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Thermographic evaluation of the temperature rise on the outer root surface of teeth during the "continuous wave of condensation" technique. An *in vitro* study

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Summary

It is generally accepted that a temperature of 47°C is the critical level at which irreversible damage to tissues surrounding the tooth root may start to occur. A temperature rise of 10°C can cause both microscopic evidence of fat cell necrosis and bone remodeling.

This *in vitro* study evaluated root surface temperature rises of teeth during the "continuous wave of condensation" technique using a System B HeatSource (Analytic Technology, USA).

Twelve extracted human premolars with a single canal were used. After root canal cleaning and shaping, the teeth were mounted in slab and obturated by the continuous wave of condensation technique using a System B HeatSource. Temperature changes on the outer root surface during root canal filling were measured using an infrared thermal imaging camera.

The results of this i*n vitro* study showed that the "continuous wave of condensation" technique using System B HeatSource generated a relatively high temperature rise (11.7°C) on the outer root surface, at which damage to the supporting structure of teeth may occur.

Key words: thermography, root canal filling, heated gutta-percha, temperature rise, root surface.

Die thermografische Beurteilung des Temperaturanstiegs an der Wurzeloberfläche der Zähne nach Wurzelkanalfüllung mit der Continuous-Wave-of-Condensation-Technik. Eine-"i*n vitro*"-Untersuchung

Die schädigende Wirkung von Temperaturerhöhungen auf das Gewebe des Zahnhalteapparates über ein gewisses Maß hinaus, ist unumstritten. Zu mikroskopisch erkennbaren irreversiblen Veränderungen in Form von Fettzellnekrosen und Knochenbildung kann es ab 47°C (Temperaturastieg von 10°C) kommen.

In dieser Studie wurden Temperaturerhöhungen an der Wurzeloberfläche nach Wurzelkanalfüllung nach der Continuous-Wave-of-Condensation-Technik mit Hilfe des Gerätes System B (Analytic Technology, USA) gemessen.

Die Untersuchung wurde an 12 Prämolaren mit einem Wurzelkanal durchgeführt. Nach dem Wurzelkanalaufbereitung wurden die Zähne in einen Ständer verankert und nach der Continuous-Wave-of-Condensation-Technik gefüllt. Die Temperaturänderungen an der Wurzeloberfläche infolge der Wurzelkanalfüllung wurden mit Hilfe einer Infrarot-Kamera registriert.

Die Ergebnisse dieser in vitro Untersuchung zeigen, dass die Wurzelkanalfüllung mit der Continuous-Wave-of-Condensation-Technik zu relativ großen Temperaturerhöhungen (11.7°C) an der Wurzeloberfläche führt, die eine Schädigung der Zahnungebung wahrscheinlich machen können.

Schlüsselwörter: Thermographie, Wurzelkanalfüllung, erwärmte Guttapercha, Temperaturanstieg, Wurzeloberfläche.

Thermology international 2003, 13: 135-139

Introduction

The use of thermoplasticized gutta-percha for obturation of root canal systems has become increasingly popular. In 1967, Schilder [1] introduced the vertical condensation warm gutta-percha technique. In this technique, gutta-percha is heated and packed with a plugger, and is believed to produce a homogeneous and dimensionally stable mass of gutta-percha. However, the vertical condensation technique is both time consuming and difficult to use in small and curved canals. Additionally, this technique employs the use of an instrument heated by an uncontrolled heat source [2-6].

Several studies have evaluated the outer root surface temperatures produced by using the vertical warm gutta-percha technique. Hand et al. [4] reported a temperature increase of 4°C on the root surface after a single insertion of a heated carrier into a tooth. Barkhordar et al. [5] recorded temperatures of between 4 to 7°C. The lower tem-

perature was recorded when a root canal sealer was used. Lee et al. [6] showed that obturation via insertion of a flame-heated carrier into the root canal produced very high temperature rises of between 13.7 and 31.1°C.

The exact temperature at which reversible or irreversible injuries occur has yet to be verified experimentally. Matthews and Hirsch [7] referred to the fact that bone alkaline phosphatase was rapidly inactivated *in vitro* at 56°C, the critical temperature for bone injury. Eriksson and Albrektsson [8] used a vital-microscopy approach to study heat-induced bone tissue injury in rabbits. They found that heating bone to 47°C for 1 min could cause microscopic evidence of bone remodelling and fat cell necrosis.

Recently, a modification of the warm gutta-percha technique was introduced using a System B HeatSource (Analytic Technology, USA) (Figure 1) [9, 10]. This device has a digital temperature display and a variable resistor control that allows the user to set an maintain the desired temperature. The System B HeatSource provides a tapered heat plugger that continuously monitors the temperature at the tip. The temperature of the heat can be adjusted, but the recommended setting is 200°C. The main advantage of the "continuous wave of condensation" technique using System B is that the downpacking of gutta-percha can be achieved in one continuous motion and a single heated plugger.

The aim of this *in vitro* investigation was to measure the temperature changes on the external root surface during the continuous wave of condensation technique using a System B HeatSource. The temperature rises were visualised using an infrared thermal imaging camera.

Figure 1
The System B HeatSource

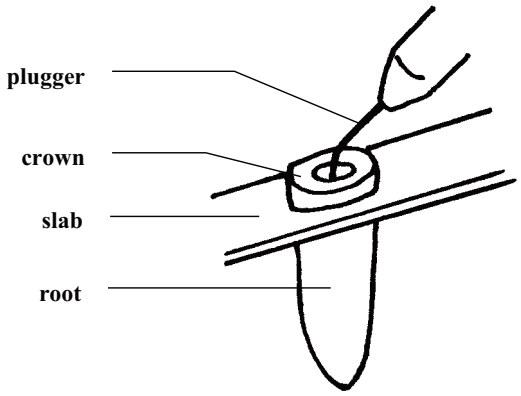

Figure 2
Schematic drawing of the fixation of the tooth during root canal obturation and temperature measurement

Material and methods

Twelve extracted human maxillary and mandibular premolars with a single canal, extracted for orthodontic reasons, were stored in 0.9% saline. The roots were stripped of soft tissue and calculus using hand instruments. All specimens were microscopically inspected to disclose any defects or root fractures and confirm complete formation of the apices. After access cavities were prepared and the pulp extirpated, a size 10 K file was introduced into the canal until it just emerged from the apical foramen. The working length was established by subtracting 1 mm from this length. The canal was enlarged apically to size 40 using a K file. The apical one-third was flared with the step-back technique, and the middle and coronal two-thirds were shaped with sizes 2 through 4 Gates-Glidden drills. The canals were irrigated with 2 ml of 1% sodium hypochlorite solution after each instrument. Finally, the canals were flushed with 2 ml of deionized water (pH 7) and dried with paper points.

