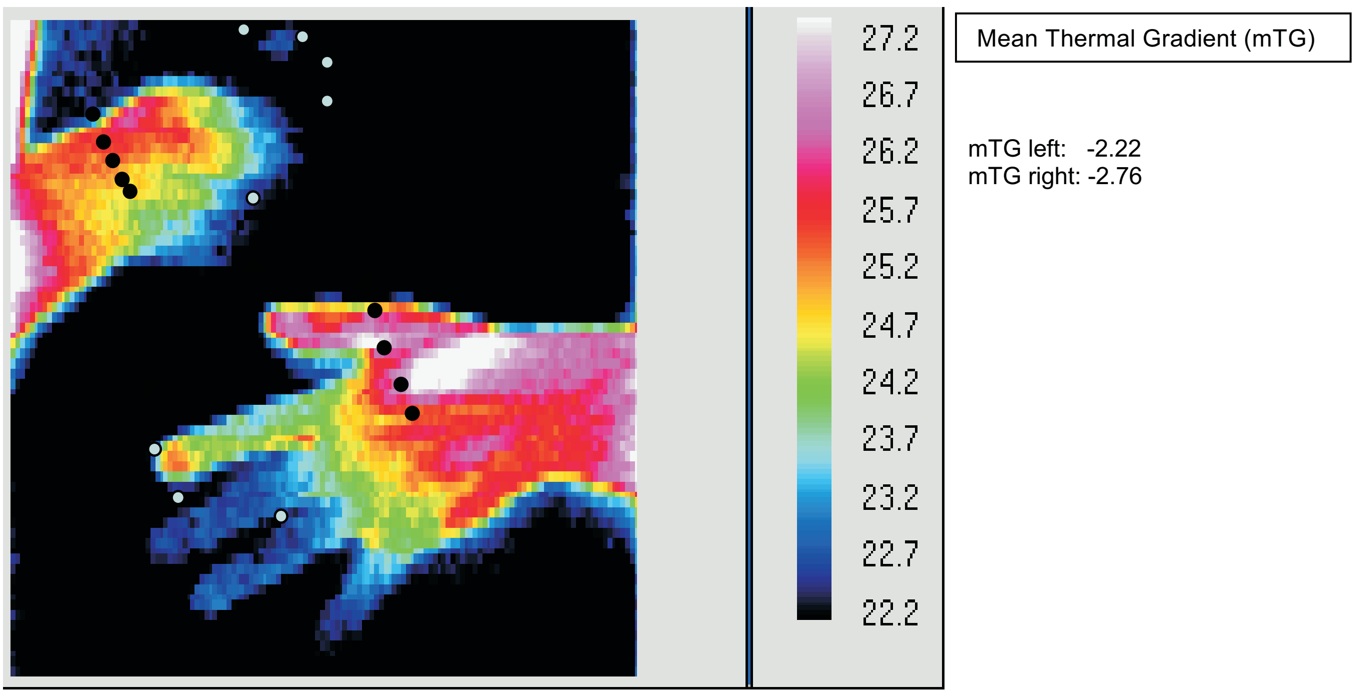


Figure. 4
Definition of temperature gradients of single fingers

	Before stress									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Finger tip	22.7	22.0	22.0	22.0	22.0	26.4	25.0	22.6	22.9	22.6
Metacarpal	25.7	25.4	25.1	24.3	24.0	28.0	25.4	25.5	26.0	25.7
Gradient	-3.0	-3.4	-3.1	-2.3	-2.0	-1.6	-0.4	-2.9	-3.1	-3.1

to the cold challenge with the image 10 or 20 minutes past cold challenge

Statistical evaluation

Using the software package SPSS 10, the three thermal indices were statistically analysed by non parametric tests The level for significant differences was set for 2-tailed p=0.05. The reliability coefficient alpha and the average interclass correlation were also calculated.

Diagnosis of Raynaud´s phenomenon was based on Thermal Index greater than -4.00 [.19]. The frequency of Raynaud´s phenomenon occurence due to different methods was compared with chi-square test.

Results

Figure 5 shows the mean Thermal Index at the right hand side obtained from all three methods 10 and minutes after cold challenge.

Comparison of the thermal index 10 minutes and 20 minutes past cold challenge, obtained a mean decrease of the Thermal Index of 0.32 ± 1,0 at the later measurement. The absolute values of the mean Ta were 0,93 to 1,28 greater than the related Thermal Index. The differences between TIg and the Thermal Index were 0.1 to 1. However, analysing all thermal indices with non parametric tests obtained no significant differences between the indices. Single mea-

Fig.ure5
Mean Thermal Indices at the right hand si

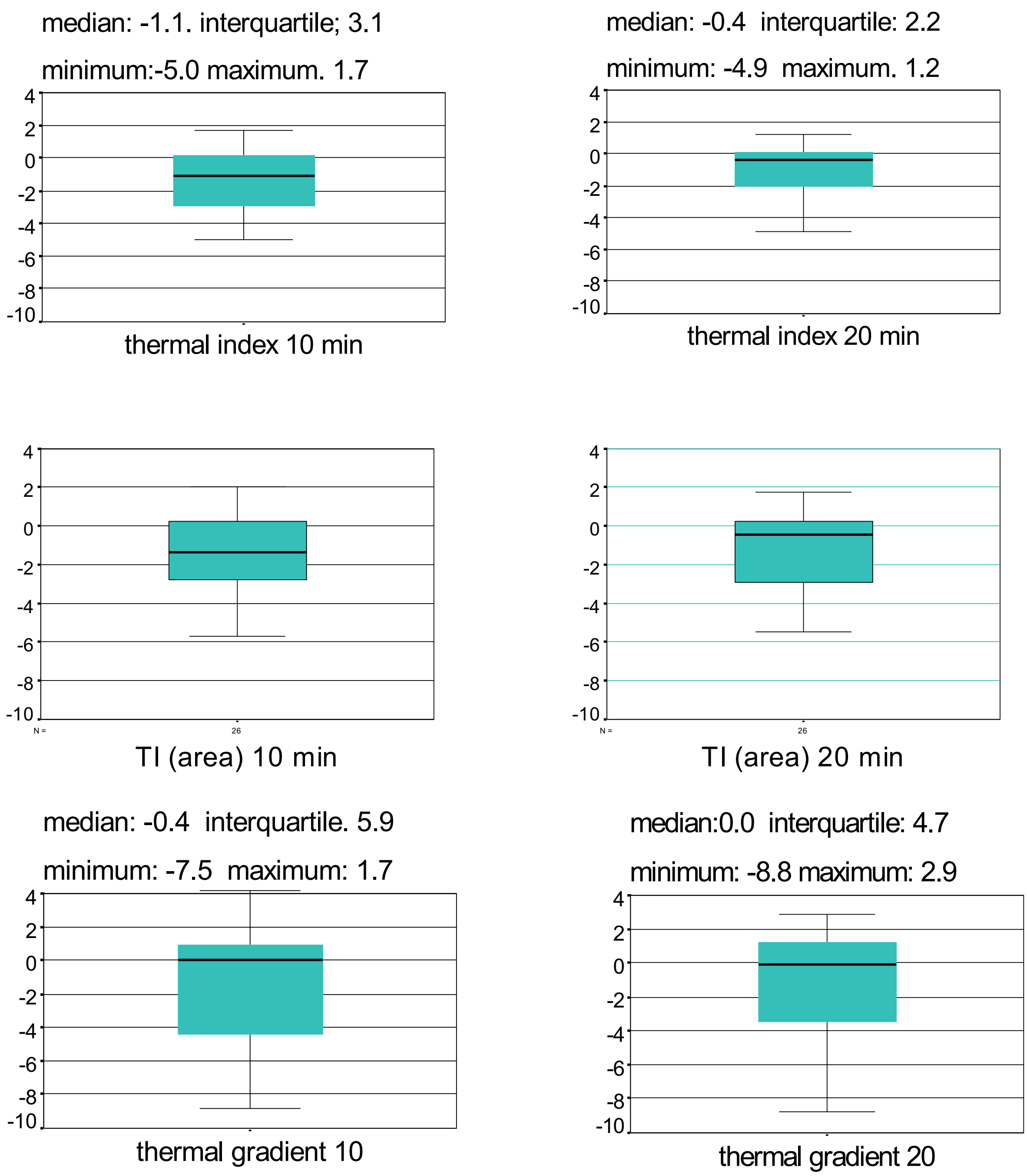


Table 4.
Cases with Raynaud´s phenomenon detected by different methods of evaluation

Time past cold challenge	Thermal Index $_{gradient}$	Thermal Index $_{area}$	Thermal index
10 minutes	13 cases	10 cases	7 cases
20 minutes:	9 cases	5 cases	3 cases

sure interclass correlations revealed values between 0.75 and 0.95.

Using a threshold of –4.0 for a diagnostic thermal index, the highest number of cases with Raynaud's phenomenon were identified with TI g, followed by TIa and the C-Therm derived Thermal Index (Table 4).

A high correlation was found between the Thermal Index determined by the dedicated tool of the software package C-therm and an alternatively calculated Thermal Index based on the temperature gradient of single fingers and comparing measurement areas over the hand and over single fingers, respectively. However, the Thermal Index derived from the temperature gradients of single fingers may by more sensitive for diagnosis than the other two Thermal Indices

Discussion

Smaller measurement areas resulted in both studies to a higher diagnostic sensitivity than larger regions of interest. This might be caused by a higher accurracy of infrared based temperature measurements from small areas taken from objects with a curved surface as the loss of radiation beyond a viewing angle of 45 °may become critical [24,25]

However, precision is higher when measurement areas cover the total field of interest and are not just placed some- where within the region of interest. Following the outline of fingers in Thermal Images revealed a high intar-and intratreader repetabilty of temperature readings, even in images with poor thermal contrast [11]. An hour glass shaped region of interest which alligned much better to the outline of the anterior knee than a circular or rectangular measurement area, resulted also in high repeatabilty of temperature measures [26]

As accuracy and precision of infrared based temperature measurements confer a different weight and importance for a diagnostic test and for a outcome measure [27], appropriate definition of measurement area may vary due to the intended utility of thermal imaging.

Conclusion

Different methods of evaluation lead to different sensitivity of thermal imaging . More cases were diagnosed of Raynauds Phenomenon were with smaller measurement areas than with with large regions of interest. Appling small measurement areas in thermograms recorded from patients suspected of thoracic outlet syndrome resulted also in more cases being diagnosed and also higher numbers of severe cases.

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Segmentation and Noise Removal on Thermographic Images of Hands

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SUMMARY

Hands are physiologically those parts of the body (together with the feet) where body radiant heat loss is highest. The temperature of the hands may be very close to the environmantal temperature and therefore may be difficult to be separated from the background in the infrared images. From all parts of the body, hands are most complex in shape and therefore difficult to segment. A correct outline, however, is needed for studying certain diseases such as arthritis, neuromusculoskeletal injuries or circulatory pathology by thermal imaging. Manual segmentation is possible but time consuming and inaccurate to reproduce.

The aim of this study was to investigate which of the many automatic edge detection algorithms known from literature produce the best performance in such low contrast thermal images. Additionally, the effect of pixel noise on this process is analysed by using a homomorphic filter prior to edge detection. This filter is appropriate because it allows pixel noise produced by the imaging system to be modelled as an additive term to the original image.

Two analyses are performed, a visual (subjective) and a quantitative (objective) for the extracted edges. Both assessment methods conclude that the best outlining results are achieved when using a probabilistic (Canny and Shen-Castan) edge detector together with homomorphic noise filter pre-processing.

KEY WORDS: Edge detection, hands, noise reduction, outline, segmentation, thermal image

SEGMENTIERUNG UND RAUSCHUNTERDRÜCKUNG IN WÄRMEBILDERN VON HÄNDEN

Physiologisch gesehen sind die Hände gemeinsam mit den Füßen die Körperteile mit dem höchsten Anteil der Abgabe von Strahlungswärme. Die Handtemperatur kann sehr nahe an der Umgebungstemperatur liegen und deswegen kann in Wärmebildern die Abgrenzung der Hände vom Hintergrund schwierig sein. Darüber hinaus gehört Form der die Hände zu den am meisten komplexen Körperteilen und deshalb ist die Segmentierung dieser Form besonders schwierig. Allerdings ist eine korrekte Umrisslinie notwendig um Krankeiten wie Gelenkentzündung, neuromuskluläre Verletzungen oder Durchblutungsstörungen mittels Thermographie zu untersuchen. Die Segmentierung von Hand ist zwar möglich, allerdings Zeit aufwändig und wenig zuverlässig.

Das Ziel der Studie war es zu untersuchen, welche der zahlreichen Algorithmen in der Literatur zur Kantendedektierung von kontrastarmen Wärmebildern die bestern Ergebnisse liefert. Außerdem, wurde der Einfluss des Rauschens der Pixel auf die Kantendedektierung analysiert, indem vor der Kantenentdeckung ein homomorphes Filter eingesetzt worden war. Eine solche Filterung erscheint geeignet, da es aus dem Pixelrauschen des bildgebenden Systems eine zusätzliche Eigenschaft des Originalbildes generiert.

Für die Kantendedektierung wurden eine visuelle (subjektive) und eine quantitative (objektive) Analyse durchgeführt. Beide Analysen kamen zu dem Ergebnis, dass die beste Umrissbestimmung der Hände in Wärmebildern mit dem probabilistischen (Canny and Shen-Castan) Algorithmus zur Kantendedektion nach Vorbearbeitung mit einem homomorphen Rauschfilter erzielt werden kann.

SCHLÜSSELWÖRTER: Kantendedektierung, Hände, Rauschunterdrückung, Umriss, Segmentierung, Wärmebild

Thermology international 2008, 18, 89-94

Introduction

The technique of infrared thermal imaging to measure temperatures, is an increasingly reliable clinical me thod for analysing vascular, neurological and musculoskeletal syndromes that affect hands and wrists (1). Hands, like feet, are the body areas where heat transfer with the environment occurs most frequently and effectively.

This in turn influences the boundaries of these extremities in thermal images, making them often difficult to detect as they may assume temperatures close to those of the environment. It is, however, necessary to have an accurate edge definition in each image so that the analysis of the thermal image neither includes any pixels belonging to the background or the environment nor excludes any parts actually belonging to the body.

Some authors suggest the use of Artificial Intelligence methods such as neural networks, genetic algorithms or edge maps to solve this problem (2, 3, 4). In practice, these techniques are computational intensive, time consuming, complex and often associated with a high probability of error.

Our approach consists of testing which of the currently existing and well documented traditional edge detection techniques for digital images is best suited for the demands of medical thermal imaging.

A second important aspect of thermal images is the presence of noise at a level of up to 5% of the dynamic signal range which is a result of the underlying sensor technology. It is therefore a second objective of this work to verify the hypothesis that noise pre-processing by a conservative noise reduction filter can improve boundary detection. It is thought that in this context one of the most appropriate filters should be the Homomorphic filter. It allows noise to be modelled as an additive term to the original image data (5) which is a close approximation of the physical processes inside the thermal camera sensor and electronics. Eleven classical edge detection techniques were selected and divided into five groups according to their underlying principle. The filters are:

-Gradient based (Roberts, Sobel, Prewitt and Kirsch);

-Second order difference based (Laplacian, Laplacian of Gauss, Marr-Hildreth);

-Probability based (Canny, Shen-Castan);

-Segmentation based (Watershed);

-Contour following based (Snakes).

The gradient based algorithms are the most simple ones. They detect both edges and their orientations, although they are sensitive to noise and due to their simplicity too inaccurate for certain applications.

Second order difference operators have fixed characteristics for all edge orientations. They find the correct place of edges and also test a wider area around the pixel than gradient based strategies. The disadvantages of these operators are their sensitivity to noise, multiple detection of the same edges, malfunctioning at corners/curves and problems in places where the grey level function varies.

Edge orientation detection is affected due to the properties of the Laplacian approach. Probabilistic methods have good localisation capabilities and response even in the presence of noise, they compute probability values for determining an error rate. Their major disadvantages are poor detection of zero crossings and the complexity of computations (6).

Segmentation based operators filter the objects boundaries and effectively remove some of the image noise, but they treat the image foreground and background asymmetrically (7). Contour following methods finally are able to reduce a second order problem to just one dimension and optimise locally. They are, however, relatively slow (8).

Material and Methods

The FLIR A40 (thermal) infrared camera with a resolution of 320x240 pixels, a measurement accuracy (bias, offset) of ±2ºC and a precision (repeatability) of ±0.1ºC was connected to a PC using the CTHERM software package developed at the Medical Imaging Research Unit and used to capture thermal images. (9).

The approach used was to follow a standard image capture protocol (10) for the collection of thermograms from the hands of volunteers. A reference shape with the standardised form and anthopometric size of both hands was used to aid the image recording, helping in the positioning of the hands and in recording similar areas of interest (11).

After capturing 35 images into a database the 5 thermograms with the poorest contrast between background and extremity were selected to be used as inputs to the edge detection and noise reduction algorithms. From the CTHERM software thermograms were exported as standard grayscale bitmaps (BMP) for subsequent processing in Matlab™.