Root canals were obturated as dedescribed by Buchanan [9, 10]. Namely, the canal walls were thinly coated with root canal sealer (AH Plus, De Trey/Dentsply, Germany) and a medium large non-standardized gutta-percha cone was placed to within 0.5 mm of the working length. A Buchanan plugger that matched the taper of the gutta-percha point was prefitted to its binding point in the canal, 5 mm short of working length. The heat source was adjusted to 200°C and the touch mode was activated as the touch switch was pressed, initiating softening prior to compaction. The plugger was driven through the gutta-percha cone in the canal to within 3-4 mm of the binding point, the touch spring was released and then apical pressure was maintained on the plugger in this position for 10 s, allowing the apical segment of gutta-percha to cool under this force (downpacking phase). The heat was activated for 1.5 s and the plugger was removed (separation phase). The obturation of the remainder of the canal was not completed since the first stage of the procedure was the focus of this study.

To obtain root canal obturation and temperature measurement, the crowns of teeth were fixed in a slab with the entire root surface exposed to the air (Figure 2). Temperature changes were visualised on the mesial root surface during root canal obturation using a ThermaCam SC500 thermal imaging camera (Flir, Sweden) and its dedicated software package. The camera was mounted on a stand perpendicular to the root surface and 15 cm away. The thermograms were recorded at 1 s intervals over a period of 60 s. Additionally, thermal images were displayed on a video monitor and were recorded continu-

Table 1
The maximum temperature rise (°C) including mean temperature rise, the standard deviation and the range recorded on the outer root surface during the continuous wave of condensation technique using a System B HeatSource

Obturation phase	**Number of teeth**	Maximum temperature rise (°C) Mean ± SD (Range)
Downpacking phase	12	8.3 ± 1.3 (6.2 – 10.2)
Separation phase	12	11.7 ± 1.8 (9.1 – 14.6)

The difference between phases (downpacking versus separation) was statistically significant ($p<0.05$)

Figure 3
The temperature increases recorded during the continuous wave of condensation technique

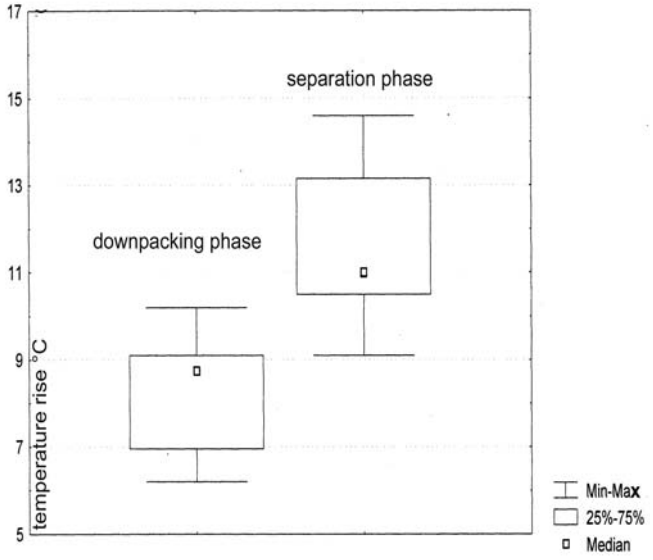

Table 2
The length of time (s) for which the temperature rise on the outer root surfaces was higher than 10°C

Number of teeth with temperature rise >10°C	Length of time (s) for which the temperature rise was higher than 10°C Mean ± SD (Range)
10	4.1 ± 3.4 (1 – 8)

ously on videotape. The experiment was carried out under controlled environmental conditions (Ta = 35.6 ± 0.7 °C, RH 50 ± 5%, air flow < 0.5 m/s). The camera was calibrated for distance, ambient temperature and emissivity of the root tissues. The emissivity of the root tissues was calculated to be 0.90 using the method described by Kells et al. [11].

Statistical analysis

Student's t test for paired samples, significant at the 95% confidence level, was used for statistical comparison of the results.

Results

The maximum temperature rise, including mean temperature rise, the range and the standard deviation recorded on the root surface during obturation are shown in Table 1 and Figure 3. The higher temperature increases were recorded after activation of the plugger immediately before its withdrawal from the root canal (separation phase) (11.7 ±1.8°C), and then after the use of the heated plugger to downpack of gutta-percha (downpacking phase) (8.3 ±1.3°C).

The length of time that the temperatures were elevated by more than 10°C is shown in Table 2. The "continuous wave of condensation" technique using a System B HeatSource resulted in root temperature rises of more than 10°C in 10 cases out of the 12 studied. The length of time that root surface temperatures were elevated by more than the critical temperature ranged from 1 to 8 s (mean of 4.1 ± 3.4 s).

The temperature change over time on the outer root surface of a representative tooth during root canal filling is shown graphically in Figure 4. The downpacking of gutta-percha caused a peak temperature elevation of 9.1°C after 7-8 s of the plugger's introduction. Subsequently, a decrease in temperature of 0.3 °C/ s was recorded. The activation of the plugger before its withdrawal caused a temperature elevation of 14.1°C. After this, the temperature decreased slowly. Figure 5 A-O presents thermograms recorded during the continuous wave of condensation technique.

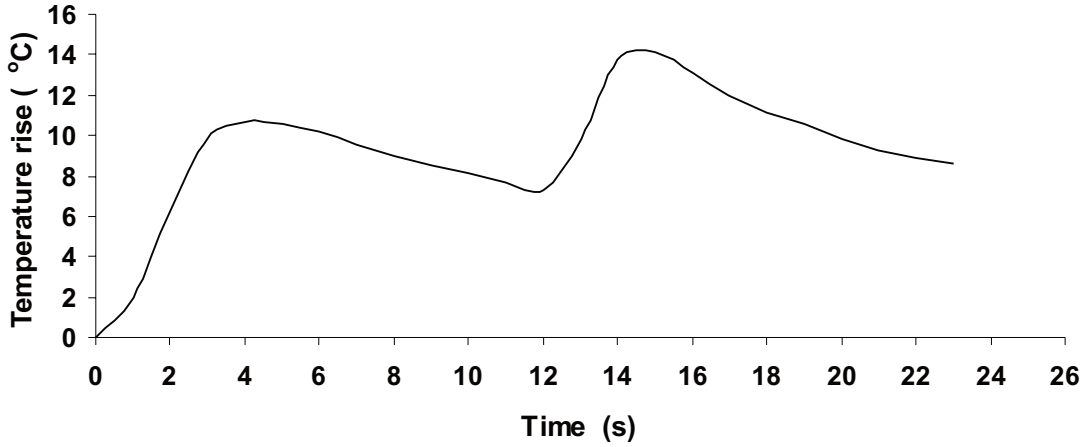

Figure 4
Temperature changes over time on the mesial surface of a representative tooth during the continuous wave of condensation technique

Discussion

It is generally accepted that a 10°C elevation in temperature on the root surface can irreversibly damage the periodontium [12-15]. The present study showed the continuous wave of condensation technique using a System B HeatSource resulted in a temperature rise exceeding 10°C.

The results report higher temperature increases than in previous studies. Venturi et al.[16] used two thermo- couples to analyse two single points on the root surface, and found an *in vitro* temperature rise of 0.1-8.5°C. In the study cited, the extracted teeth were immersed in a thermostatic bath at a constant temperature of 37°C during root canal filling. In another *in vitro* study, Sweatman et al. [17] measured temperature changes on the outer root surface at 2, 4, and 6 mm from the root apex with thermocouples and found the highest temperature at 6 mm distance (temperature change from 4.17°C to 9.12°C). Floren et al. [18] used 10 thermocouples and a split tooth model, and found a temperature range from 1.28°C (2 mm from root apex) to 10.62°C (5 mm from root apex).