The selected Bitmap images were processed in two ways: the first using pre-process noise reduction filtering with a Matlab™ implementation of the homomorphic filter followed by the edge detections, the second employed edge detection algorithms only without pre-processing.

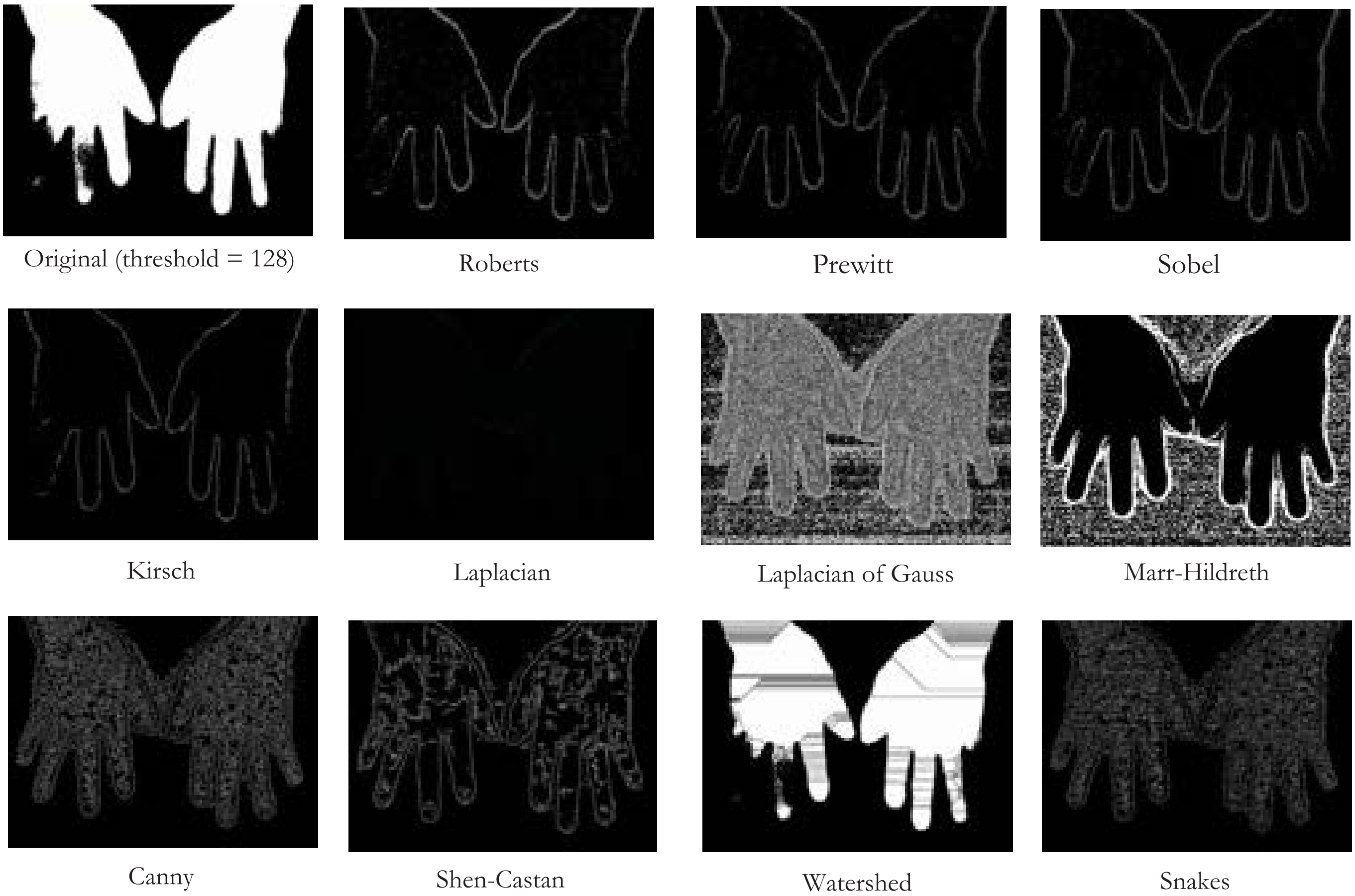
All edge detection algorithms were implemented as Matlab™ scripts (12). The parameters used for defining the Homomorphic filter were: 'low filter' value equal to 0.1 and 'high filter' value equal to 1 in order to decrease the illumination contribution and increase the reflectance contribution. The value used for the 'delimiter' was 7.

The gradient based edge detectors had the usual automatic threshold based on the average grey-level of the image to

Figure 1
Original thermal image

Figure 2
Optimal Outline drawn manually

Table 1
Edge detection without noise pre-processing



maintain consistency for subsequent comparisons. Line thinning was applied and all detectors (with the exception of the Sobel one where the direction was rotated in multiples of 45°) used both horizontal and vertical directions of edge detection.

In the Laplacian filter the 'shape value' was set to 0.2, whereas the Laplacian of Gauss filter used an automatic threshold and a standard deviation value of 2. The Marr-Hildreth algorithm used a Gaussian kernel of size 11, a standard deviation value of 1 and the median of Gaussian was set to 0.

In the probability based operators, the Canny filter used automatic low and high thresholds and 6 as standard deviation preset. The Shen-Castan filter used 1 as the 'smoothing factor', 0 for the low and 3 for the high threshold value (chosen empirically). The watershed segmentation based edge algorithm used an automatic threshold calculated using the average image grey level together with an 8 pixel connected neighbourhood for each individual location. The parameters used for the Snake algorithm were 0 for the 'energy' contributed by the distance between control points, 0.1 as 'energy' contributed by the curvature of the snake and 1 pixel for each incremental move of the snake in order to reduce computation time. For the initial seeding outline the output of the Canny filter was used.

Two evaluation methods were used to compare and assess the edge detection algorithms and to verify any improvements as a result of noise filter pre-processing. In the first (subjective) method, 5 image processing professionals graded the edge detection algorithms on a 10 point scale. The algorithm with the cumulative smallest score was considered the best. If the images resultant from noise filter pre-processing obtained better scores than the ones without, the conclusion was that in this instance noise filtering enhanced the results of the respective outlining process. On occasions where the subjective judgement resulted in a draw a second review stage was used to arrive at a ranking.

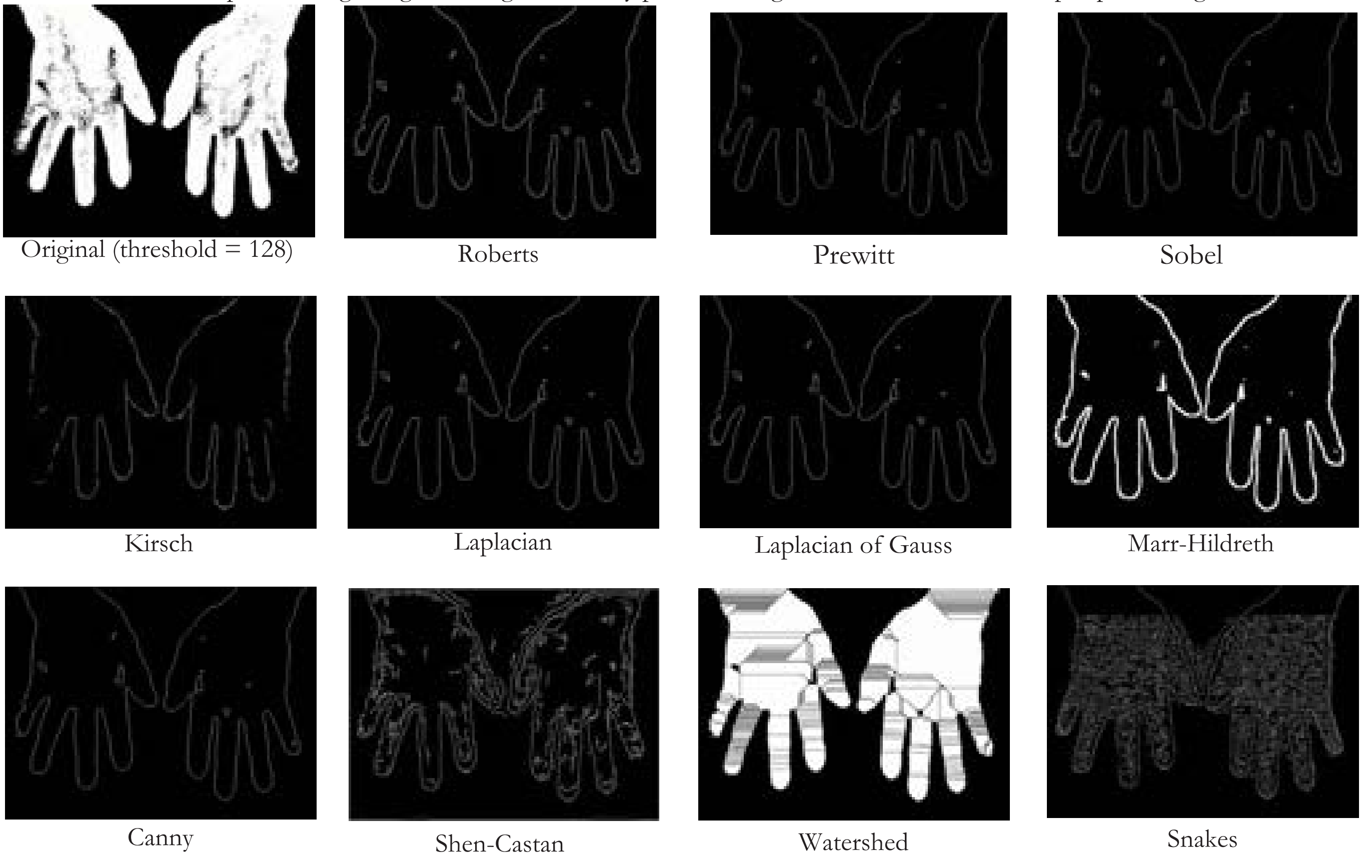
The second (quantitative) method is based on a reference outline that was produced in a graphics package under high magnification and aided by contrast enhancement techniques. The performance measure here is the total length of the outline (in pixels). The same quantitative method was used to assess noise filtering.

Results

Figure 1 shows a typical input image selected from the database with poor edge to background contrast. Figure 2 shows the corresponding optimal outline drawn by hand.

Table 1 shows the images resulting from the application of the edge detection algorithms without applying any noise

Table 2
Difference between optimum edge length and algorithmically produced edges with and without noise pre-processing



reduction filtering. Subjective grading selected probabilistic methods and contour following methods as best performers.

Table 2 presents algorithm outputs with homomorphic pre-processing applied. According to the subjective grading scale the best output was produced by second order based methods, followed by gradient based methods (excluding the Kirsch algorithm and probabilistic methods). It can be observed that homomorphic filtering enhances the results for all algorithms.

Table 3
Comparison of the number of outline pixels

		Hand Images	
		Non-Filtered	Non-Filtered
Outlining Algorithms	Optimal	4562	4562
	Roberts	7217	5442
	Sobel	5989	4320
	Prewitt	5991	4224
	Kirsch	4007	4221
	Laplacian	15097	4630
	Laplacian of Gauss	122374	10838
	Marr-Hildreth	70199	24415
	Canny	29888	2804
	Shen-Castan	16853	16246
	Watershed	138456	150622
	Snakes	26428	22806

Table 3 lists the result of the objective classifying method on the average of the 5 selected thermograms, (i.e. the number of pixels that form the outline). The best edge detection algorithms when not using noise filtering are the classical gradient based methods (Roberts, Sobel, Prewit, Kirsch). When using pre-process noise filtering the best results are produced by the gradient based, probabilistic based and second order based methods (excluding Marr-Hildreth).

Figure 3 demonstrates the benefit of the homomorphic filter by plotting the line length percentage difference between the optimum edge and the output of the respective filters.

Discussion

The subjective performance evaluation method used human judgement. The number of characteristics that a human eye can reliably distinguish is, however, limited (13). For this study a combination of subjective and objective validation was therefore used. The number of pixels forming the outline was used as an objective comparison method as it is simple to compute and provides a single figure for grading results. It could be argued that the difference between the areas enclosed by the outlines would be a more suitable measure since it is these areas that are used for subsequent clinical analysis and this approach will thus be studied in future work.

The results of this work support previous studies that used other types of digital images (6, 13). It demonstrates that traditional techniques which are usually computationally inexpensive and thus fast and simple to implement can produce adequate if not superior results (2, 3, 4) to more complex recent approaches such as those based on artificial intelligence, edge maps or neural networks.

Conclusions

From this study it can be concluded:

1.Probability based and gradient based edge detection techniques are the most suitable methods to outline hands in medical thermal images.

2.The homomorphic filter enhances boundary detection by reducing noise and 'clearing up' previously undetectable constructive features that assist edge detection algorithms.

3.Some post-processing such as such as thinning, artifact removal, etc. is needed to improve the results.

The outcomes of this work are now used in an ongoing project that introduces template outlines in addition to the edge detection process in regions where contrast between background and extremity is low or non- existent and edge detection therefore fails completely. This approach is using anatomical control points (i.e. well defined points such as finger tips) to assist the alignment between the template outline and the outline produced by edge detection. Eventually this work will assist hand pathology studies, clinical 'cold stress' examinations and the production of an atlas of normal infrared medical images as a reference source for clinicians (14).

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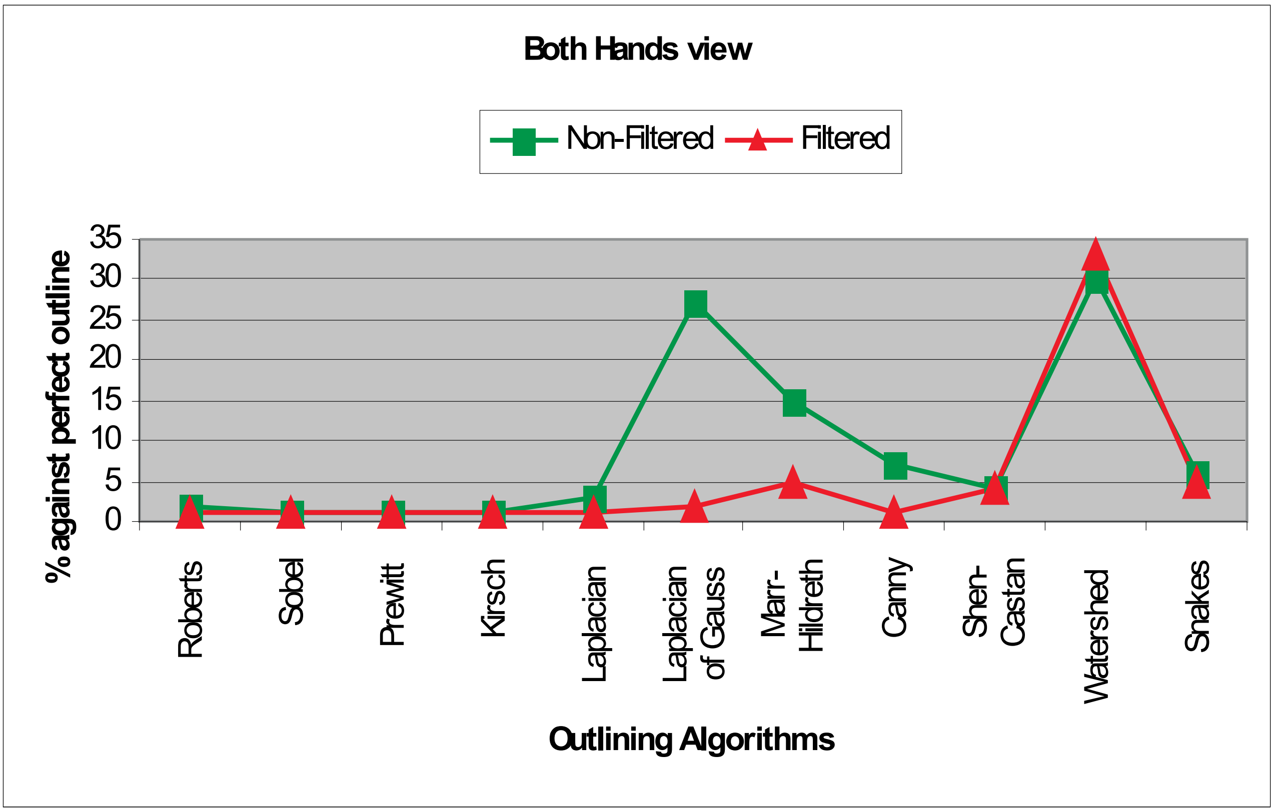
Figure 3
Difference between optimum edge length and algorithmically produced edges with and without noise pre-processing



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Equilibration period following exposure to hot or cold conditions when using infrared thermography

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SUMMARY

INTRODUCTION: The proper use of Infrared Thermal Imaging (ITI) requires following strict protocols. The International Academy of Thermology (IAOCT) has copied standards and procedures which were developed in Europe in the late 1970's, and have subsequently been adopted by both the Japanese Society of Thermography and the American Academy of Thermology. A minimum of 15 min for equilibration is suggested by existing standards. However, it is unclear if the suggested 15 minute equilibration is adequate for stable skin temperature measures when the individual has previously been exposed to either a hot or cold environment.

PURPOSE: To determine the equilibration time required after exposure to a hot or cold environment at a constant 50% relative humidity using ITI non-contact thermal measures.

METHODS: This investigation used a randomized crossover design in which the participants were exposed to either the hot (31.7 °C) or cold (18.9°C) environment at a constant 50% relative humidity. Male and female college age participants wore minimal attire in order to expose maximal skin surface to room temperature. Each test trial had three phases: equilibration, hot or cold exposure, and recovery. Prior to the thermal exposure, a 60 minute equilibration period in a climate controlled room at ambient temperature (24.2 °C, 50% humidity) provided the baseline infrared thermal skin temperature measures. After infrared images were taken (anterior and posterior; trunk and extremities), the participants stood in the thermal chamber for 20 min exposure period (hot or cold) trial. Images were taken after the thermal exposure and participants once again returned to the ambient room condition where infrared images were taken at 0, 15, 30, 45, and 60 min of recovery. Surface temperature measures between the equilibration measures, exposure and recovery time were statistical compared using repeated measures ANOVA ($p < 0.05$).

RESULTS: During the hot trial mean trunk temperature remained significantly different from control until the 30 min time period. The mean periphery temperature remained significantly different during the entire 60 min time period following the hot trial. During the cold trial the mean trunk temperature remained significantly different until the 15 min time period, while the peripheral region was significantly different until the 30 min time period.

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

KEYWORDS: Infrared Thermal Imaging, Equilibration Period, Skin Temperature

AKKLIMATISATIONSZEIT FÜR DIE INFRAROTTHERMOGRAPHIE NACH KÄLTE- ODER WÄRMEEXPOSITION

EINLEITUNG: Für die korrekte Verwendung der Infrarotthermographie muss einem genauen Protokoll gefolgt werden. Die Internationale Akademie für Thermologie (IAOCT) hat Standards und Prozeduren kopiert, die in den späten 1970iger Jahren in Europa entwickelt und die später sowohl von der Japanischen Gesellschaft für Thermographie als auch von der Amerikanischen Akademie für Thermographie übernommen und adaptiert worden waren. Für die Anpassung an die Raumtemperatur wird in diesen Standards eine minimale Zeit von 15 Minuten vorgeschlagen. Allerdings ist es unklar, ob 15 Minuten ausreichen, um eine eine stabile Hauttemperatur zu erreichen, wenn der zu Untersuchende vorher einer kalten oder sehr warmen Umgebung ausgesetzt war.

ZIEL DER STUDIE: Welche Akklimatisationszeit ist notwendig, um nach Exposition an eine kalte bzw. sehr warme Umgebungstemperatur bei einer relativen Luftfeuchtigkeit von 50% eine konstante Hautemperatur zu erreichen, die mit kontaktlose Infrarotthermographie gemessen werden soll.

METHODE In einem Crossover-Studiendesign wurden die Teilnehmer in randomisierter Abfolge entweder einer sehr warmen (31.7 °C) oder kühlen (18.9°C) Umgebungstemperatur bei konstanter 50% relativer Luftfeuchtigkeit ausgesetzt. Die männlichen und weiblichen teilnehmenden Collegestudenten waren minimal bekleidet, um möglichst viel Haut der Umgebungstemperatur zu exponieren. Jede Test bestand aus drei Phasen: Akklimatisation, Kalt- oder Warmexposition, Erholung. Vor der Temperaturexposition akklimatisierten die Teilnehmer 60 Minuten lang in einer Klimakammer mit einer kontrolierten Raumtemperatur von (24.2 °C und 50% Feuchtigkeit, um die Ausgangswerte für die mit Infrarot gemessener Hauttemperatur zu erhalten. Nachdem Infrarotbilder der Vorder - und Rückseite des Stammes und der Extremitäten aufgezeichnet worden waren, wurden die Teilnehmer stehend 20 Minuten lang der sehr waren oder kühlen Umgebungstemperatur ausgesetzt. Danach kehrten die Teilnehmer in eine Umgebungstemperatur von 24° zurück, wobei sofort und 15, 30, 45 und 60 Minuten nach Eintritt neuerliche Wärmerbilder angefertigt wurden. Die Hauttemperaturmessungen zwischen Ausgangswerten, Temperaturexposition und Erholung wurde mittels ANOVA für Messwiederholungen analysiert ($p < 0.05$).

ERGEBNISSE: Nach Wärmexposition unterschied sich die mittlere Rumpftemperatur bis zum Messzeitpunkt 30 Minuten nach Exposition signifikant vom Ausgangswert. Die mittlere Temperatur der Extremitäten blieb bis 60 Minuten

nach der Wärmexeposition zum Startwert signifikant unterschiedlich. Nach Kaltexposition blieb die mittlere Rumpfmuskulatur bis 15 Minuten nach Exposition siggnifikant unterschiedlich zu den Ausgangswerten, die mittlere Temperatur der Extremitäten unterschied sich 30 Minuten nach Exposition signifikant von den Ausgangswerten.

SCHLUSSFOLGERUNG: Die Ergebnisse dieser Infrarotthermographiestudie legen nahe, dass Personen, die einer kalten oder sehr warmen Umgebungstemperatur ausgesetzt waren (31.7 °C bzw. 18.9 °C), möglicherweise eine längere Akklimatisationszeit als die empfohlenen 15 Minuten benötigen, um eine ausreichende stabile Hauttemperatur zu erreichen.

SCHLÜSSELWÖRTER: Infrarot- Thermographie, Akklimatisationszeit, Hauttemperatur

Thermology international 2008, 18: 95-100

Introduction

Infrared Thermal Imaging (ITI) utilizes a noninvasive imaging technique that accurately maps and measures skin surface temperature. The skin temperature of the region of interest is determined from the mean of numerous individual pixel temperature measures within the region. The interest in the application of ITI has evolved in recent years because of the non-contact capability to determine skin temperature. ITI detectors are able to capture the natural thermal radiation generated by an object at a temperature above absolute zero. The speed and spatial resolution of cameras have improved over the last ten years. ITI is unique in that it does not utilize an external source of infrared illumination. The radiation that is detected is generated by the objects within the plane of view [1]. Planck's radiation law represents the maximum thermal power that can be radiated by an object; this is known as the emissivity of an object [2]. The radiant heat being emitted from the skin is independent of race and depends only on the actual skin surface temperature (1). The current ITI systems are able to detect skin temperature up to 1.5cm deep with a sensitivity of 0.01°C (FLIR Systems, Wilsonville OR). These principles suggest that ITI is an ideal candidate for skin temperature measurements.

The infrared image represents a visual thermal map that correlates with the anatomical distribution of skin blood vessels and blood flow that assist in heat transfer from the skin [3]. While skin temperature or heat emissions can be easily accessed, the measurement of the skin surface represents a complex thermal interface or barrier between core body temperature which reflect cellular metabolism and environmental conditions. The temperature of the body is regulated by neural feedback mechanisms which operate primarily through the hypothalamus. Circulation to the skin is regulated by local skin temperature, core temperature, and via the sympathetic nervous system and autonomic nervous system's control over the neural reflex.

The skin's variable blood flow and ability to transfer heat plays a crucial role in the thermoregulation of the human body. Control of skin blood flow is regulated by neural, hormonal, and local factors that are capable of regulating vasoconstriction and vasodilation in response to metabolic heat production and surrounding environmental condition [4]. This blood flow regulation effectively manages heat transfer between core environment, skin surface area, and the external environment. As such, the accurate measurement of the skin surface area is paramount to understanding these heat transfers.

The vasoconstrictor system in skin is tonically active in thermoneutral environments that enable normal body temperature to be maintained during slight changes in activity or temperature [4, 5]. Slight changes in skin blood flow can cause relatively large changes in heat dissipation, this allows the body to regulate heat loss and heat production within vary narrow physiological limits [4]. Ammer demonstrated that skin surface temperature readings from thermal images were less dependent on the ITI number of pixels as the variations in room temperature [6]. Olsen, based on the compilation of 800 trials in numerous studies, found that the number of sites necessary for estimating mean skin temperature was dependent on the accuracy of the measure required and the environmental conditions [7]. Fewer sites were necessary in the warm conditions (more homogeneous skin temperatures) and more sites were necessary in colder conditions (more heterogeneous skin temperatures). While the Olsen paper suggests the variable flow response of the skin to environmental conditions, it must be recognized that the research involves skin thermistor probes and the mean skin measures were being used to calculate a whole body mean skin temperature. The use of skin thermistor probes can be problematic because skin surface temperature is taken form a single site in which the location of the probe can provide variation and the contact attachment of the probe creates a micro-environment that can alter the skin temperature measure. There is valuable information that can be gained form these earlier studies, but the improved measurement technology of ITI may provide some new insights and improved accuracy of skin thermal measures.

The International Academy of Thermology (IAOCT) has copied standards and procedures which were developed in Europe in the late 1970's, and have subsequently been adopted by both the Japanese Society of Thermography and the American Academy of Thermology. A minimum of 15 min is the current amount of time suggested by existing standards [8}. While a minimum of 15 minutes is needed for equilibration, different time periods are seen throughout the literature when using ITI [9, 10, 11, 12].

Varying environmental temperatures may affect the amount of time it takes for skin temperature and room temperature to stabilize. Our investigational design allowed us to determine the equilibration time (stable skin thermal measures) required in thermoneutral ambient room conditions (24°C, 50% relative humidity) after exposure to 2 different environmental conditions (31.7°C and 18.7°C and 50% relative humidity).

Methods

The study was performed on a group of 17 volunteers (6 male and 11 female) ages (19-22 ±1). Subjects were instructed to respond to a PAR Q Medical Questionnaire (Par Q), in which they were required to respond without any notation that suggests potential orthopedic, medical, or pharmacological conditions that may affect the outcome, in order to be included in the study [13]. Following the Par Q, each participant met with the primary investigator to read and sign University approved informed consent forms. Subjects were encouraged to refrain from physical activity, caffeinated beverages, and any topical creams that may affect skin temperature on the day of the study.

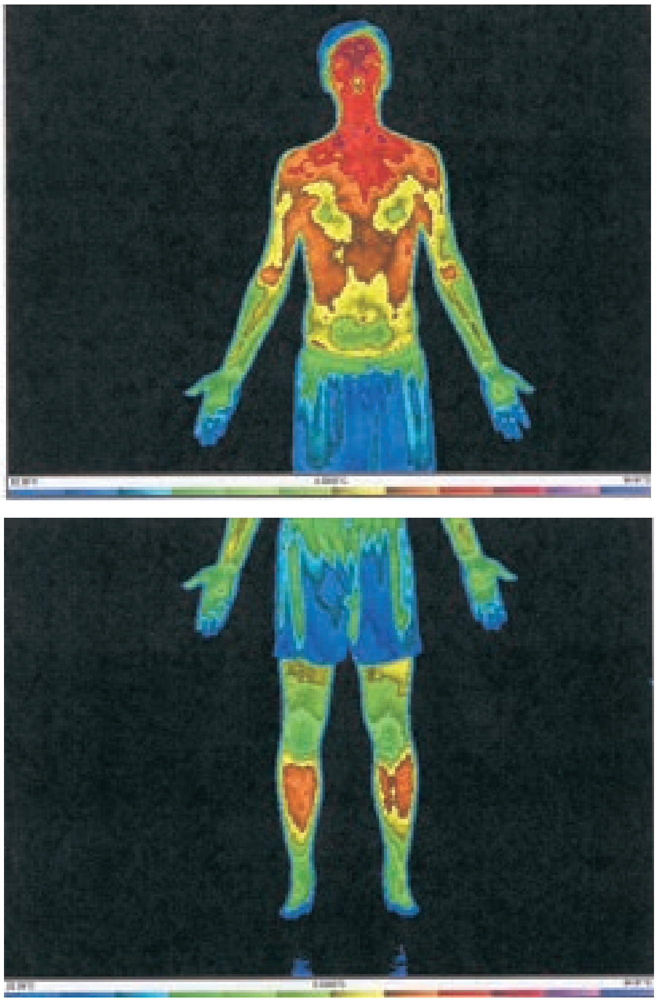
Height, weight, and body fat % were assessed during the first visit. Measurements of weight were completed by asking the subjects to step on a balance scale (Electronic Michelli Scale), weight was recorded to the nearest 0.5 kilogram. Height measurements were completed by asking the subjects to stand flatfooted and erect with their backs facing the height scale. Height was recorded to the nearest 0.25 centimeter. Body fat % was assessed by means of Lange calipers using the sum of three skinfold thickness (triceps, suprailium, and thigh for women; and chest, abdomen, and thigh for men). The procedures for skinfold were those outlined by Pollock and Wilmore [14].

Thermal images were taken during four separate trials; subjects were split into 2 groups. Using a randomized crossover design, subjects were exposed to either the hot or cold environment. The experimental sessions were separated by at least 24 hrs and performed at the same time each day in order to reduce physiological changes that might occur from circadian rhythm differences.

Hot Trial

Thermal images of male and female subjects (males wearing shorts and females wearing shorts and sports bra) were taken of the anterior superior, anterior inferior, posterior superior, and posterior inferior view after allowing 60 minutes for the body to equilibrate to ambient room temperature (22°C-25°C, 50% humidity), which is considered optimal room temperature for comfort (15). Participants were asked to stand and were instructed to not touch any part of their body in order to minimize conductive heat transfer. A Quest 34 WBGT (Wet Bulb Global Temperature) monitor was used to measure room temperature and humidity throughout the trial. Subjects were then placed in the environmental chamber for 20 minutes. Temperature was maintained in the environmental chamber during each trial (mean temp 31.7°C, 50% humidity). After the 20 minute time period subjects were moved to a room in which thermal conditions were maintained at ambient room temperature (23.5°C-25.2°C, 50% humidity). Ambient room temperature was maintained within 1°C during each trial. Thermal images of the anterior superior, anterior inferior, posterior superior, and posterior inferior view were taken immediate-post, 15, 30, 45, and 60 minute time periods.

Figure 1.
Sample of thermal image taken of the superior and inferior anterior views using TIP MED. Average temperature of the arms and legs were designated periphery region, and average



The skin temperatures from these images were used to determine time for recovery of thermal images to the pre-trial equilibration values. These time intervals were chosen because 15, 30, 45, and 60 minute time periods have commonly been used in previous literature (9, 10, 11, 12).

Cold Trial

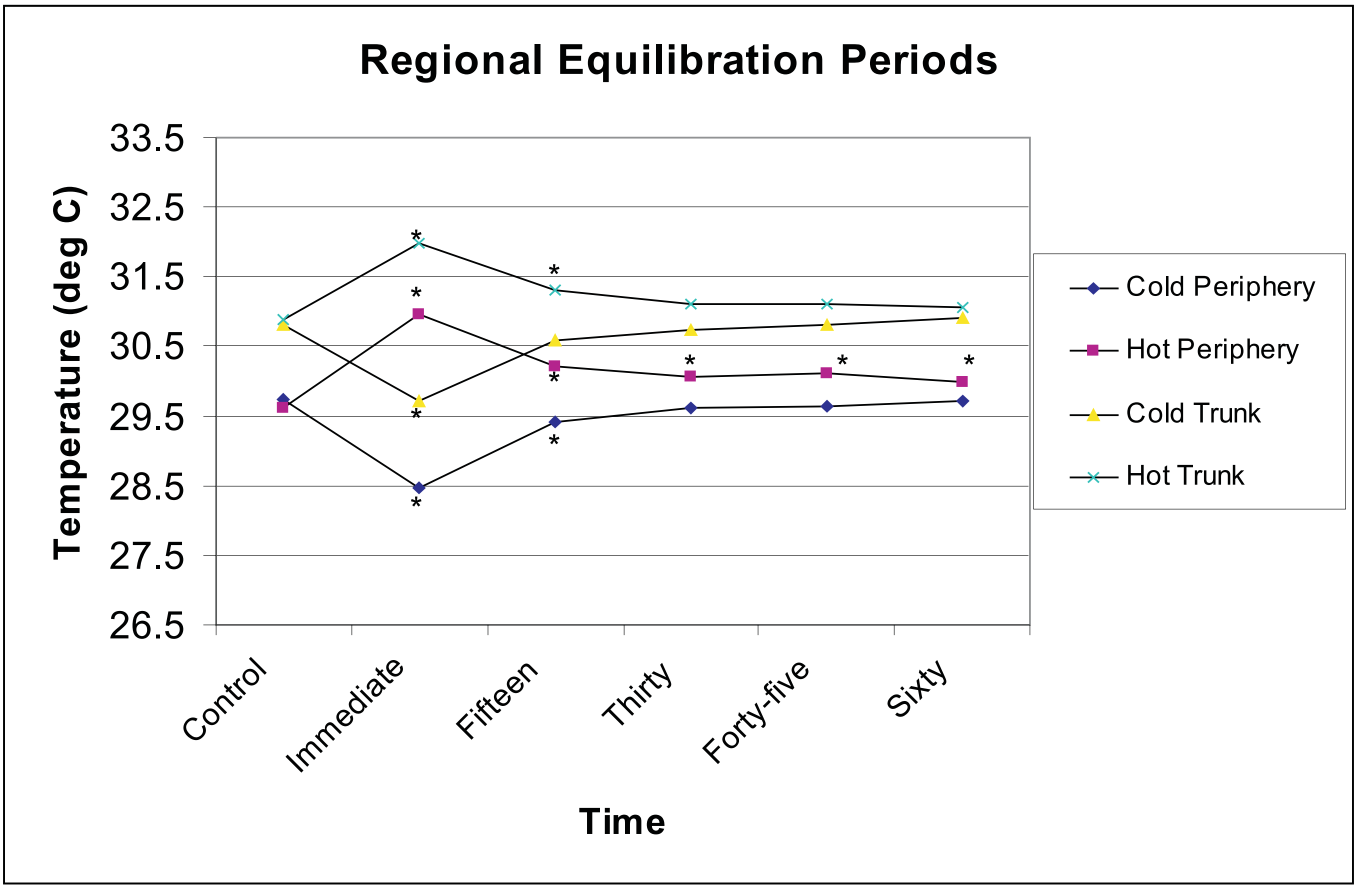
Thermal images of the anterior and posterior views were taken following the 60 minute equilibration period. Subjects were then placed in the environmental chamber for 20 minutes. During this trial temperature in the environmental chamber was maintained at (mean temp 18.7°C and 50% humidity). Following the 20 minute time period, subjects returned to neutral temperature conditions. Thermal images of the anterior superior, anterior inferior, posterior superior, and posterior inferior were again taken immediate-post, 15, 20, 30, 45, and 60 minute time periods.