It is not suprising that the mean temperature increases found in the present study are higher than those reported earlier. In the current study, temperatures were measured firstly on the whole root surface, and secondly using a thermal imaging camera. Mc Cullagh et al. [19] suggest that infrared thermography data are consistently higher than the thermocouple recordings. In the study cited, the mean temperature increase on the outer root surface produced during the continuous wave of condensation technique using a System B HeatSource, as measured by the two thermocouples, averaged 13.9°C, whilst the thermal imaging camera measured an average increase of 28.4°C at the same sites.

The destructive effect of a temperature increase of more than 10°C on the bone is significantly influenced by time. In the current study, the length of time that the temperature was increased by more than 10°C, varied from 1 to 8 s. However, to produce irreversible changes within tissues surrounding the tooth, a temperature rise of more than 10°C should have a duration of at least 1 minute [8].

In the present investigation, two peak temperature rises during root canal filling were recorded. The first temperature increase was caused by the insertion of heated plugger for downpacking; the second temperature rise was caused by the second activation of the plugger in the canal prior its removal. As expected, the second activation of the plugger generated a higher temperature increase than the first one, probably because the root tissues had not cooled down after the downpacking. Considering the above, a lower second peak temperature elevation could be expected if the time between the first

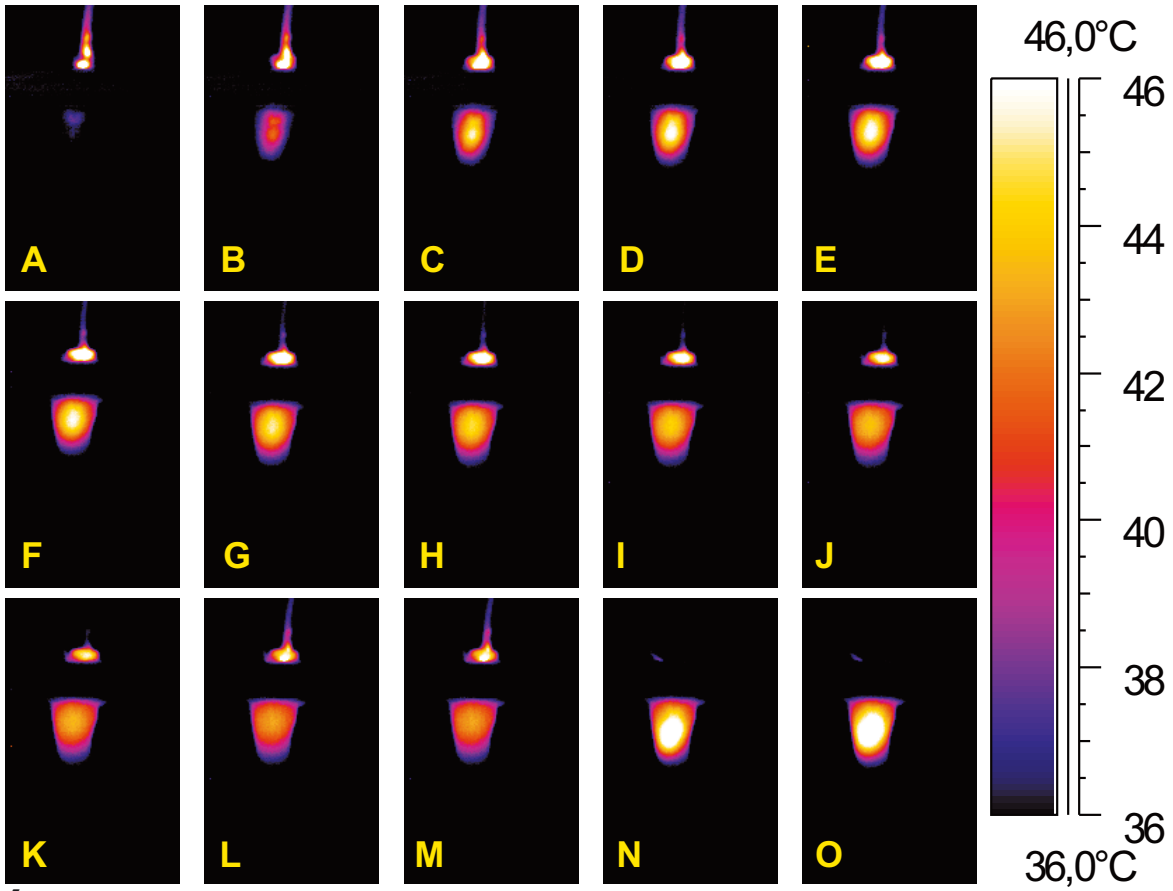

Figure 5
Thermogram recordings of the tooth root undergoing the continuous wave of condensation technique. (A) and (B) thermogram recordings during the introduction of the heated plugger; (C) 1 s after introduction of the heated plugger; (D) 2 s; (E) 3 s; (F) 4 s; (G) 5 s; (H) 6 s; (I) 7 s; (J) 8 s; (K) 9 s; (L) 10 s; (M) immediately before the withdrawal of the heated plugger; (N) immediately after the withdrawal of the heated plugger; (O) 2 s after the withdrawal of the heated plugger.

and second activation of the plugger were prolonged. These are important considerations which need to be verified experimentally.

This experiment was performed with the outer root surface exposed to the air. This *in vitro* model, however, does not take into account the water content and high vascularity of the periodontal ligament and alveolar bone, which may be able can to dissipate heat quite efficiently. Nevertheless, this model has been used by many authors [6, 11-13, 15, 17, 19-29].

In conclusion, the use of a System B HeatSource resulted in an increase of the root surface temperature by more than 10°C, and this could cause damage to the structures surrounding the tooth root. Because the possibility exists that periodontal structures including the periodontal ligament, alveolar bone, and vasculature could insulate and protect the periodontal unit from damaging temperature rises, this study should be repeated using an *in vivo* model. Meanwhile, endodontic practitioners should exercise caution when using the continuous wave of condensation technique technique in root canal obturation.

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Evaluation of psoriasis vulgaris lesions based on thermography

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Summary

The aim of this study was to evaluate usefulness of thermography for the assesment of the severity of psoriatic lesions

Four patients with plaque type psoriasis vulgaris presenting a newly developed eruption were included. An INFRAMETRICS 760 thermal camera with temperature resolution of 0.1 ^{o}C was employed. Both visual and thermal images of the patients were recorded. This study was based on our preliminary findings that higher temperature found in thermographic images within the selected psoriatic plaque and its close surroundings might either predict which lesions would be more resistant to the treatment or predict new lesion formation and justify earlier introduction of more potent additional local agents. In either case thermography would provide means of more focused local treatment, thus leading to improved clinical results and fewer side-effects. Further extensive research on this subject based on the much larger group of patients is required and is in progress.