All thermal images were recorded using Computerized Thermal Imaging Processor systems. Thermal Images were analyzed using TIP Thermal Imaging Process Software (anterior and posterior views were subdivided into periphery area and trunk area by calculating mean temperature of the arms and legs for peripheral temperature, and using the

Table 1.
Anthropometric Data for Male and Female Participants

Gender	Age	Height (inches)	Weight (kg)	% Body Fat
Female	20	60	51	18.5
Female	19	68	66.7	14.8
Female	21	66	57.2	13.9
Female	20	62	58.5	17.5
Female	21	63	54.2	18.6
Female	20	62	59.2	13.2
Female	21	69	71.5	22.9
Female	21	64	59.5	20.3
Female	19	66	61.1	17.1
Female	21	66	57	13.9
Female	20	70	82.9	20.8
Male	22	69	113.6	31.7
Male	22	75.5	78.3	11.4
Male	22	67	67.2	12.3
Male	20	69	64.7	14.4
Male	19	67	68.4	10.8
Male	21	71	84.3	14.9
Mean	20.5	66.7	67.9	16.9
SD	1.0	3.8	15.2	5.14
Mean Male	21	69.75	79.4	15.9
SD Male	1.3	3.2	18.3	7.9
Mean Female	20.3	65.1	61.7	17.4
SD Female	0.78	3.2	8.9	3.2

Figure 2.
Regional equilibration periods following exposure to hot or cold environmental conditions. *(P < 0.05). The graph begins with the first thermal image following 60 minutes of equilibration at optimal ambient room temperature, this served as the control temperature for each condition.



anterior and posterior views of the torso to represent trunk temperature).

Data was placed into an excel spreadsheet and later analyzed using SPSS software. Temperature differences between control, immediate-post, 15, 30, 45, and 60 minute time periods were compared using repeated measures ANOVA. When significance was found, pair-wise comparisons were performed ($p < .05$).

Results

All 17 subjects completed the study (Anthropometric data presented in Table 1).

Temperature change over time for each environmental condition is illustrated in Figure 2.

Figure 2 illustrates the changes in skin temperature in both the trunk and peripheral regions following exposure to either hot or cold environmental conditions. Mean peripheral skin temperature was reduced from 29.73°C during the control period to 28.48°C following cold exposure. Peripheral skin temperature remained significantly different then control period till the 30 minute recovery time period, indicating failure to return to skin temperature values that were identified during equilibration. Following the hot trial, mean peripheral skin temperature increased from 29.62°C during the control period to 30.97°C during the recovery in ambient room conditions. Peripheral skin temperature remained significantly different for the entire 60 minute time period.

Mean skin temperature decreased from 30.80°C during the control period to 29.71 in the trunk region following cold exposure. Skin temperature was significantly different immediately after exiting the chamber, but was fully equilibrated in 15 minutes. Following the hot trial, skin temperature increased in the trunk region from 30.88°C during the control period to 31.97°C during the recovery in ambient room conditions. Skin temperature remained significantly different from control till 30 minutes, failing to return to previously established equilibration values within 15 minutes.

Discussion

Results from this study suggest that exposure to hot or cold conditions (31.7°C and 18.9°C) prior to an ITI imaging session may require more than the recommended 15 minute equilibration period for skin temperature to stabilize to room temperature. The subject's environmental exposure prior to the ITI session can have a significant effect on the dynamic response of skin temperature. Ensuring proper equilibration is crucial when comparing thermal measurements between multiple sessions. If equilibration has not been reached, there will be significant variability when comparing skin temperature.

The ability of the body to maintain precise core temperature is the result of physiological processes in the body that works to maintain homeostasis during resting conditions, and to strive for state conditions during exercise. The skin has a significant role in maintaining core temperature near a homeostatic value of 37°C, rarely deviating from this mean. Communication between central thermoreceptors and peripheral thermoreceptors provides a precise feedback mechanism enabling vasoconstriction during colder conditions and vasodilation during warmer conditions (16, 17). These physiological responses regulating skin blood flow are the primary reasons that ambient room temperature and proper equilibration must be controlled prior to screening using ITI, especially when comparing multiple sessions.

As far back as the Egyptian culture, humans have recognized the importance of thermal measures taken from the skin. Since these early observations, medical clinicians have discovered the importance of absolute temperature measures, thermal symmetry, and thermal patterns (isotherms, dermatomes). In order to properly interpret the ITI images the researcher and clinician need to understand the anatomical and physiological responses that are responsible for changes skin temperature and skin circulation during thermoregulation. While the ITI imagers capture a skin surface thermal image from a single point in time, one should recognize that this image is capturing a dynamic response that is constantly being changed and regulated according to outside factors and stressors. As a result, ITI can be used to observe the thermal responses of dynamic stress tests (e.g. cold water immersion, convective air movements, and exercise) to better understand human physiological responses.

As ITI imagers increase in image quality, image analysis, and computerized program functions while decreasing in size and cost, the use of infrared imaging will continue to see an increase in use and applications. As with any methodology, proper techniques and guidelines are essential to assure and maintain validity, reliability, and overall credibility of ITI. Allowing appropriate equilibration period will stabilize skin surface measures and patterns. In all cases, the equilibration period should be recorded. While generalized guidelines can be suggested, the ITI imager needs to be cognizant of factors that may require extended equilibration periods. Prior environmental exposures, area of the body being imaged, and ambient room temperature are all factors that can effect either the equilibration period or the thermal image itself. The data from this study suggest that a 30 minute equilibration period may be more reliable for ensuring proper equilibration, as opposed to the previous standard of 15 minutes.

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Dermatoscopy and thermal imaging: a comparative investigation of melanocytic nevi of the skin

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SUMMARY

BACKGROUND: Thermography is a noninvasive technology for accurate registration of temperature distribution of the surface of the body studied.
METHODS: The study enrolled 245 patients with 735 melanocytic nevi and 12 patients with malignant melanoma. All melanocytic lesions were studied with a dermatoscope and an thermal imager. A Heine delta 10 dermatoscope was used to determine the TDS (total dermatoscopy score – according to Stolz) coefficient. A ThermaCAM™ S.C. 500 thermographic camera measured the maximum (Tmax), minimum (Tmin), and average temperatures in the area of the melanocytic lesions. The range of temperatures was calculated by the difference of maximum and minimum temperatures shown as ΔT (°C)=Tmax-Tmin. Histopathological evaluation was performed in 127 surgically excised melanocytic nevi and 12 malignant melanomas. According to the dematoscopic score lesions were allocated in three groups labelled "benign", "suspicious" and "malign".The comparative analysis of mean values between the groups was performed with –Student t- test, and Pearson (r) coefficient was applied to test the linear correlation between the variables.
RESULTS: Positive correlations were found between the results of dermoscopic and thermographic examination of the melanocytic nevi (p<0.001).
CONCLUSIONS: 1) Infrared thermal imaging may be an adjuvant method of investigation that supports the dermoscopic evaluation in the diagnosis of atypical (suspicious) melanocytic nevi and other skin lesions suspected for malignancy. 2) The temperature measurement including the ΔT (°C) coefficient correlated with the result of the dermoscopic evaluation and TDS score. 3/ Surgery or close follow-up to recognize malignant metaplasia may be applied in cases of the melanocytic nevi with ΔT (°C) coefficient >1,4 ^{0}C and TDS score> 4.75.

KEY WORDS: thermography, atypical melanocytic nevi, dermoscopy

DERMATOSKOPIE UND THERMOGRAPHIE: EINE VERGLEICHENDE STUDIE BEI MELANOZYTÄREN HAUTVERÄNDERUNGEN

HINTERGRUND: Thermographie ist eine nicht invasive Technik zur genauen Erfassung der Temperaturverteilung an der Oberfläche eines untersuchten Körpers.
METHODE: 245 Patienten mit 735 melanozytischen Naevi und 12 Patienten mit malignem Melanom wurden in die Studie aufgenommen. Alle melanozytische Läsionen wurden mit einem Dermatoskop und einer Infrarotkamera untersucht. Mit einem Heine delta 10 Dermatoskop wurde der TDS- Koeffizient (dermatoskopischer Gesamtskore nach Stolz) bestimmt. Mit einer thermographischen Kamera der Marke ThermaCAM™ S.C. 500 wurden die maximale (Tmax), minimale (Tmin), und durchschnittliche Temperatur innerhalb der melanozytischen Läsion gemessen. Der Temperaturbereich wurde als ΔT bestimmt, in dem von der maximalen die minimale Temperatur subtrahiert wurde [ΔT (°C)=Tmax-Tmin]. 127 melanozytische Hautveränderungen wurden chirurgisch entfernt und so wie 12 Melanome histopathologisch untersucht. Entsprechend des dermatoskopischen Gesamtskores wurden die Läsionen in die Gruppen "gutartig", "verdächtig" und "bösartig"eingeteilt. Die vergleichend Analyse der Mittelwerte der Gruppen wurde mit dem Student-T-test durchgeführt, und für lineare Korrelationen wurde der Pearson Koeffizient (r)berechnet.
ERGEBNISSE: Positive Korrelationen wurden zwischen den dermatoskopischen und den thermograpischen Ergebnissen gefunden (p<0.001).
SCHLUSSFOLGERUNGEN: 1)Thermographie kann als adjuvante Untersuchungsmethode die Ergebnisse der Dermatoskopie bei der Diagnose atypischer (verdächtiger) melanocytischer Naevi und anderer auf Malignität verdächtiger Hautläsionen stützen. 2) Die Temperaturmessungen einschließlich des Temperaturbereichs ΔT (°C) korrelierten mit den Ergebnsissen der Dermatoskopie und dem dermatoskopischen Gesamtskore TDS. 3) Chirugische Excision oder regelmäßige kurzfristige Untersuchungen sollten bei melanozytischen Läsionen mit einem Temperaturbereich ΔT (°C)>1,4 ^{0}C und einem TDS > 4.75 durchgeführt werden, um eine maligne Metaplasie rechtzeitig zu diagnostizieren.

SCHLÜSSELWÖRTER: Thermographie, atypische melanozytische Naevi, Dermatoskopie

Thermology international 2008, 18: 101-106

Introduction

Skin tumors show increasing morbidity thus necessitating elaboration of new diagnostic methods for early detection (1). Excess exposure to ultraviolet and other chemical and physical factors occurring in the environment and at workplaces may negatively influence the skin and trigger development of malignancy (2,3). Genetic factors should also be considered in the etiology of melanoma (4,5). Some melanomas originate from the preexisting melanocytic nevus (6,7). Melanocytic nevi occur in 92% of the total population with a mean rate of 14 nevi per person. Furthermore, the dysplastic (atypical) nevus syndrome (DNS) is seen in approximately 7% of the population (8). The atypical nevi, previously described as dysplastic nevi, are believed to be both risk factor and precursor of melanomas (9). These lesions cause frequently diagnostic difficulties because of close clinical and histological similarity to the melanoma (10). The symptoms associated with development of the melanoma should be thoroughly investigated (11). During the clinical examination with application of magnifying glass, only the ABCDE rule proposed by the American Cancer Society is used most frequently. The so called 7-point checklist is also applied for the evaluation of melanocytic nevi (12, 13).

Dermatoscopy (dermoscopy, epiluminescent microscopy) is widely applied in diagnostics of melanocytic nevi. That method allows not only magnification of the lesion but provide also a partial look into the skin (14,15). Recently teledermoscopy that provides transfer of the image and consultation of the specialist, has gained some interest. A computed analysis of the melanocytic nevi may be performed with application of videodermoscopes (16,17). Fluorescence has been also used in the diagnostics of melano- cytic lesions. Autofluorescence of nevi subjected to UVA radiation is evaluated in the latter method (18). Bono et al. (19) introduced the spectrophotometric method into the diagnostics of the lesions for the very first time. It was found that confocal scanning laser microscopy (CSLM) may facilliate an improved accuracy of clinical examination (20).

Thermal imaging has been recently used for medical diagnosis in increased frequency (21,22). Research in application of infrared thermal imaging in dermatological diagnostics has been conducted (23, 24, 25). There are some reports on the usefulness of thermal imaging for diagnosis and monitoring of the treatment in patients with malignant melanoma (26,27). However, previous research on the diagnostic value of thermal imaging for melanocytic nevi did not reached unequivocal conclusions (28, 29). The relationship between thermal imaging and histopathologi- cal findings in pigmented nevi and particular skin cancers was investigated (30).

The aims of the study were: 1) evaluation of the diagnostic value of thermal imaging for the identification of malignant metaplasia in melanocytic nevi; 2) comparison of dermoscopic, thermographic and histopathological results in melanocytic nevi.

Material and methods

The study enrolled 245 patients. These patients showed melanocytic nevi located in the skin of the trunk, arms, thighs and cheeks. The melanocytic nevi located in the scalp (also in the hairy skin located in the trunk or any other site), feet, hands, skin folds and mucosal membranes were excluded from the study

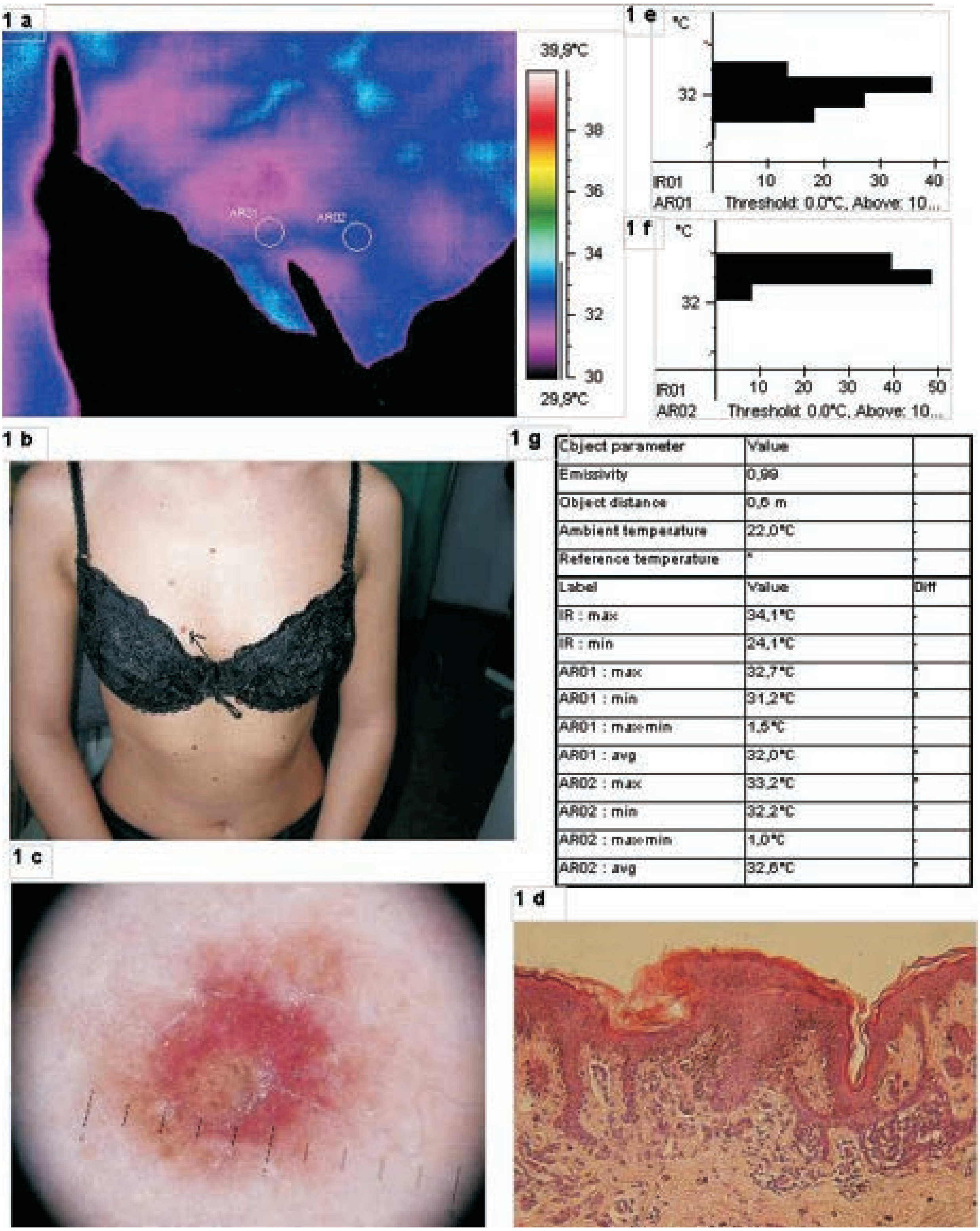
The Heine delta 10 dermatoscope was applied for the evaluation of all melanocytic nevi. The initial algorithm differentiated between melanocytic and non-melanocytic nevi (31,32). The initial assessment of all melanocytic nevi found in patients included qualification for surgery or follow-up.. The Derma-Phot device (dermatoscope and digital camera) was applied to obtain digital images of the nevi. The ABCD rule introduced by Stolz et al. was applied to dermatoscopic evaluation of the studied melanocytic nevi (33,34). The benefit of that method is the generation of the total dermatoscopy score (TDS). According to the ABCD rule the following parameters were evaluated: A (asymmetry), B (border), C (color), D (differential structures). The scores range: for asymmetry 1-2, border 0-8, color 1-6, differential structures 1-5. Each parameter was described using a specific weighting factor: for A- 1,3, for B-0,1, for C-0,5 and for D- 0,5. The sum of the products gives the TDS value. A TDS value below or equal to 4,75 reveals the benign melanocytic nevus, TDS values higher than 4,75 but lower than 5,45 indicate suspicion of malignancy that requires surgery or frequent follow-ups, and TDS higher than 5,45 – indicates likely malignancy.

The thermographic examination of the melanocytic nevi was performed with the ThermaCAM ™ SC500 thermovision camera with a measurement sensitivity of 0.1 ^{0}C. The examinations were performed according to guidelines described by the European Association of Thermology (35,36). Patient adaptation in the room microenvironment was approximately 10 minutes, and the distance between the camera and human skin was 0.5 m (37, 38). The site of the melanocytic lesion was marked in order to locate precisely the nevus on the monitor screen and in the thermographic record. The ThermaCAM 2000 Professional software was used for analysis. In the defined area of the melanocytic lesion the maximum (Tmax), minimum (Tmin), and average (Tavg) temperatures were measured. The range of temperatures within the melanocytic nevus was represented by the ΔT index calculated as the difference between the maximum (Max) and minimum (Tmin) temperature (ΔT (^{0}C)= Tmax- Tmin.) Based on histograms, the distribution of temperatures within the area of the melanocytic lesion was described.

For each of the 735 melanocytic lesions a control skin areas without melanocytic lesions was defined. This allowed the comparison of temperatures in areas with and without melanocytic lesions in the same indivdual subject. Histopathological studies were performed in 127 surgical excised elanocytic lesions.

Figure 1 gives an example of the thermographic, clinical, dermatoscopic and histopathological picture of an atypical (suspicious) melanocytic nevus in 27-year-old female with atypical (dys plastic) nevus syndrome. Figure 1 e shows the histogram of temperature distribution within the area of atypical (suspicious) melanocytic nevus (area ARO1) and figure 1 f provides the histogram of temperature distribution within the area free of melanocytic lesions (area ARO2).

Statistical analysis was performed using Statistica 6,0 software. Lesions were allocated with respect to the TDS to the groups "benign" (TDS value ≤ 4.75), „suspicious (atypical)" (TDS value between 4,75 and 5,45) and "malign" (TDS >5,45) The comparative analysis of mean values between the groups was performed using the t-Student test, and correlation between the variables was tested with linear Pearson (r) coefficient.



Object parameter	Value	
Emissivity	0,99	-
Object distance	0,6 m	-
Ambient temperature	22,0°C	-
Reference temperature	*	-
Label	Value	Diff
IR : max	34,1°C	-
IR : min	24,1°C	-
AR01 : max	32,7°C	*
AR01 : min	31,2°C	*
AR01 : max-min	1,5°C	-
AR01 : avg	32,0°C	*
AR02 : max	33,2°C	*
AR02 : min	32,2°C	*
AR02 : max-min	1,0°C	-
AR02 : avg	32,6°C	*

Figure 1
Clinical, thermographic, dermoscopic and histopathological picture of atypical melanocytic nevus in a 27-year-old female patient with the atypical nevus syndrome.
1a - Thermogram of 27-year-old female patient, the area of atypical melanocytic nevus indicated by the arrow- the area ARO1. The skin area without melanocytic nevi indicated as ARO2 (thermovision camera ThermaCAM ™ SC 500)
1 b -A picture of 27-year-old female patient with atypical nevus syndrome; the evaluated melanocytic nevus indicated by the arrow.
1 c - Dermatoscopic image (Heine delta 10 dermatoscope) of the atypical melanocytic nevus in a 27-year-old female patient; scale in mm.
1d - Histopathological picture of atypical melanocytic nevus in a 27-year-old female patient (HE staining; oryginal magnification 400x)
1e - Histogram of temperature distribution within the area of melanocytic nevus with visible difference between maximal and minimal temperature 1,5^{0}C (ΔT=1,5°C)
1f - Histogram of temperature distribution within the area free from melanocytic lesions with visible difference between maximal and minimal temperature 1,0^{0}C (ΔT=1,0°C)

Table 1
Temperature findings in benign, suspicious and malign lesions

	All lesions (n=735)	Normal skin	Benign (n=554)	Normal skin	Suspicious (n=181)	Normal skin	Malign (n=12)	Normal skin
Total dermatoscopy score (TDS).	4.03±0.68		3.89±0.36		5.19±0.21		5.96±0.25	
Maximum Skin Temperature °C	33.5±0.3	33.2±0.6	33.1±0.7	33.1±0.8	33.7±0.4	33.0±0.6	34.1±0.8°	33.2 ± 0.7
Mean Skin Temperature °C	31.9±1.0	31.8±0.9	31.8±0.9	31.7±0.8	32.0±1.1	31.9±0.9	33.0±0.9	31.8±0.8
ΔT(= maximum minus minimum temperature	1.2±0,2	1.1±0.2	1.1±0.3	1.1±0.2	1.39±0.28	1.1±0.2	1.6±0.4	1.1±0.2

Results

The study enrolled 245 patients with 735 melanocytic nevi. There were 152 (62%) females, 75 (30,6%) males, and 18 children (7,4%). The age of the studied patients ranged from 8 to 72 years. The study group included als 12 patients with malignant melanoma aged 34 to 72 years.

554 lesions were allocated to the group "benign" (TDS value ≤ 4.75), 181 melanocytic skin changes were labelled as „suspicious (atypical)" (TDS value between 4,75 and 5,45) and 12 lesions were diagnosed as "malign" (TDS >5,45). The mean TDS value was 4.03 ± 0-68. for all lesions, 3.89±0.36 for all benign lesions, 5.19±0.21 for suspicious lesions and 5.96±0.25 for melanomas (table 1).-

The obtained variation coefficients (v%) of temperature measurements in a randomly selected group of 5 patients were below 10%. This procedure was performed to evaluate the sensitivity of measurements with the ThermaCAM™ SC500 thermovision camera

Maximum temperatures (Tmax) within the area of melanocytic nevi and unaffected (controll) skin were not sigificantly different (p>0.05) in all lesions investigated. Benign lesions showed also no significant differences in maximum temperature when compared to normal skin. Maximum temperatures of suspicious lesions were higher than those measured in normal skin and in the group of benign melanocytic nevi. The difference was statistically significant (p<0.05). Between Tmax of melanomas and normal skin a statistically significant difference was calculated (p<0.01). Also the mean temperature of malign lesions differed significantly from the mean temperature of unaffected, normal skin (p<0.01). All other comparisons i.e. all lesions versus normal skin, benign lesions versus normal skin, suspicious lesion versus normal skin or benign lesion did not reveal any significant difference in mean skin temperature.

The range of temperature within the melanocytic lesion (ΔT) was significantly higher in suspicious lesions (p<0.01) and melanomas (p<0.001) than in normal skin, but not in the total sample (p>0.05). or in benign lesions (p>0.05)

The linear correlation between the TDS scores and maximal temperatures Tmax, revealed statistically significant positive correlation in the groups of atypical melanocytic nevi and melanomas. The correlation coefficient between TDS and average temperatures was: +0.126 (p>0.05) in the group of benign lesions, +0.284 (p<0.05) in atypical melanocytic nevi, and +0.507 (p<0.05) in the group of melanomas: Linear correlation between TDS and ΔT were statistically significant for both subgroups and also in the total group of melanocytic nevi.

As found in our studies the melanocytic nevi with TDS equal or higher than 4.75 and thermographic index ΔT (°C) >1.4 may be suspected as malignant metaplasia.

Histopathological examination of 127 melanocytic skin lesions excised in the study revealed 97 atypical lesions and 26 common nevi without the features of atypia according to the accepted criteria. Histopathological findings and dermoscopic images are correlated in melanocytic nevi. The dermoscopic examination of atypical nevi frequently revealed the presence of blood vessels. Atypical nevi showing an altered thermographic picture revealed an increased number of blood vessels in the dermoscopic examination and also in the histopathological picture of these lesions.

Discussion

Melanocytic nevi are the most frequent skin lesions in human (39). Currently it is believed that the risk of malignant melanoma development increases along with the increase of number of melanocytic nevi (6). One of the classifications of the melanocytic nevi includes congenital and acquired types of lesions. It is believed that congenital nevi develop before the end of the twelfth month of life, while the acquired lesions develop between 2nd and 6th year of life with highest occurrence in puberty. Melanocytic lesions may partially subside in elderly (40). Based on clinical and histological picture the melanocytic nevi were classified as common or atypical ones; the latter were also known as dysplastic lesions. The clinical features of atypical nevi have been described according to the dermoscopic rules. The rule of ABCD introduced by Stolz (33) that was applied in our study showed the sensitivity of 97.9% and specificity of 90,3%. The results of dermoscopic examination obtained by means of the ABCD rule are comparable to the results obtained in the seven-point checklist proposed by Argenziano (41). Other dermoscopic methods include structural analysis described by Pehamberger (42) and the Menzies scoring system (43). The two latter methods are also very useful; however, they did not allow the calculation of a numerical index.

Histological evaluation of atypical melanocytic nevi (previously known as dysplastic ones) is based on histological criteria (44,45). The histological definition of atypical melanocytic nevi is widely accepted and applied. However, Akerman (46) pointed out in his critique that histological examination did not allow differentiation between atypical lesions and malignant melanoma. Due to the latter statement, the definition of "dysplastic nevus" has been abandoned and the new definition of "lesions with altered architecture and various degree atypia" has been introduced. The colloquial name for that condition is "atypical nevus" (7). Multiple atypical lesions in the skin of the patients are known as the FAMMM syndrome (Familial Atypical Multiple Mole Melanoma syndrome) (47). The atypical nevus syndrome is a shortened name for the syndrome (48).

The clinical and histological association between the a- typical melanocytic nevi and malignant melanoma prompts research on new methods allowing early detection of malignant metaplasia of these lesions. The special interest is put on patients with multiple lesions in the course of the atypical nevus syndrome. The occurrence of multiple lesions causes diagnostic and therapeutic difficulties.

Thermal imaging requires no direct contact and is completely safe for both patient and the examining physician. That is why thermal imaging currently gains wider interest in various branches of medicine (49,50). Following the guidelines of thermographic examination proposed by the Euro- pean Association of Thermology is of paramount importance (37,38). The studied group of 181 atypical nevi with the features of atypia shown in the dermoscopic examination revealed increased maximal temperatures and increased differences between maximal and minimal temperatures described as ΔT (°C) index in our study ($p<0,01$). This index positively correlated with the TDS obtained in the dermoscopic examination and the results of histopathological studies. The literature lacks reports on the use of dermoscopic examination in melanocytic nevi showing features of atypia. The studied group of 12 malignant melanomas revealed higher maximal temperatures and higher differences between maximal and minimal temperatures described as ΔT (°C) index, than the temperatures obtained in the skin without pigmented lesions ($p<0.01$). Nodular melanomas showed higher average temperatures while in cases of lentigo maligna and superficial spreading melanoma the temperature was not increased.

Based on our research of 735 melanocytic nevi, it is concluded that the average temperature of all studied melanocytic nevi was not significantly different to 375 skin areas without pigmented lesions in the same group of 245 patients enrolled in the study ($p>0,05$). Convex lesions revealed lower average temperatures than the surrounding skin. In the analysis of maximal temperatures and differences between maximal and minimal temperatures described as ΔT (°C) index the whole studied group of 735 melanocytic nevi and subgroup of 554 common melanocytic nevi also did not reveal significant discrepancies in the temperature measurements when compared to normal unaffected skin. These results are concordant with the data obtained by Krauze et al. (29), who studied 31 melanocytic nevi in 31 patients and found no significant changes in the thermographic measurements.

Conclusions

1.)Thermovision may be an adjuvant study method supporting the dermoscopic evaluation in the diagnostics of atypical (suspicious) melanocytic nevi and other skin lesions suspected for malignancy.

2) The result of thermographic examination and the calculated ΔT (°C) coefficient correlate positively with the result of the dermoscopic evaluation and TDS.

3) Surgery or close follow-up to recognize malignant metaplasia may be applied in cases of the melanocytic nevi with ΔT (°C) coefficient >1,4 ^{0}C and TDS > 4, 75.

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An Infrared Thermographic And Laser Doppler Flowmetric Investigation of Skin Perfusion In The Forearm and Finger Tip Following A Short Period of Vascular Stasis

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SUMMARY

The use of Infrared Thermography to diagnose circulatory problems in the hands is based upon the assumption that a change in skin temperature can be related to a change in skin blood flow. In this study 7 healthy volunteers were exposed to a 3 min period of vascular stasis of the right arm. The resultant reactive hyperaemia with associated skin erythemia was monitored on the forearm and finger tip of the 2nd digit with Infrared Thermography (IR) and with Laser Doppler Flowmetry (LDF). Following vascular stasis clear increases in skin perfusion as measured with LDF were seen at both the finger tip and forearm. However, a concomitant increase in skin temperature was only seen at the finger tip. This finding indicates that changes in skin blood flow associated with skin reactive hyperaemia and its associated erythemia may not be the same as that used for thermoregulatory purposes. It is concluded that caution should be applied when using IR thermal imaging to monitor blood flow changes associated with induced changes in skin perfusion associated with erythemia.

KEYWORDS: Infrared Thermography, Skin blood flow, Laser Doppler Flowmetry, Vascular stasis

BEURTEILUNG DER HAUTDURCHBLUTUNG AM UNTERARM UND AN DEN FINGERN MITTELS INFRAROTHERMOGRAPHIE UND LASER-DOPPLER-FLUSSMESSUNG NACH KURZEM DURCHLUTUNGSSTAU

Der Einsatz der Infrarot-Thermographie zur Diagnose von Durchlutungsstörungen beruht auf der Annahme, dass die Veränderungen der Hauttemperatur mit Veränderungen der Hautdurchblutung vergesellschaftet sind. In dieser Studie wurden 7 gesunde Freiwillige 3 Minuten lang einem Durchblutungsstau des rechten Arms ausgesetzt. Die darauf folgende reaktive Hyperämie mit Hauterythem wurde am Unterarm und an der Fingerspitze des Zeigefingers mittels Infrarotthermographie (IR) und Laser-Doppler-Flussmessung (LDF) erfasst. Mit LDF konnte ein eindeutiger Anstieg der Hautdurchblutung am Unterarm und an der Fingerspitze nach Beseitigung des Durchblutungsstaus beobachtet werden. Allerdings fand sich eine begleitende Erhöhung der Hauttemperatur nur an der Fingerspitze. Dieses Ergebnis weist darauf hin, dass eine veränderte, mit Erythembildung vergesellschaftete Durchblutungssteigerung nicht mit Perfusionsänderungen zur Thermoregulation gleichgesetzt werden kann. Deshalb ist Vorsicht in der Interpretation angezeigt, wenn Infrarotthermographie zur Beurteilung der Durchblutung bei provozierten Veränderungen der Hautperfusion mit begleitendem Erythem eingesetzt wird.