Key words: thermography, thermal imaging, non-invasive, psoriasis vulgaris, skin lesions

Thermographische Beurteilung von Psoriasisläsionen

Das Ziel dieser Untersuchung war es, die Brauchbarkeit der Thermographie in der Beurteilung von psoriatischen Läsionen zu beurteilen.

Vier Patienten mit Psoriasis, die erst kürzlich einen neuen Schubs von Hautläsionen entwickelt hatten, wurden untersucht. Photographien und Wärmebilder wurden von den Patienten aufgenommen. Dabei wurde eine INFRAMETRICS 760 Wärmekamera mit einer Temperaturauflösung von 0.1° C wurde verwendet. Aufbauend auf einer vorläufuigen Untersuchung, wurde angenommen, dass in den Wärmebildern höhere Temperaturen innerhalb ausgewählter Psoriasis-Plaques bzw in deren unmittelbaren Umgebung entweder voraussagen, dass diese Läsion therapieresistent sein wird oder dass sich neue Läsionen bilden werden, die den Einsatz einer wirksameren lokalen Therapie rechtfertigen. In jedem Fall sollte die Thermographie die gezielte Lokaltherapie fördern und so bessere klinische Ergebnisse bei weniger unerwünschten Wirkungen ermöglichen. Weitere ausführliche Untersuchungen zu dieser Frage sind notwendig und derzeit auch imLaufen.

Schlüsselwörter: Thermographie, Wärmebild, nicht invasiv, Psoriasis vulgaris, Hautläsion

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Introduction

Thermography methods are finding more applications in medicine including evaluation of allergic skin tests, deep vein thrombosis,assessment of burn depth, diabetic foot, Raynaud's phenomenon, thyroid gland changes, pneumonia development and many others [1, 2, 3, 4, 5].

Psoriasis is a complex, multifactoral, inflammatory, non-contagious recurrent skin disease involving 2 -4 % of human population whereas arthropathic variant is observed in about 0.02-0.1% of the total population [6, 7, 8, 9]. Patients with psoriasis account for above 40% of dermatological hospitalization in Poland. In contrast to the western world, in-patient dermatological departments are quite large (40-100 beds) in Poland. The economic situation favors to some extent psoriatic patient hospitalization rather than out-patient treatment [6, 10]. Psoriasis is one of the commonest genetically inherited dermato- logical conditions. Its genetic background is not fully understood, but it is clearly polygenic with a different gene expression. Nowadays, psoriasis is considered as a T cell- mediated auto-immune disorder with type 1 cytokine pattern predominance. This information should guide further the development of management and treatment. [9, 11]. Psoriasis is observed in different races, all over the world. There is no sex predominance. As regards histopathology a few distinct features can be observed: hyperparakeratosis and a lack of the granular layer in the epidermis, inflammatory infiltrate in the upper parts of the dermis and vascular change [6, 8]. All of the above abnormalities could influence surface body temperature measurements. However, microvascular abnormalities seem to be of crucial importance in the development of psoriatic plaques [6, 12, 13, 14]. Blood vessels are increased in number, are elongated, tortuous and dilated [15, 16]. It has been demonstrated that structural expansion and in-

creased tortuosity of the dermal capillary loops occurs early in the formation of the lesion, before epidermal hyperplasia can be detected both clinically or histopathologically [17, 18]. Furthermore, vascular abnormalities could persist even after the application of successful treatment, when the lack of all epidermal disturbances is clearly observed and subsequently they can be responsible for the recurrence of the disease [6, 8]. Increased blood flow is observed through such pathologically changed blood vessels [12, 15]. In addition, it has been demonstrated that cutaneous blood flow in psoriasis is 10 times greater in psoriatic lesions compared to the normal skin [12]. Other studies have reported 2-9 fold increase in the blood flow in psoriatic lesions comparing with clinically normal skin [19, 20]. It is widely accepted that increased blood flow leads to increased skin temperature.

Psoriasis exerts a strong negative impact on patients both psychological and physical well-being. Stressful events are recognized as triggering factors of new eruptions or exacerbating the existing one. It should be underlined that psoriasis as a highly disfiguring disease is a stress factor itself, and as such exerts a negative influence on both psychosocial status of the patient and persistence of the lesions [6, 21, 22]. Psoriasis is an incurable disease with sometimes quite long remission periods. So, the development of the methods facilitating disease remission should be highly encouraged.

The aim of this pilot study was to perform a preliminary evaluation of thermography in psoriatic lesion severity. A sensitive measurement of the thermal gradient as a prognostic marker could prove to be of value in the management of this condition.

Methods

This preliminary study involved 4 patients with plaque type psoriasis vulgaris presenting with a newly developed eruption with a clear tendency to spread. The patients did not take any systemic or local treatment in the previous 2 weeks, except for emollients and keratolytic agents for removing dead skin over for the last week to lessen the interference with temperature measurement. The disease duration ranged from 8 to 10 years. The selected patients did not suffer from psoriatic arthritis. On the day of thermographic procedure all the patients were instructed not to apply any local treatment to the skin in order to avoid irritation and additional stimulation of blood flow. Just before the examination, they were prepared in a special room with controlled temperature for 30 minutes at 20^{o}C.

A thermal camera INFRAMETRICS 760 was employed in the study. The temperature resolution of this camera was 0.1 ^{o}C. The temperature range, mean and standard deviation were calculated. All thermal images were captured and processed through a high-speed Peripheral Component Interconnect (PCI) interface. This interface links up to 4 CCD cameras and one thermal camera with a powerful computer, it offers a high performance of 32-bit data transfer and an optional burst mode that provides accelerated throughput of data across the bus of 132 MB/s. ThermalStudio software was used. Both thermal (once) and visual images (twice) of all the patients were recorded [4].

The severity of the disease was evaluated by PASI (Psoriasis Area and Severity Index) and expressed in whole numbers (points). The following parameters were estimated – *area of involvement* (expressed in % and then recalculated to points – scale 0-6); *infiltration* (evaluated by palpation; scale 0-4); *erythema* (scale 0-4); *desquamation* (scale 0-4).

PASI formula

PASI = Head {[(I + E +D) x A] x 0.1}
+ Trunk {[(I + E + D) x A] x 0.3}
+ Upper limbs {[(I + E +D) x A] x 0.2}
+ Lower limbs {[(I + E + D) x A] x 0.4} [23].

Despite many critical issues regarding this score and an urgent need to create a "gold standard" (which is still lacking), since 1978, the PASI score has remained the most widely used evaluation system employed in psoriatic research [24, 25, 26, 27, 28, 29]. In the evaluation of a single plaque, the PASI plaque score was employed [26].

PASI evaluation for both, the global and the plaque score were performed twice at 3-week intervals, while in-patient treatment was in progress.