SCHLÜSSELWÖRTER: Infrarot Thermographie, Hautdurchblutung, Laser-Doppler-Flussmessung, Durchblutungsstau

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Introduction

Infrared thermography (IRT) and Laser Doppler flowmetry (LDF) are two methods commonly used for measuring skin perfusion when diagnosing circulatory problems in the hands and feet, such as Raynaud's phenomenon [1-5]. LDF provides a more direct technique for measuring skin blood flow and normally involves the attachment to the skin surface of individual measuring probes with low spatial resolution (1 mm^2). Although non-contact scanning laser Doppler flowmetry permits measurements of skin blood flow over larger skin areas, the available systems are not able to scan the skin surface quickly enough to measure rapid changes in skin blood flow [6]. On the other hand, IRT has the advantage of being able to instantaneously measure the skin surface temperature over a large area without direct contact with the skin [7]. Conclusions from previous studies in which comparisons have been made in the use of these 2 techniques have confirmed that IRT is a reliable indirect method for measuring skin perfusion, especially in the peripheral appendages [8.9]

In examining skin perfusion thermal provocations are often used where, for example, the time course and thermal pattern on the skin surface resulting from the cooling and recovery protocol provides useful information concerning skin perfusion, including the functional status of autonomic control. Another approach for measuring the status of skin perfusion in patients is to examine circulatory responses following a short period of venostasis. This has previously been examined using both IRT and LDF [8, 10-15]. Hanssler et al using IRT and LDF before and after arterial occlusion of the upper arm concluded that both techniques provided useful tools for the assessment of physiological and pathophysiological functions of the cutaneous circulation [8]. On the other hand Seifalian et al using an older type of imaging system concluded that skin perfusion measurements using LDF did not correlate well with IRT following a thermal provocation [15, 16].

Since LDF is regarded as being a more sensitive technique for measuring small changes in peripheral circulation we were interested to see whether our high sensitive IR-camera (see methods for details) could register small invoked changes in skin perfusion associated with erythemia that we know can be detected by LDF (11, 17). In this study we have used IRT and LDF to monitor skin perfusion in the forearm and finger tip following a short period of venous stasis in healthy subjects who were not subjected to any form of pre-heating. Since the magnitude of changes in skin blood flow is known to be greater in fingers compared to the forearm we have used these two sites in our comparison of these 2 techniques.

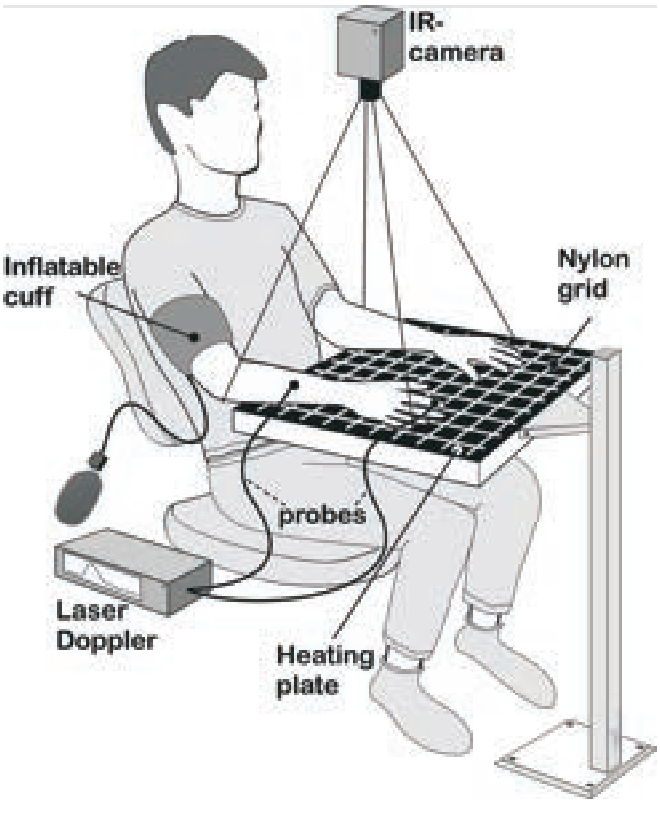
Methods

Subject recruitment

Seven volunteers were recruited among students at the University of Tromsø. All the subjects were non-smokers without any chronic diseases and none were on permanent medication. Four male and 3 females were included in the study. The mean age was 24.1 year, average height 171.6 cm, average weight 68.7 kg, and average BMI 23.2. Prior to the experiments blood pressure and tympanic ear temperature (EXERGEN LightTouch LTX-1, Newton, MA, USA) were measured. All subjects had normal ear temperature (35.9-37.7 °C, average 37.0°C) and normal blood pressure (105/60-130/70 mmHg, average 118/72 mmHg).

Participants were asked to abstain from alcohol, caffeine, physical activity and cold exposure in the 12 h preceding the study. The volunteer were also asked neither to drink hot liquids nor to wash their hands in cold water less than two hours before the experiments.

Figure 1.
Overview of the experimental setup



Permission to carry out the experiments was granted by the Norwegian Regional Committee for Research Ethics.

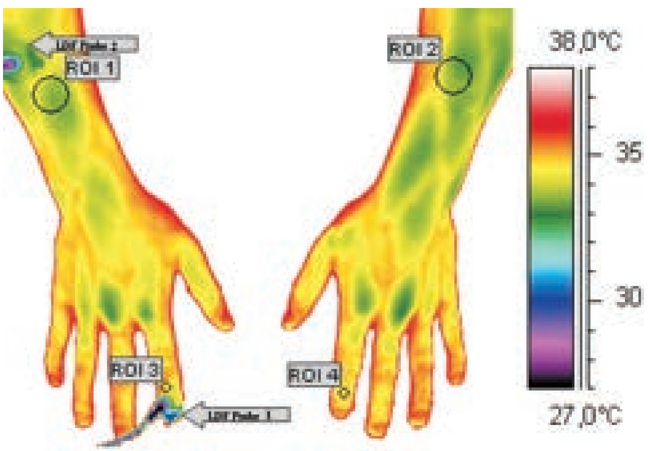
Experimental protocol

The experiments were performed at room temperature (21.4 ±0.4 °C) in a draught free room. During the experiments the lightly clothed volunteers sat in an upright position a chair with their hands resting, palm down, on a grid made of thin nylon strung on a wooden frame (Fig 1). The purpose of the nylon grid was to minimize skin contact with the surface supporting the hands. An electrically heated plate was placed 5cm below the grid in order to provide a uniform background with a constant temperature of ca. 39 °C. (Fig 1)

To occlude blood supply to the test arm (right arm), an inflatable cuff was attached around the right upper arm. Skin surface temperature was measured by infrared thermography using a Flir ThermaCAM S65HS IR-camera (Flir Systems, Boston, MA, USA). The HS version of this camera has a temperature sensitivity of 0.06°C. Images were analyzed with the ThermaCam Researcher Pro 2.8 software (Flir Systems AB). Four circular regions of interest (ROI) were selected for temperature measurements, one on each forearm and one on each index finger (Fig 2). The regions of interest were placed adjacent to the attachment points of the laser Doppler probes (see below).

Skin blood flow was measured with laser Doppler probes using a Periflux 4001 Master (Perimed, Sweden). Two probes were attached to the right arm. Probe 1 was attached to the tip of the index finger, just proximal of the nail. Probe 2 was attached to the center of the forearm, halfway between the styloid process of the radius and the lateral epicondyle of the humerus (Fig 2). Data from the laser Doppler recording was processed with the PhysAqu and PhysAna software (Knut Steinnes, Faculty of Medicine, University of Tromsø). Heart rate was continuously measured telemetrically (Polar Advantage Interface System, Kempele, Finland).

Figure 2.
IR-image of forearm and hands showing the location of the 4 regions of interest (ROI 1 - 4) used for temperature measurement, and the location of the 2 laser Doppler probes (Arrows)



Following baseline recordings of blood pressure, tympanic ear temperature, body weight and height, the subjects were subjected to a 15 min equilibration period. Skin temperature and blood flow measurements commenced during the last 2 min of the equilibration period. At the end of the equilibration period the cuff was inflated to supra-systolic pressure (230 mmHg). After 3 min the cuff was rapidly deflated. A 3 min occlusion time was selected to give a significant reactive hyperemia without causing to much discomfort for the test persons (18). LDF and IRT recordings continued during the occlusion period and for a further 5 min during the recovery period.

IR images were recorded at a rate of 3 images/second, and laser Doppler measurements were recorded at 4 readings/sec. The experimental protocol was repeated 3 times in each subject.

Results

Fig 3 shows the results from a single experiment. As expected there is a much higher level of blood flow in the finger tip than in the forearm (19). Inflation of the cuff caused an almost complete cessation in blood flow, as shown in the LDF measurements. When the cuff was released a reactive hyperaemic response was observed (upper panel), with a clear, short lasting overshoot before returning to base line level. This hyperaemic response was evident on both the fingertip and forearm and was associated with short-lasting skin erythemia.

In the lower panel of Fig. 3 the corresponding skin surface temperature measurements are shown. During cuff inflation there was a 1.8°C decrease in temperature in the fingertip of the test arm (Fig. 3, ROI-3). In the forearm of test arm there was very little change in temperature (Fig. 3, ROI-1).

Although 24 experiments were conducted, only 16 have been included in the results presented in Fig. 4 due to unstable skin temperatures during the pre occlusion period or due to the subject having symptoms of a Raynaud like phenomenon (see below). The time courses of both the blood flow and temperature values shown in Fig. 4 were very similar to those seen in the single experiment (Fig. 3), with a clear reactive hyperaemic response seen for both ROI's in the test arm as well as a clear change in finger tip temperature. Skin temperature in the test forearm showed no change.

Figure 5 shows the result from one of the subjects who exhibited symptoms of a Raynaud's like phenomenon. Skin temperature on the fingertips of both hands were just below 26°C at the start of the recording, which was ca 7°C colder than the average value of 32.7 °C seen in the other subjects. Skin blood flow was also much lower than that seen in the other subjects (Fig. 4). In this subject fingertip

Figure 3
Time course of changes in skin temperature and skin blood flow before, during and after a 3 minute period of vascular stasis in a single experiment.

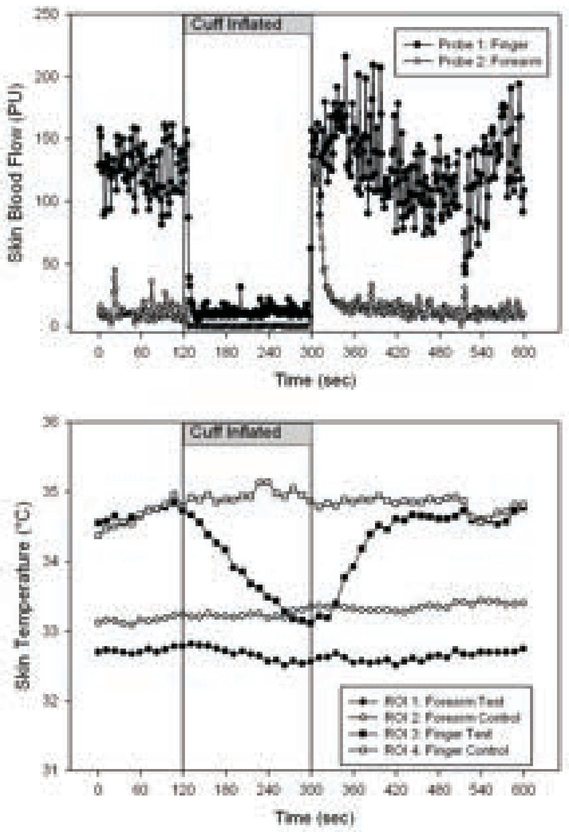
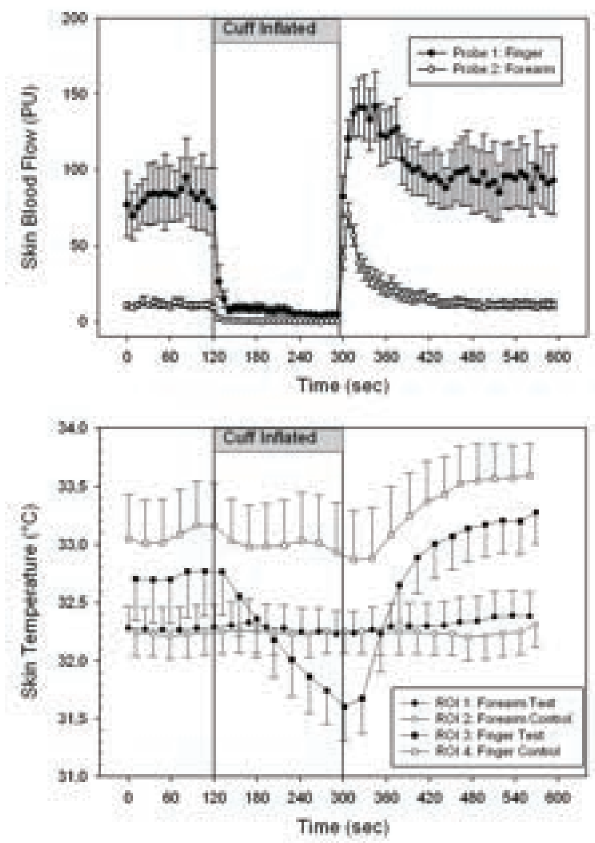


Figure 4
Time course of mean changes in skin temperature and skin blood flow before, during and after a 3 minute period of vascular stasis. N=16. Mean values ± SEM

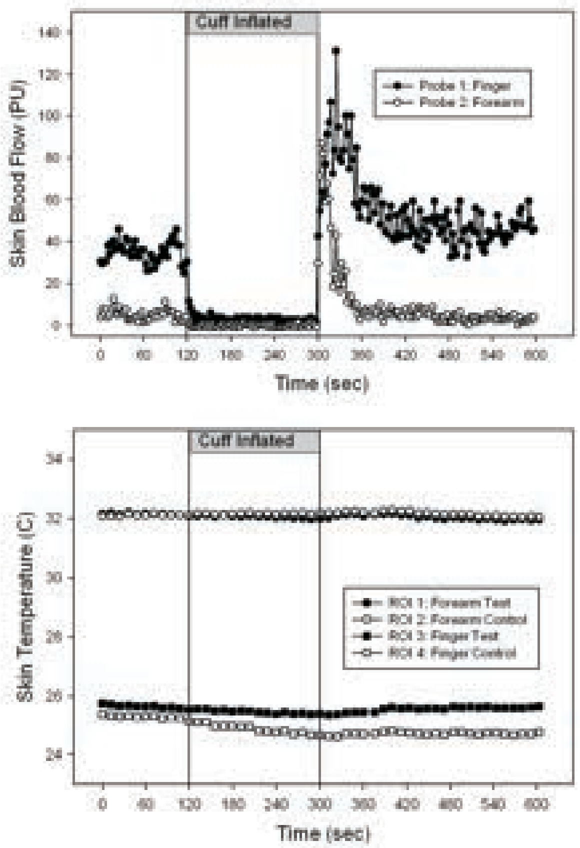


temperature decreased slightly during the occlusion period, but to a much lesser degree than in the other subjects. Despite the clear reactive hyperraemic response following release of vascular stasis as shown in the LDF measurements (upper panel), there were no corresponding changes in skin temperature (lower panel).

Discussion

In this study we have used two non-invasive methods for measuring skin blood flow, Laser Doppler flowmetry and infrared thermography. Neither method give a direct measurement of the blood flow, but it is clear from the results that there were occasions where LDF was able to monitor changes in skin blood flow that could not be detected as changes in skin temperature by IRT. The experiments showed that the skin temperature on the forearm did not decrease during an ischaemic period, and furthermore, did not increase when blood flow returns. This is consistent with other studies, who have shown that it is only in the digits, palm and toes that skin temperature can be clearly related to perfusion [20]. This observation is most likely related to local differences in skin vascular anatomy. Arterio-venous anastomoses (AVA) in the skin are present in high numbers in the face, hands and feet, areas well known as thermoregulatory windows. In these locations the vessels in the skin are organized in three layers, with AVA's that are controlled by the autonomic nervous system. When the AVA's are open they allow a higher level of blood flow by shunting some of the blood flow directly into the venous plexus to facilitate heat loss. The skin blood flow in the forearm is mainly a nutritional flow, and not thermoregulatory as in the hand and digits, and there are fewer AVA's [21]. The smaller number of AVA's present in the forearm may explain why the infrared camera did not detect any change in temperature in ROI-1 and -3 (Fig 2). The same explanation may be used to explain the results in the subject with Raynaud like symptoms. In this subject it is assumed that there is a malfunction in the autonomic control of blood flow in the digits, resulting in the lower than normal skin temperatures. The increased finger tip blood flow registered with LDF in this subject is presumably a superficial, nutritional flow, of insufficient magnitude to cause a change in temperature.