Results

The PASI was evaluated by a dermatologist at the time of thermographic procedure – **examination I** (Figs. 1a, 2a) and 3 weeks thereafter – **examination II** (Figs. 1b, 2b, close-up – 1c, 2c, respectively) (Table 1). Thermograms for the whole profile of all patients were also recorded at the time of **examination I.** Subsequently, five areas representing predilection sites for psoriasis occurrence (vertebral area, skin above the elbows and knees) were evaluated in each patient together with temperature measurement, the latter however, was recorded only once (Figs. 1d, 2d) (Table 2). On clinical examination the following parameters were noted: extension of the lesions (%), infiltration (scale 0-4 points), erythema (scale 0-4 points) and desquamation (scale 0-4 points). All the studied patients were on in-patient treatment, including systemic therapy (PUVA – 3 patients or methotrexate – patient JS) and local one (anti-mitotic – such as dithranol, anti-inflammatory drugs – like steroids). During PUVA method patients ingested psolarens (compounds which increase skin sensitivity to light) and subsequently their skin was irradiated with UVA. Methotrexate is a cytostatic agent, which inhibits hyperproliferation of keratinocytes.

Two vertebral areas have been chosen for presentation both, at visual wavelengths and thermographically. Table 3 demonstrates detailed plaque scores of those lesions. All the selected plaques were evaluated separately. Actually, we were interested in the thermal gradient within the single psoriatic plaque, irrespective of the localization. We deliberately did not compare thermal gradients between plaques. Thermal gradients within the selected plaque were correlated with the clinical evaluation at the beginning of the treatment. Further clinical

Figure 1a.
Patient MC - clinical presentation of the lesions prior to the in-door treatment

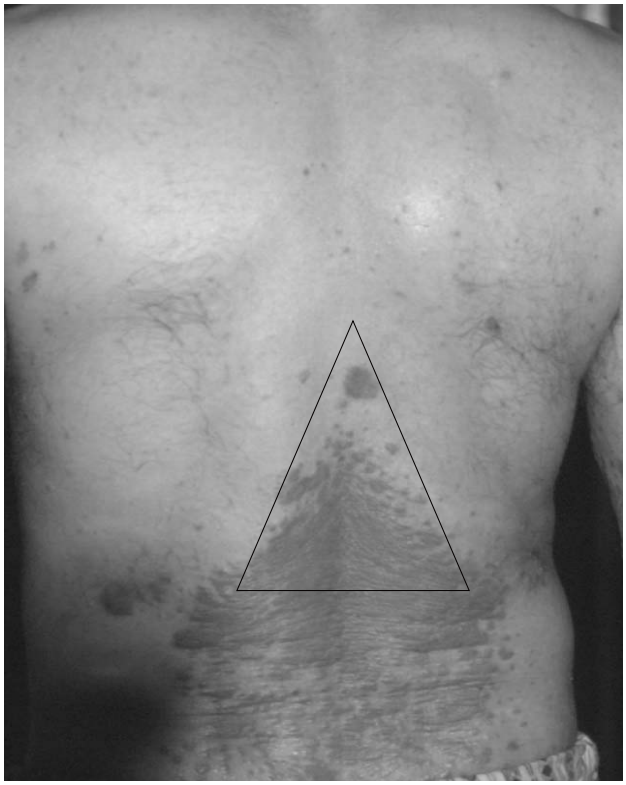

Figure 2a.
Patient KP - presentation of the lesions prior to the in-door treatment

Table 1.
Clinical evaluation of psoriasis based on Psoriasis Area and Severity Index (PASI)

Patient (initials)	**Estimated parameters**	**Examination I**				**Examination II**			
	Range: 0-6 (area) 0-4 (others); 0-28.8 (partial PASI) 0-72 (total PASI)	Head	Trunk	Upper limbs	Lower limbs	Head	Trunk	Upper limbs	Lower limbs
MC	Area	2	4	4	4	0	4	3	3
	Erythema	2	3	3	3	0	1	1	1
	Infiltration	2	3	3	3	0	1	1	2
	Desquamation	2	1	4	2	0	0	0	1
	Partial PASI	1.2	8.4	5.6	12.8	0	2.4	1.2	4.8
	Total PASI	28.0				8.4			
KP	Area	4	2	2	5	0	2	2	4
	Erythema	1	3	3	3	0	1	1	1
	Infiltration	1	3	3	3	0	1	1	2
	Desquamation	2	1	1	2	0	0	0	1
	Partial PASI	1.6	4.2	2.8	16.0	0	1.2	0.8	6.4
	Total PASI	24.6				8.4			
JS	Area	6	3	2	3	0	3	2	3
	Erythema	2	4	3	3	0	3	2	2
	Infiltration	2	2	3	3	0	1	2	1
	Desquamation	2	0	0	1	0	0	0	0
	Partial PASI	2.4	5.4	2.4	8.4	0	3.6	1.6	3.6
	Total PASI	318.6				8.8			
ZM	Area	3	5	3	5	0	5	3	4
	Erythema	2	3	2	3	0	2	1	1
	Infiltration	2	3	3	3	0	2	2	2
	Desquamation	2	0	0	1	0	0	0	0
	Partial PASI	1.8	9.0	3.0	14.0	0	6.0	1.8	4.8
	Total PASI	27.8				12.6			

Figure 1b.
Patient MC - improvement of the lesions after a 3-week in-door treatment.

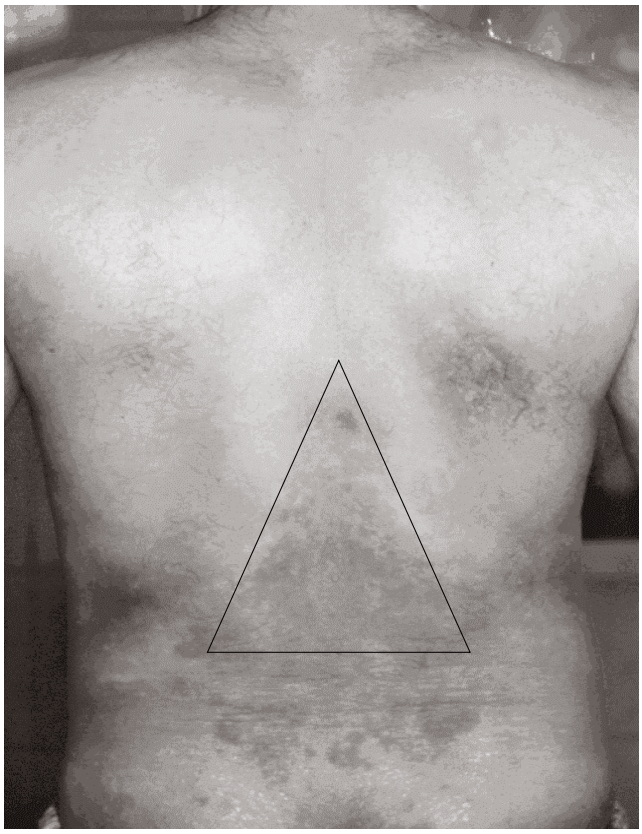

Figure 2b
Patient KP - improvement of the lesions after a 3-week in-door treatment.

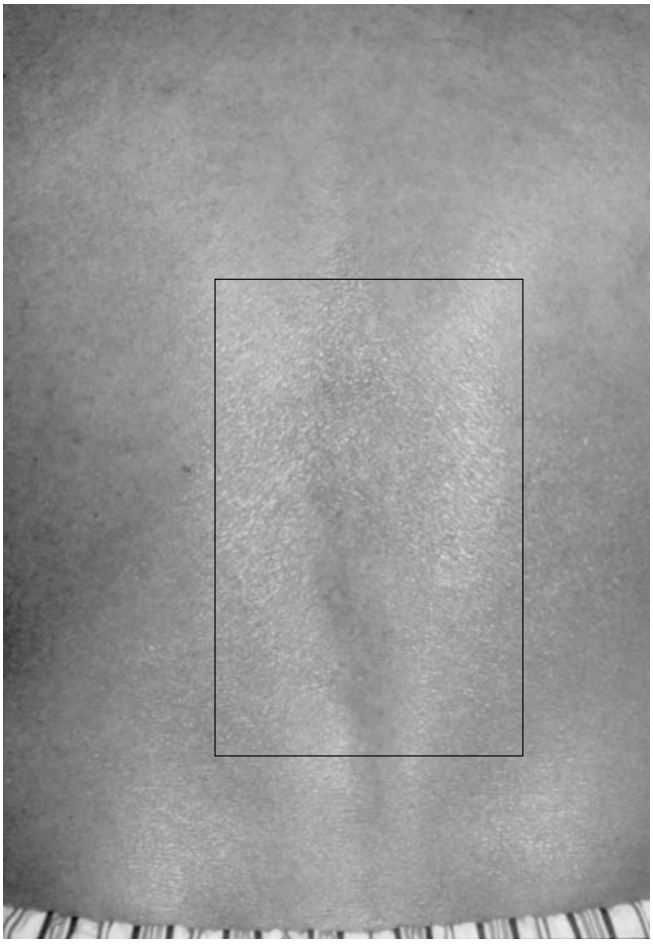

Figure 1c.
Close-up of the vertebral area presented in Fig 1a.

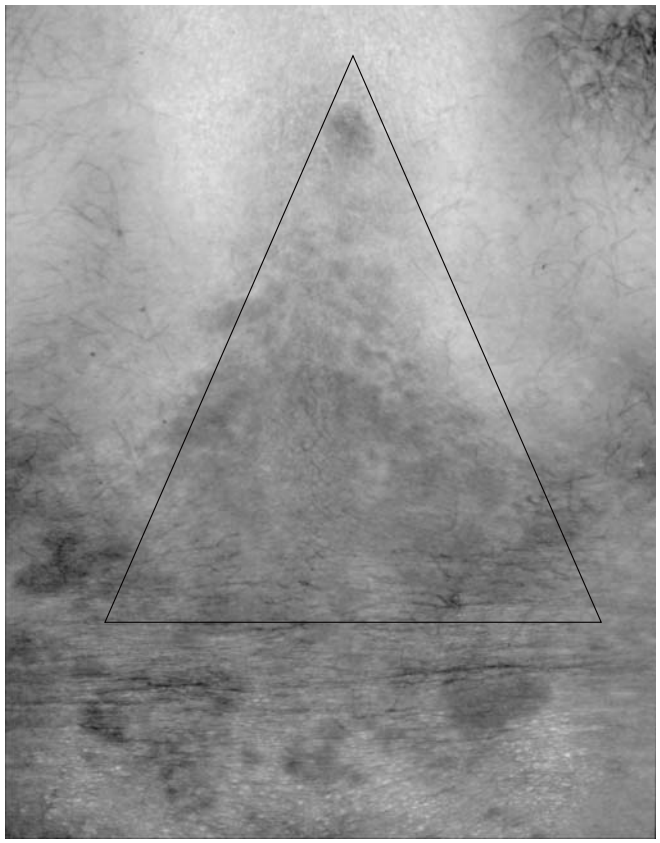

Figure 2c
Close-up of the vertebral area presented in Fig 2a

evaluation of a single plaque was performed after a 3-week-treatment course and some correlation with thermal gradient, evaluated unfortunately only once before the treatment, was also observed. In a 3 week-follow-up period we observed that in the areas of relatively increased temperature (range between 33.9 °C and 36.3 °C) lesions

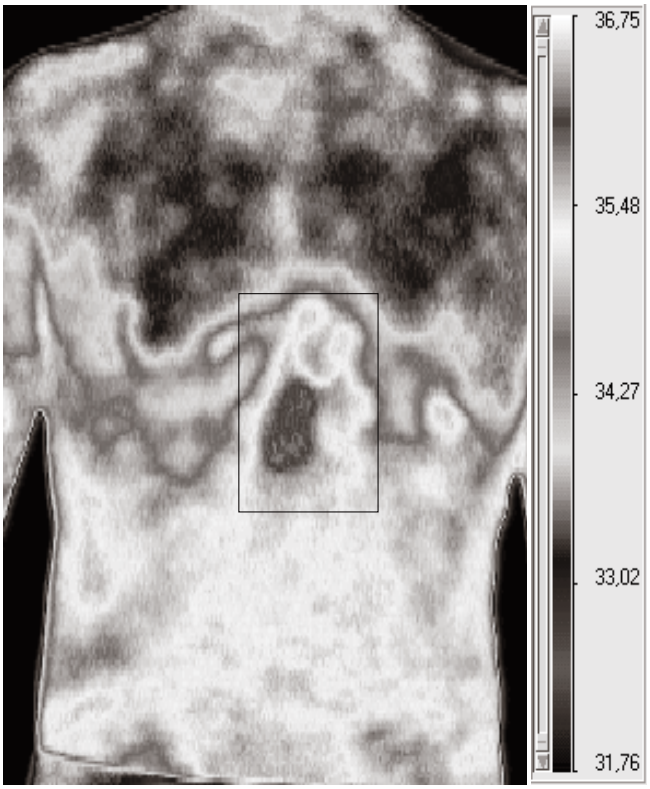

Figure 1d.
Thermographic picture of the lesions presented in Fig 1a

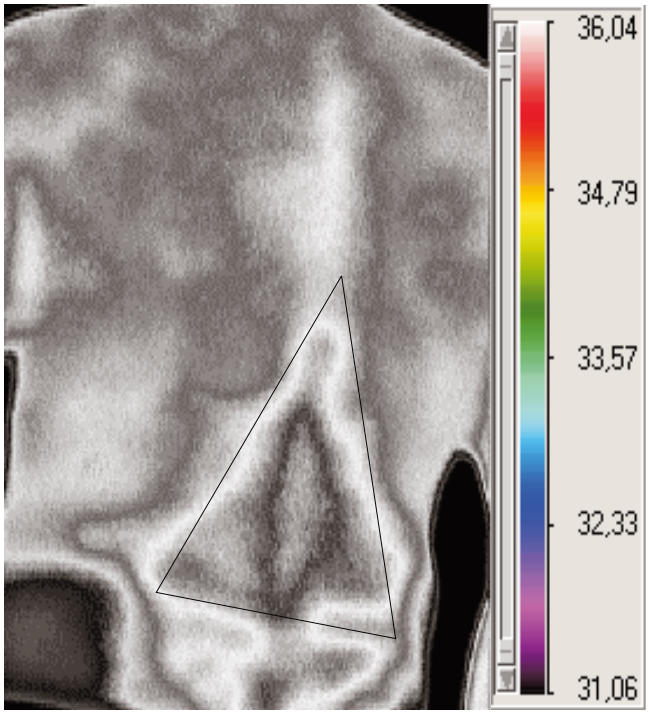

Figure 2d.
Thermographic picture of the lesions presented in Fig 2a

Table 2.
Detailed clinical and thermographic evaluation of five selected areas in each patient.