Figure 5
Time course of changes in skin temperature and skin blood flow before, during and after a 3 minute period of vascular stasis in a single experiment in a subject with Raynaud-like symptoms



The measurable changes in forearm skin blood flow, measured with LDF, which did not result in a temperature change large enough to be detected by IRT may also be related to poor camera sensitivity. However, while this may be the case in some studies involving the use of older generation IRT-technology [8, 15], we feel it is unlikely that low camera sensitivity was the problem. Our FLIR S65 camera is the high sensitivity (HS) version of this model, and in other clinical situations we have been able to measure changes in skin temperature related to erythemia coupled to facial blushing (un-published observation). We have also unpublished observations where our IR camera was unable to detect changes in skin temperature associated with a flare (triple) response initiated by a ca 4 cm long linear scratch on the skin with associated erythemia and increases in skin blood flow measured by LDF. However, if a larger area of skin was scratched (ca 2 cm2) the camera was then able to pick up an increase in temperature. In addition to the size of the skin area being examined, the region of skin being measured (and the presence of AVA's) may also have an impact on the correlation between IRT and LDF. Bornmyr et al compared the big toe with the dorsum of the foot, and found an exponential relationship between IRT and LDF on the big toe, but a linear relationship on the dorsum of the foot. They explain the different correlation as a result of differences in the vascular geometry [22]. Hanssler et al measured the hypothenar eminence, and found a close correlation [8], while Seifalian et al measured at the fingers and at the back of the hand, and found a weak correlation [15].

In this study we have shown that a 3 min period of upper arm vascular stasis results in a clear hyperemic responses in both the forearm and fingertip. This was associated with a reduction in skin temperature on the finger tip during the period of vascular stasis, followed by an increase in temperature and skin erythemia during the resultant hyperemia. There were no concomitant changes in forearm skin temperature. It is concluded that there are situations in which caution must be used even when using high sensitive IR-camera as an indirect method for monitoring skin perfusion.

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News in Thermology

Thermography Meeting at NYU

On Saturday May 3, 2008, a conference entitled "CRPS/RSD: Diagnostic/Technical Advances and Understanding Autonomic Function" was held at NYU Medical Center.

This meeting resulted from the combined efforts of faculty from NYU Medical Center and the American Academy of Thermology. Dr. Jeffrey Cohen from the Rusk Institute of Rehabiltation Medicine, NYU Medical Center, was the Course Director. This course was offered 6 AMA PRA Category I CME Credits and was offered by the Post-Graduate Medical School of New York University School of Medicine. The course was supported by independent Medical education grants from Endo Pharmaceuticals, Inc and Pfizer, Inc.

The conference audience was welcomed by NYU Dr. Cohen and AAT President Dr. Hoekstra. Dr. Hoekstra introduced Dr. Robert G Schwartz, Vice President. The NYU/ AAT 2008 Meeting abstracts were published in Vol 2 of Thermology international 2008.

Summary of presentations

Dr. Mathew H. M. Lee MD, FACP presented the Power, Beauty and Vision of thermography. His presentation included applications in Pre-Post acupuncture, Tranfer of heat, Thermal patters of human body, Applications in sport injuries.

Dr. Jeffrey Cohen reviewed history of thermography from ancient egyptians (29^{th} centuary BC) to military 1940s and to the present knowledge and applications and included, equipment contact/ computerized infra red imaging and areas of research in myofacial pain syndrome, complex regional pain syndrome, hyperhidrosis, repetitive strain injury, osteoarthritis, vasospastic diseases/Raynaud's phenomenon, peripheral nerve injuries and neuropathic ulceration/ charcot's arthropathy. Also application in clinical cases were discussed.

Dr. Robert G. Schwartz presented " We Help What Hurts " and covered areas of current clinical applications, skin temperature measurement, thermography & medical research, AAT: statement of need, AAT: guidelines: indications, regulation of skin temperature, skin temperature physiology, equilibration, controlled conditions, heat emission asymmetry patterns, CRPS diagnostic criteria, thoracic outlet syndrome, cervical plexus & stellate ganglion block, vasomotor mapping and differential diagnosis.

Dr. Srini Govindan presentation was on "Thermography in migraine headaches and trigeminal neuralgia". It included anatomy, functional/ physiological, angiosomes, referred pain and trigeminal neurovascular control, thermography and extracranial bloodflow criteria for trigeminal / facial blood flow imaging, extracranial vascular receptors, pathophysiology, protocal for migraine and facial neuralgia, clinical cases with imaging drug effect and future clinical/ research applications.

Drs. Bryan J. O'Young discussed "The Role of Thermography in the Diagnosis and Management of Complex Regional Pain Syndrome".

Dr. Timothy D. Conwell from Colorado Infrared Imaging Center presented "The Role of Cold-Water Autonomic Functional Stress Testing in Evaluating Patients with Presumptive CRPS-1". The presentation included functional cold water autonomic stress testing: rationale, benefits in CRPS evaluation, physiological concepts, protocals and included case studies. Discussion was also done on somatoautonomic reflex test, evaluating the integrity of the sympathetic vasoconstrictor reflex, autonomic nervous system, evoked C- fiber impulses, sensitivity/ specificity, mimics of CRPS and references.

Dr.Ram Purohit discussed veternary applications, monitoring treatment /prognosis, published Veterinary Thermography protocols and guidelines. Future research and clinical applications were shared with audience participation from veterinary thermographers from New York.

Dr.Philip Hoekstra, President of AAT introduced "Practical Logistics of Clinical Thermology". His presentation included physics, rationale, practical imperative, skin temperatures in neurological disorders, practical methodology, applied methodology, case studies, different infrared cameras and their capabilities.

The international invited speaker Dr. Marcos Leal Briochi had a detailed account of his research " Advancements in medical IR high sensitivity applications,: fusion IR Imaging and 3D IR-MRI/TC software ". The presentation included clinical thermology, coronary and cardiac perfusion intraoperative thermal analysis, from 1950 anatomical exams to 1980 functional exams, radiological ir interpretation, similarity grading criteria, symmetry, dermatomal/ radicular and non-radicular, fibromyalgia, radiogenicity, thermal texture, position and fusion image new IR software tools, IR radiology report and 3D visualization.

The meeting was well attended and received. The audience included physicians (MD, DO, DC), representing Physical Medicine, Neurology, Internal Medicine/Family Practice, Veternary Medicine and Technologists and allied health professionals who have an interest in the diagnosis and management of Chronic Pain.

Discussions about future meeting sites in 2009 (Cleveland Clinic, Duke University Medical Center) were initiated.

Dennis McCabe, Scientific Segment Engineer, FLIR Systems, Inc had latest IR camera for demonstration and to discuss hardware and software with attendees.

Technology Examination and Certification

Janet Vics Infrared Technologist from Schenectady, NY who completed Dr. Jim Waldsmith's course in the West Coast passed the written and presented clinical veterinary cases to the satisfaction of the Examining Board and was accepted as a Certified Veternary Thermography Technologist.

Thermal Imaging in Sleep Medicine

As reported in the newsletter section of the previous issue of this journal, Dr Srini Govindan, executive Director of the American Academy of Thermology, is active in raising awareness of thermal imaging in Sleep Medicine. The following paper was presentecd by Srini at the Conference of the American Sleep Society 2008 held in Baltimore, Maryland, from June 7-11, 2008(reprint with permission of the American Sleep Medicine, first published in the journal SLEEP. Imaging Cranial Angiosomes in Hypersomnia. Govindan S. SLEEP. Volume 31, Abstract Supplement 2008: A219.)

Imaging Cranial Angiosomes In Hypersomnia

Govindan S [1, 2]

[1] Internal Medicine, Wheeling Hospital, Wheeling, WV, USA, [2] Neurology, West Virginia University Medical Center, Morgantown,WV, USA

Introduction: Thermography can monitor skin temperature regulation in the cranial angiosomes. Normal Forehead Nose Temperature Ratio (FNTR), nose is colder by 6-8 degrees C compared to the forehead. Stabilization of FNTR following treatment in hypersomnia, relating to changes in the arteriovenous shunting between the internal and external carotid angiosomes, under trigeminal vasomotor control and hypothalamic regulation was imaged.

Methods: Infrared imaging (with FLIR A 40 Camera) of facial temperature was done in a temperature and humidity controlled draft free laboratory using committee for the protection of human subjects approved protocol (induced hyperoxia five minutes 100% oxygen inhalation) and drug challenge with Modafinil (Provigil TM) infour, Dextro-Amphetamine/Amphetamine (AdderellTM) in two and Methyphenidate (RitalinTM) in one. Thermograms done at baseline, for 20 minutes after hyperoxia and 1-2 hours after the drug. Normal response to hyperoxia is vasoconstriction. Altered response can be decreased/ absence of response or paradoxical vasodilatation. Seven Caucasians, six females, one male, 51-67 yrs, with hypersomnia evaluated by sleep medicine/ clinical neurological exam, lab testing and PSG/ MSLT. Their Epworth Sleepiness Scale 11 to 20. HLA DQ tested in 7, positive in 4. MSLT sleep onset latency mean 6.9 minutes. One patient had two SOREMS. AHI normal in six. Seventh patient AHI 6.9. She lost 35 pounds before thermography testing

Results: 0.5 degree C change is significant, Vasomotor response to hyperoxia at baseline was not normal for the group. Skin temperature regulation was calculated as FNTR. Baseline FNTR, group mean 1.88 degree C, after treatment 5.97 degree C. Closing of arteriovenous shunts in external carotid angiosomes made nose colder. FNTR improved in six patients. Seventh patient, FNTR no improvement.

Conclusion: Altered response to hyperoxia indicates possible role of oxygen radicals in hypersomnia. Drug effect correlated with improvement in FNTR. Cranial- facial skin temperature regulation imaging in hypersomnia can be correlated with sleep propensity.

Election of the board of the German Society of Thermography and Regulation Medicine (DGTR) - International Medical and Veterinary Thermographers IMVT

At the 2008 annual meeting and general assembly of the German Society of Thermography and Regulation Medicine (DGTR) - International Medical and Veterinary Thermographers IMVT, on May 31st, 2008 in Mannheim the board of the organization was elected. Prof. Reinhold Berz, MD, president, Dr. Helmut Sauer, MD, vice president, and Dr. Ronald Dehmlow, PhD, treasurer, were unanimously reelected

6th DGTR curriculum on veterinary and horse thermography in Germany

There is a huge demand for a structured and scientific based curriculum regarding infrared imaging of horses (equine thermography). Since 2006, the German Society of Thermography and Regulation Medicine (DGTR) - International Medical and Veterinary Thermographers IMVT has up to now organized 5 educational training and teaching courses, each over a period of 3 to 4 months. More than 50 participants have been trained, and more than 25 of them have got the DGTR certification (stage 1) after a one day examination in theory and practical application.

The 6th curriculum starts at Saturday, September 6th
Teaching language: German and English
Further details on page 120-122

Short Course on Medical Thermography in Bucharest

In collaboration of the University of Medicine and Pharmacy " Carol Davila" in Bucharest, the University of Glamorgan, the European Association of Thermology and financially supported by the Romanian Ministry of Research and Education (Explanatory Workshop grant No. 89 / 31.03.2008) a short course on Medical Thermography will be organised in Bucharest on 11th-to 13th September. 2008. This course is based on the material of previous courses held at the University of Glamorgan between 2001 and 2007 and its adaptations presented at the 8th International Thermography Con- ference in Auburn 2007 and the 7th QIRT Conference in Krakow 2008. Along with the medical and physics background of infrared imaging, the participants will learn standard procedures for checking the equipment for medical infrared imaging and how to apply standard views of the human body for recording reliable and accurate medical thermal images. The detailed programme can be found on page 117 of this issue. In the session following this course, members of the Romanian Society of Thermology will present thermographic studies from Romania.

7th International QRM Conference 2nd– 4th April 2009

QRM is pleased to announce that QRM 2009 will also co-host in parallel with QRM and with the support of the United Kingdom Thermography Association (UKTA) 'The European Thermographers Conference 2009' at St Edmund Hall, Oxford 2-4th April 2009. This conference brings together researchers and industrial users of various condition monitoring techniques and will include a special focus on Infrared thermography in all its applications from Europe. This event builds on other successful thermography conferences from around Europe since 1996 and in England since 2000 that cross the boundaries of thermography including medicine, non-destructive testing, condition monitoring and remote sensing. The conference will include a historical tour of Oxford University where science research has been continuous since 1240 and a conference dinner in one of the ancient halls of the University.

We would again ask for your support and will be inviting keynote lectures, Chairpersons and themed sessions closer to the date. Multiple authors from the same Institution will also be offered discounted registration costs.

As you know there is traditionally a social programme, at QRM which is always well attended and we have another interesting social programme planned but always happy to receive your ideas and volunteers especially those musical.

A short course on Standardisation in Medical Thermal Imaging will be organised by the Medical Imaging Unit at the University of Glamorgan. Quality control in recording and analysing thermal imaging is an important task for users of thermal imaging in medicine and industry. In both fields of application accurate and reliable equipment is urgently needed. This course will provide information how thermal imagers can be tested to avoid poor imaging quality and what standards and protocols are available to achieve the best results in medical thermal imaging.

Invitation to Prospective Authors and Scope of Papers

All papers are refereed and edited. The range of papers includes the following applications of QRM:

- Condition Monitoring Techniques, including vibration analysis, IR thermography, wear debris, acoustic emission, building services engineering
- Industrial and business applications of QRM e.g., Quality systems and safety.
- Educational research, new courses and innovative techniques of instruction.
- Medical aspects of QRM including medical thermography.
- Digital Engineering and computer applications including artificial intelligence
- Non-Destructive Testing condition monitoring techniques

Instructions for Authors

Only completed papers must be submitted in word format on CD-Rom with completed registration to the Registrar, Mrs Karen Thomas, address below. An electronic template is available at the QRM website
http://www.qrmconference.co.uk/call_papers.htm

Mrs Karen Thomas, Registrar, Tyn-y-Coed,
Glynhir Road, Pontardulais, Swansea, SA4 8PX, UK.
Email: karen@qrmconference.co.uk
Tel/Fax: +44 (0)1792 885089. Mobile: 07854 003 327

Deadlines

Papers can be submitted before September 1st

Completed papers to the Registrar by this year October 31st 2008

16thTHERMO in Budapest

The Scientific Society of Measurement, Automation and Informatics (MATE) will organise the 16th International Conference on Thermal Engineering and Thermogrammetry (THERMO) from the 24th to 26th of June, 2009 in the House of Technology Budapest, V., Kossuth Lajos tér 6-8.

The language of conference and abstracts is English. Along with oral presentation of papers, a poster session will be organised.

Duration of each presentation will be limited to 15 minutes and additional time for discussion will also be provided. The English translation of lectures not read in English should be submitted at the registration desk on the spot. LCD projector and computer with Windows OS for Microsoft Power Point format presentations is available. (Pleas note, that using your own computer is not allowed.)

Those intending to attend the conference are kindly invited to send a registration form to the address listed later, under "Information".

During the conference an exhibition of scientific and industrial instrumentation will be organised. Exhibitors from the field of temperature measurement and control, thermal properties, IR-imaging, anemometry, industrial energy control, heat loss detection equipment etc. are welcome.

The conference is hosted by the House of Technology in Budapest (Bp.V., Kossuth Lajos tér 6-8) located near the House of Parliament and the Danube. More information about the conference place and hotel accommodation will be sent after the arrival of the Registration Form.

Call for Papers

The photocopy-ready papers(for CD-ROM presentation) of max. ten A4 format pages to be presented on the conference are to be submitted **before 15 February, 2009.** To assist the work of the Scientific Committee the authors are kindly requested to point out the aim, method and results of their work in the summary to be provided according to the typing instructions.

Notification of the acceptance of abstracts will be forwarded to the authors until 30 November, 2008. The full text of all accepted papers will be included the CD-ROM Proceedings to be presented to the participants at the Conference.

Information

Application Forms and abstracts/papers should be sent to:

Dr. Imre Benkö, MATE Secretariat, House of Technology, III. 318. H-1372 Budapest, POB. 451., Hungary

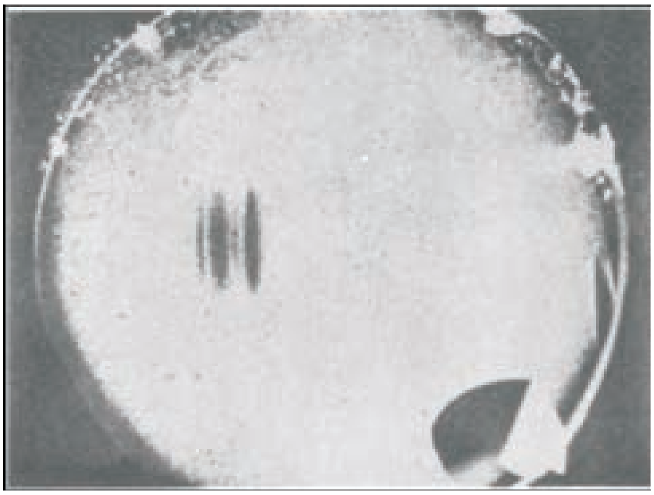
Fax: +361-353-1406, Phone: +361-332-9571.
E-mail: mate@mtesz.hu

11th European Conference of Thermology

In 2006, the 10th European Conference of Thermology was held in Zakopane Poland and for the 11th Congress, scheduled for 2009 a number of proposals including Portugal, Greece, Majorca, Norway, England and Germany. The board of the European Association of Thermology discussed all these proposals during a board meeting at the QIRT conference in Krakow and came to the conclusion to organise the 11th European of Thermology in Germany in cooperation with the German Society of Thermography & Regulation Medicine (DGTR) that celebrates its 55th Anniversary in 2009. The German Society of Thermology (DGT) is also planning to join these meetings.