Patient (initials	**Estimated parameters**	Examination I					Examination II				
	Range: 0-4	Vertebral area	Right elbow	Left elbow	Right knee	Left knee	Vertebral area	Right elbow	Left elbow	Right knee	Left knee
MC	Erythema	3	3	3	2	2	1	1	1	1	1
	Infiltration	3	3	3	3	3	1	1	1	2	2
	Desquamation	0	0	0	0	0	0	0	0	0	0
	Temperature (C) range	33.0-36.3	32.1-35.6	34.0-35.4	33.3-35.2	33.3-35.4	Not performed	Not performed	Not performed	Not performed	Not performed
	Temperature (C) mean ± SD	34.7±0.9	35.0±0.3	34.7±0.2	34.9±0.2	34.6±0.3					
KP	Erythema	3	3	3	2	2	1	1	1	1	1
	Infiltration	3	3	3	3	3	1	1	1	2	2
	Desquamation	0	1	1	2	2	0	0	0	1	1
	Temperature (C) range	33.7-35.8	33.9-34.7	32.9-34.7	33.7-35.2	33.1-35.1	Not performed	Not performed	Not performed	Not performed	Not performed
	Temperature (C) mean ± SD	34.7±0.5	34.3±0.2	34.3±0.2	34.5±0.3	34.3±0.3					
JS	Erythema	4	3	3	3	3	3	2	2	2	2
	Infiltration	2	3	3	3	3	1	2	2	1	1
	Desquamation	0	0	0	0	0	0	0	0	0	0
	Temperature (C) range	31.8-35.4	33.1-34.4	34.3-35.1	32.2-34.0	32.1-33.8	Not performed	Not performed	Not performed	Not performed	Not performed
	Temperature (C) mean ± SD	34.0±0.6	33.8±0.2	34.6±0.2	33.0±0.4	33.0±0.4					
ZN	Erythema	3	2	2	2	2	2	1	1	1	1
	Infiltration	3	3	3	3	3	2	2	2	2	2
	Desquamation	0	0	1	1	1	0	0	0	0	0
	Temperature (C) range	32.0-35.2	31.3-34.2	32.6-33.7	31.1-33.9	31.6-34.2	Not performed	Not performed	Not performed	Not performed	Not performed
	Temperature (C) mean ± SD	33.8±0.6	33.5±0.2	33.1±0.2	33.0±0.4	33.0±0.5					

Table 3
Clinical and thermographic characteristics of the encircled areas presented on photographs

Patient (initials)	**Estimated parameters**	Examination I	Examination II
	Range: 0-4 or C	Encircled vertebral area	
MC	Erythema	partly 0, partly 3	partly 0, partly 1
	Infiltration	partly 0, partly 3	partly 0, partly 1
	Desquamation	0	0
	Temperature (C) range	33.9 - 36.3;	Not performed
	Temperature (C) mean ± SD	35.4 ± 0.5	
KP	Erythema	partly 0, partly 3	partly 0, partly 1
	Infiltration	partly 0, partly 3	partly 0, partly 1
	Desquamation	0	0
	Temperature (C) range	34.2 - 35.8	Not performed
	Temperature (C) mean ± SD	35.2 ± 0.3	

were either fully developed (Fig. 1b) and relatively resistant to treatment or were invisible to the naked eye (Fig. 2b) and gradually started to appear on the skin, as was clinically observed in the course of the in-patient treatment.

Discussion

Thermography is increasingly being used in medical applications especially in the areas associated with blood flow or inflammatory processes [1, 2]. It is well documented that in psoriatic lesion development increased blood flow, hyperkerparakeratosis and inflammation are observed [6, 12]. All these findings influence surface body temperature measurements. All our patients were treated with keratolytic agents in order to minimize the influence of hyperparakeratosis on temperature measurement.

First reports of thermographic methods in psoriasis both psoriasis vulgaris and/or psoriatic arthritis, dates back to the early seventies of the last century [30,31,32]. Mustakallio employed contact thermography to study influence of dithranol - which is one of the classical local therapies in psoriasis - staining properties on erythema estimation in psoriasis [33]. Psoriasis continued to attract attention relating to thermography also in the eighties [34, 35, 36, 37, 38]. There is a very interesting study by Warshaw and Lopez who observed that psoriatic patients present disturbed reaction to a cold challenge i.e. the majority of them did not react to decreased temperature by immediate drop in temperature of the limbs in contrast to the healthy people [35]. Ippolito et al employed thermographic methods to study the blood flow in psoriatic patients treated with cyclosporin, which is a potent immunomoduatory agent, and observed prolongation of the thermal recovery time together with plaque clearance [39].

Studies of the joints are much better represented in the literature data, to mention only a few, but definitely much more extensive research work on this subject deserves to be cited at this point [32, 40, 41, 42, 43]. Maleszka et al also concentrated more on psoriatic arthritis rather than skin lesions . The group mentioned that the skin lesions covered with scales seemed to be hypothermic because those scales acted as an isolation layer and only papular lesions on erythematous base demonstrated increased temperature. Because of those effects, the authors examined only joints, over which no psoriatic lesions have been observed [44].

Our study comprised patients with a long medical history of psoriasis vulgaris in which psoriatic arthritis was excluded. According to the history given by each patient and because of highly negative psychological impact of the disease, for further closer clinical examination the most resistant skin lesions for an individual patient were selected. The vertebral area is one of the predilection sites of psoriasis vulgaris classical presentations, the other being scalp, skin over the elbows and knees. For this pilot study the skin on the back was selected in order to avoid mechanical trauma (which can trigger psoriasis lesion development and favors their resistance to treatment) and is much easier to visually document than for example scalp skin. Skin lesions situated on the lower legs are the most resistant ones to treatment (general clinical observation), on many areas presenting augmented temperature on thermography – despite previous keratolytic treatment, slight desquamation was observed, which could interfere with temperature measurements. In general, vertebral area is characterized by higher temperature than other parts of the body, however this fact was of no crucial importance in our study, because comparisons in disease resistance between skin lesions situated in other parts of the body were not performed. We have deliberately chosen the vertebral area to minimize the influence of mechanical trauma of the lesions and comparisons between symmetrically located psoriatic plaques. A study investigating thermal gradient in psoriatic lesions situated in different parts of the body would be most valuable and of considerable interest in the future and inevitably deserves to be addressed.