It is also 80 years ago that Marianus Czerny, who worked as Professor for Experimental Physics and Director of the Institute of Physics at the Johann Wolfgang Goethe-University in Frankfurt /Main from 1938 to 1961, published his paper on evaporography (*Czerny M. Uber Photographie im Ultraroten. Zeitschrift für Physik. 1929, 53. 1-12.*). He used celloluid membranes covered with white napthalene on one side and soot on the other side. When the naphataline side was exposed to infrared radiation it evaporated and the area where naphtaline was sublimed became visible as a black image. Using this technique, Czerny was able to image an infrared spectrum (Figure 1). Further development of this technique using paraffinoil and bismuth layers on the celloluid membrane was named evaporography (*Czerny M Mollett P. Neue Versuche zur Photographie im Ultraroten. Zeitschrift für Physik. 1937. 114: 85-100*). Evaporography continued to be used as a method for thermal imaging (*McDaniel GW, Robinson DZ. Thermal Imaging by Means of the Evaporograph. Appl. Opt.1962;1, 311-324*) and equipment was produced until 1974 (*Heinrich H. Die historische Ent. wicklung der Infrarot. Meßtechnik. Thermologie Österreich 1992, 2: 6-15*)

Figure 1
Infrared spectrum, imaged by Czerny in 1928 using evaporography



The venue will be one of the conference centres in the region nearby Frankfurt like Kronberg which served successfully for a conference of the Veterinary Branch of the DGTR in 2007.

The scientific committee of the European Congress is formed by experts in the field around Europe and the national delegates in the committee of the European Association of Thermology (names in alphabetical order:
Prof. Dr K Ammer, Prof Dr R Berz, Dr G DallaVolta, Dr J-M Engel, Prof. Dr A Jung, Prof Dr J.Mercer, Prof Dr A Nica, Prof Dr F Ring).

Main theme of the conference will be "Temperature measurements in humans and animals". The conference language will be English. However, papers in German will be accepted for presentation in the sessions of the Annual Meeting of the DGTR.

Papers related to the following topics in human and veterinary medicine are kindly invited:

- History of temperature measurement
- Current developments of temperature measurement devices for human and veterinary medicine
- Standards and Guidelines for Thermal Imaging in Human and Veterinary Medicine
- Thermal Physiology
- Temperature Measurement and Thermal Imaging as a diagnostic tool in
  Angiology,
  Complementary and Alternative Medicine
  Dermatology
  Gynaecology and Breast Imaging
  Neurology
  Neurosurgery
  Paediatrics
  Orthopaedics
  Preventive Medicine
  Rheumatology
  Regulation Medicine
  Rehabilitation Medicine
  Surgery
  Sports Medicine
- Temperature Measurement or Thermal Imaging for Treatment Monitoring or as Outcome Measure in
  Angiology
  Complementary and Alternative Medicine
  Dermatology
  Gynaecology and Breast Imaging
  Neurology

Neurosurgery,
Paediatrics
Orthopaedics
Preventive Medicine
Rheumatology
Regulation Medicine
Rehabilitation Medicine
Surgery
Sports Medicine

•Temperature Measurement and Thermal Imaging as a diagnostic tool in Veterinary Medicine

•Temperature Measurement or Thermal Imaging for Treatment Monitoring or as Outcome Measure in Veterinary Medicine

•Thermotherapy in human and veterinary medicine

Papers outside the topics mentioned above are also welcomed. Deadline for the submission of papers is 15th May 2009. Abstracts should be structured into Background, Objective, Method, Results and Conclusion and must not show more than 300 words at maximum. A template for the abstract is provided on page 119 of this issue. Electronic submission is preferred and strongly suggested.

Meetings

11th- 13th September 2008

Theory and Practice of Infrared Imaging in Medicine

Venue: University of Medicine and Pharmacy
" Carol Davila" in Bucharest
National Institute of Rehabilitation,
Physical Medicine & Balneoclimatology
11 A Ion Mihalache Blvd
Sector 1, Bucharest, Romania

Programme

Thursday 11th September 2008

15.00 Welcome and introduction Prof A.Nica

15.05 -16.30 History, development and future of Infrared imaging in Medicine Prof F. Ring

16.30-16.45 Physical priciples of heat transfer Prof F.Ring

16.45-17.00 break

17.00-17.45 Infrared detectors Dr. R.Thomas

17.45-18.30 Camera systems and Calibration of IR-Cameras Dr.R.Thomas

Friday 12th September 2008

9.00 -10.00 Principles of Thermal Physiology Part 1 Prof K.Ammer

100-10.15 Film: Exposure to Hot and Cold

10.15-11.15 Principles of Thermal Physiology Part 2 Prof K.Ammer

11.15.11.30 break

11.30 -12.30 ProvocationTests Prof F.Ring, Prof K.Ammer

12.30 -13.15 Standard protocol for image capture Prof F Ring

13.15-14.15 lunch

14.15-15.15 Quality control and image processing Dr.P.Plassmann

15.15-15.35 How to produce a thermographic report Prof K.Ammer

15.35 -15.50 break

15.50 - 16.50 Causes of temperature increase Prof K.Ammer

16.50 -17.20 Film Living body

17.20.-18.20 Causes of temperature decrease Prof K.Ammer

Saturday 13th September 2008

9.00-9.30 Introduction to practical session and demonstration Dr.R.Thomas

9.30- 11.30 Practical session
A. Camera evaluation Dr.R. Thomas, Dr-P.Plasmann
B. Human body image capture Prof.F.Ring, Prof.KAmmer

11.30-11.45 break

11.45 -12.45 Medical education, journals and conferences Prof.Dr K.Ammer

13.00 lunch

Further information:
Prof Dr Adriana Nica
National Institute of Rehabilitation,
Physical Medicine & Balneoclimatology,
University of Medicine "Carol Davila"
11 A Ion Mihalache Blvd
Sector 1, Bucharest, Romania

Email: adisarahnica@yahoo.com

15th November 2008

21st Symposium of the Austrian Society of Thermology,
SAS Hotel Vienna, Austria

Topic: Recent Advances in Thermology

Deadline for Abstracts: 10thOctober 2008

Confirmed speakers Prof F. Ring, UK
Prof A.Jung, Poland
Prof. A.Nica, Romania
Dr. R.Thomas. UK
Prof.K.Ammer, Austria

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

Information
Prof K. Ammer, MD, PhD
Austrian Society of Thermology
Hernalser Hauptstr 209/14
Email: KAmmer 1950@aol.com

2009

27th - 29th March 2009

13th National Congress of the Polish Association of Thermology, Zakopane, Poland

REGISTRATION FEE: 200-Euro

ABSTRACT DEADLINE January 15th 2009.

Please submit to

Prof Dr. Anna Jung
Pediatric and Nephrology Clinic,
Szaserów Str 128 00 909 Warsaw 60, POLAND
Fax (48 – 22) 6816763
Email: ajung@wim.mil.pl or a.jung@spencer.com.pl

2nd - 3rd April 2009

7th International Conference 2009- Quality, Reliability and Maintenance . Oxford, England, UK St. Edmund Hall, University of England, Oxford OX1 4AR UK

Including a short course on Standardisation in Medical Thermal Imaging

Co-sponsor
Institution of Engineering and Technology

Conference Organiser
Dr R A Thomas
QRM Ltd, Tyn-y-Coed, Pontardulais, Swansea, SA4 8PX, UK
Tel/Fax: +44 (0)1792 885089
Email: rod@qrmconference.co.uk

Registration
Mrs Karen Thomas
QRM Ltd, Tyn-y-Coed, Pontardulais, Swansea, SA4 8PX, UK
Tel: +44 (0)1792 885089 Mobile number: 07854 003 327
Email: karen@qrmconference.co.uk

Consultant to QRM
Prof GJ McNulty
Email: mcnulty@qrmconference.co.uk

Chairman of Academic Referees
Dr Les Mitchell
University of Hertfordshire
Aerospace, Automotive and Design Engineering (AADE)
College Lane, Hatfield, Hertfordshire, AL10 9AB, UK
Tel: +44 (0)1707 284225
Email: l.mitchell@herts.ac.uk

Oxford advice and social programme
Dr Edward Reed
Tel: +44 (0)113 2936435

1st-3rd July, 2009

16th International Conference on Thermal Engineering and Thermogrammetry (THERMO), Budapest, Hungary

Information
Application Forms and abstracts/papers should be sent to:
Dr. Imre BENKÖ,
MATE Secretariat, House of Technology, III. 318.
H-1372 Budapest, POB. 451., Hungary
Fax: +361-353-1406, Phone: +361-332-9571.,
E-mail: mate@mtesz.hu

/eng/Pages/2009/Thermo2009/index.php and for previous 15th THERMO
/eng/Pages/2007/Thermo2007/index.php

17th -20th September 2009

Combined Conferences

11th European Congress of Medical Thermology

55th Annual Congress of the German Society of Thermography and Regulation Medicine

22nd Thermological Symposium of the Austrian Society of Thermology

Conference of the German Society of Thermology (DGT)

Venue: Region of Frankfurt/Main, Germany

Main theme: Temperature Measurement in Humans and Animals

Further information:

Prof Dr med Reinhold Berz
President of the German Society of Thermography and Regulation Medicine (DGTR)
International Medical and Veterinary Thermographers IMVT
Harbach 5
D-36115 Hilders / Rhön

Tel +49 (0) 66 81 - 72 70, Fax +49 (0) 66 81 - 85 51
Email: reinhold.berz@inframedic.de

or

Prof Dr med Kurt Ammer PhD
Austrian Society of Thermology
Hernalser Hauptstr 209/14
A-1170 Wien, Österreich

Tel & Fax: +43 1 480 54 23
Email: KAmmer1950@aol.com

Return to TOC

Combined Conferences

11th European Congress of Medical Thermology

55th Annual Congress of the German Society ofThermography and Regulation Medicine

22nd Thermological Symposium of the Austrian Society of Thermology

17th-20th September 2009

Last Name..First Name... Title ....

Institution ....

Street ....

ZIP Code ....City..Country ....

Phone.. Fax .... E – mail..

Title Autors Abstract

Return this form not later than May 15th, 2009 to:

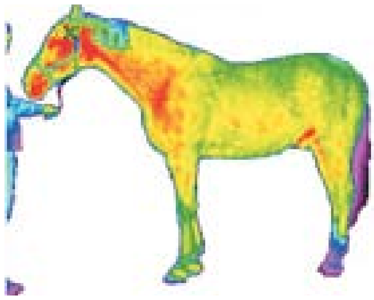
Prof. Reinhold Berz
Harbach 5; D-36115 Hilders / Rhön
Email: reinhold.berz@inframedic.de

Submission by email to the following adresses is also possible:

Prof F. Ring: efring@glam.ac.uk
Prof K. Ammer: KAmmer1950@aol.com

Veterinärmedizinisches Infrarot-Imaging
Schwerpunkt Pferde-Thermographie
(mit Zertifikat Stufe 1)

Kursprogramm 1. Halbjahr 2008



Veranstalter Deutsche Gesellschaft für Thermographie und Regulationsmedizin e.V. (DGTR, gegr. 1954)

Kurstermine 6. und 7. September; 18. und 19. Oktober; 1. und 2. November 2008 (jeweils Sa. und So.)

Examen 22. November 2008 (Sa.)

Ort Rittergut Holdenstedt, Schlossstr. 2, 29525 Holdenstedt bei Uelzen, Lüneburger Heide

Dozenten Prof. Dr. med. Reinhold Berz, Dr. med. vet. Andreas Feuerherdt, Armgard von der Wense

Seit 2006 bietet die DGTR in Verbindung mit der Pferdepraxis Rittergut Holdenstedt zertifizierte Kurse für Equine Thermographie an. Weltweit gibt es nur noch in den USA eine vergleichbare Ausbildungsmöglichkeit. An fünf Ausbildungszyklen nahmen bisher mehr annähernd 50 angehende Experten für diesen Bereich teil, von denen der Großteil nach Ablegen der Prüfung das Zertifikat der DGTR erworben hat. Die DGTR bietet im Jahr 2008 einen sechsten Kurszyklus im zweiten Halbjahr an.

Kurs 1 **6. und 7. September 2008**

Grundlagen der veterinärmedizinischen Thermographie

Charakteristika der Infrarotabstrahlung an der Körperoberfläche

Infrarotstrahlung: physikalische Grundlagen

Die Infrarotkamera im praktischen Einsatz

Einsatzgebiete der Thermographie bei Pferden

Aufnahmestandards für die Thermographie am Pferd

Sicherheitsaspekte bei der Pferde-Thermographie Teil 1

Anatomie und Physiologie des Pferdes

Aufnahmestandards in der Praxis

Weiterbearbeitung von Messdaten am Computer

Messdaten-Management, Datenverarbeitung

Kurs 2 **18. und 19. Oktober 2008**

Die Infrarotkamera als thermographisches Werkzeug

Besonderheiten von Infrarotkameras, Fehlmessungen und Fehlervermeidung

Demonstrationen und praktische Übungen mit der eigenen Infrarotkamera 1

Infrarotmessungen am lebenden Objekt: Wo und was wird gemessen, wie zuverlässig sind die Werte?

Sicherheitsaspekte bei der Pferde-Thermographie Teil 2

Die Beurteilung des Pferdes

Die praktische Arbeit mit der Infrarotkamera am Pferd: Standards selbst anwenden

Selbständiges Arbeiten im Stall mit Supervision: Messungen durchführen und Messwerte speichern

Realisierung veterinärmedizinischer Anforderungen in einem spezifischen Softwarepaket

Vom Messen zur Beurteilung, Schritt für Schritt

Aufbereitung der Ergebnisse, Beschreibung, Dokumentation und Erstellen eines Berichts

Präsentation der Lösungen durch die einzelnen Teilnehmer mit Feedback

Kurs 3 **1. und 2. November 2008**

Probeablegen der schriftlichen Prüfung

Besprechung der Resultate der probeweisen Theorieprüfung

Professionelle Handhabung der eigenen Infrarotkamera

Sicherheitsaspekte bei der Pferde-Thermographie Teil 3

Probeablegen der praktischen Prüfung am Pferd

Messungen durchführen, Aufbereitung der Ergebnisse bis zum Erstellen eines Berichts

Besprechung der Ergebnisse der probeweisen praktischen Prüfung

Examen **22. November 2008**

Schriftliche Prüfung

Praktische Prüfung am Pferd

Erstellen eines Berichts

Die Kurse bauen aufeinander auf, daher muss ihre Reihenfolge eingehalten werden. Es ist jedoch möglich, Kursteile vom ersten mit Kursteilen vom zweiten Halbjahr 2008 oder folgenden zu kombinieren. Ebenso kann das Examen auf einen späteren Zeitpunkt verlegt werden.

Gebühren Kurse 1 bis 3 395 Euro zuzüglich MwSt. pro Kurs

Examen incl. Zertifikat 275 Euro zuzüglich MwSt.

Anmeldung Prof. Dr. med. Reinhold Berz

Harbach 5

D-36115 Hilders

Tel. +49 (0) 6681 7270

Fax +49 (0) 6681 8551

E-Mail reinhold.berz@inframedic.de

Deutsche Gesellschaft für Thermographie und Regulationsmedizin e.V (gegr. 1954)

Präsident: Prof. Dr. med. Reinhold Berz

Vizepräsident: Dr. med. Helmut Sauer

Kassenführer: Dr. rer. nat. Ronald Dehmlow

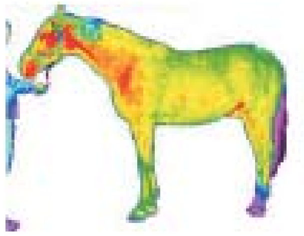
Geschäftsstelle D-76337 Waldbronn-Reichenbach, Rheinstr. 7, Telefon 0 72 43 – 6 60 22, Fax 0 72 43 – 6 59 49

Deutsche Gesellschaft für Thermographie und Regulationsmedizin e.V. (gegr. 1954)

Ausbildungsgang 6/2008

Equine Thermographie

Stufe 1



Anmeldung

Hiermit melde ich mich verbindlich an für

☐ **Kurs 1**
6. und 7. September 2008 Gebühr 395,— € zuzüglich MwSt.

☐ **Kurs 2**
18. und 19. Oktober 2008 Gebühr 395,— € zuzüglich MwSt.

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Österreichische Gesellschaft für Thermologie

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