We have concentrated on the thermal gradient within a single selected plaque (plaques), as for example within the encircled areas presented in figures 1b and 2b, in order to investigate whether subtle changes in temperature measurements might be of any importance in further development of pathological lesion development and/or regression and their subsequent response to treatment. It was very interesting that quite subtle changes of temperature in one region, which are indistinguishable to inspection of the naked human eye and palpation, can

somewhat "visualize" difference in future regression of the examined skin lesion. These changes could be the result of either thermal gradient in deeper organs situated under the skin lesions or pathological plaque formation process in the dermis and epidermis still invisible to the naked eye. So, based on thermography somehow regression of the lesions could be predicted. In such cases, it would be justifiable to implement more potent local treatment (i.e. steroids) even under occlusion which increases absorption of the local agents but can easier cause irritation and/or side effects such as teleangiectasias or skin atrophy. Potent steroids should be applied for shorter periods and reserved for areas resistant to treatment.

It is obvious that systemic treatment such as PUVA or methotrexate acts on the whole organism. However, it has been observed that some lesions are more resistant to that treatment than others and require some additional local agents to be applied. It seems probable that those lesions could be identified by thermography.

In this study, the second clinical evaluation of the patients was chosen after 3 weeks of treatment because in general this period seems to be adequate to clearly observe regression of most stubborn psoriatic skin lesions. After such period hyperpigmentation is most commonly observed. This sign however can interfere with photographic documentation but is easy recognized on examination. PUVA regimen also leads to suntan thus brownish skin surrounding lesions may also disturb photographic outcome. However, on examination a final result is obvious for a clinician. Unfortunatelly, the thermographic examination has not been performed because of technical problems.

In our opinion, psoriatic lesion thermography performed before treatment implementation may be very useful in distinguishing areas which are likely to be more resistant to the medical regimen used than others, thus requiring a stronger pharmacological approach together with psychological coping strategies. Another interesting implementation of thermography, being a non-invasive procedure, would probably be the identification of psoriatic plaques which as for histopathological criteria are still active and could be responsible for recurrence of those lesions, if untreated. It seems useful to correlate the temperature measurements of symmetrically localized skin lesions with different parameters severity (erythema, infiltration, desquamation) in a larger group of patients to establish proper standarisation, which is a mandatory procedure [43]. Also dynamic correlation of thermographic findings with the treatment regimen outcome would be of utmost importance. This study is only a pilot and requires further research, which is in progress.

We hope that by using thermography, the most resistant lesions may be recognized, and development of new skin lesion within the apparently uninvolved skin might be predicted, thus justifying additional local treatment implementation. However, because of the real scarcity of the patients in this pilot study, definite conclusions should not be drawn and those presented are only provisional. Our findings require further evaluation on a larger groups of properly prepared patients.

Conclusions

Higher temperatures observed within a single psoriatic plaque on thermographic images which are impossible to distinguish on palpation, may either predict which lesions would be more resistant to a specific treatment and allow for earlier introduction of more potent additional local agents or prevent new lesion development. In either case thermography would allow the introduction of more focused local treatment leading to better clinical results and fewer side-effects.

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Examples of evaluation of thermography in pediatric surgery

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Summary

The authors describe examples of the use of thermographic examination in pediatric surgery. They give examples of thermographic images of typical clinical states of selected traumatology, urology and neurosurgery diseases in children with a brief clinical history. The authors consider thermography to be a useful tool in diagnosis and in following the effects of surgical treatment.

Key words: thermal imaging, pediatric surgery, abdominal pain, traumatology, urology

Beispiele des Einsatzes der Thermographie in der Kinderchirurgie

Die Autoren beschreiben einige Beispiele des Einsatzes der Thermographie in der Kinderchirurgie. Sie zeigen typische Wärmebilder von ausgewählten traumatologischen,urologischen und neurochirurgischen Krankheitsbildern in Verbindung mit einer kurzen Verlaufsbeschreibung der erkrankten Kinder. Die Autoren schätzen die Thermographie als nützliche Methode bei der Diagnosefindung und in der Erfolgsbeurteilung der chirurgischen Behandlung ein.

Schlüsselwörter: Thermographie, Kinderchirurgie, Bauchschmerzen, Traumatologie, Urologie

Thermology international 2003; 13: 148-152

Introduction

Thermographic examination (THV) as a non-invasive, painless, repeatable and highly-sensitive test is a valuable aid to diagnose in pediatrics. THV is also used in pediatric surgery, urology, traumatology and neurosurgery. (1, 2, 3)

It has high sensitivity, but low specificity. A thermographic map of the whole body or of a given region together with clinical data improve the efficiency in diagnosis, or in avoiding diagnostic errors. Repeated examination in the same patient may be used to follow the changes in the pathological lesion or the dynamics of the therapeutic process.

A. Selected cases – abdominal pain

Thermal imaging has an application in abdominal pain (e.g. inflammations and tumors), especially in undefined cases. Thermograms are often consistent with anatomical localization of disease, not with reported point of pain. THV examination is also of great assistance, especially when a child complains of a hypersensitive abdomen. (4, 5)

Figure 1 shows the vascular consequences known as "caput medusae" of an hepatic tumor in a 10 year old girl.

Figure 2 is the thermal image of the back of 3 year old girl who was admitted to hospital because of abdominal pain.

Figure 1
10 years old girl – Hepatic tumor – „caput medusae"

Figure 2
3 years old girl with a hot spot in the lumbar region. The cause for that was found to be a neuroblastoma.

Figure 3
7 years old boy with a hot spot in the region of liver.His symptoms were ultimately found to be caused by hepatitis.

Laboratory tests of blood, urine, ultrasound investigation was normal. The THV examination detected a hot spot in the lumbar region. Such a picture may be normal at patients with hyperlordosis, but this girl did not have increased lordosis. CT made after the suggestion of the thermographert showed a tumor in the retroperitoneal space. It was found to be a neuroblastoma.

Figure 3 shows the thermal image of the abdomen of a 7 year old boy admitted to hospital with symptoms of acute abdomen.The surgeon suspected appendicitis. The thermographic examination showed a hot spot in the region of liver, but not in appendix region. The boy was able to avoid surgery. His symptoms were ultimately found to be caused by hepatitis.

Acute abdominal pain in children requires expeditious diagnosis and correct therapeutic decision making. Thermography can help to localize the organ involved, which quite often can be remote from the localization of pain perceived by the patient. The younger the child, the more unreliable or even impossible is the process of accurate clinical history taking. Hot spots visualized in infrared images are usually due to increased blood flow, inflammation or increased metabolic rate (e.g. in neoplastic disorders).

In the girl with hepatic malignancy and distended abdominal veins thermography confirmed the pathology and visualized other hot vessels, which are not detected by clinical examination. THV revealed that pathology progressed further than had been first appreciated. In the other girl with neuroblastoma THV directed the diagnostic process by pointing to the localization of the pathologic lesion, which was different from the one suggested by the patient's symptoms. The boy presenting with an acute abdomen and suspected of suffering from appendicitis avoided unnecessary surgical intervention. A hot spot in appendicitis would be found in the right iliac fossa and not in the right upper quadrant. On the other hand, HBV hepatitis very rarely presents as an acute abdomen and therefore the diagnostic error and incorrect therapeutic decision would easily be made especially before obtaining the result of laboratory tests.

B. Selected cases – fracture healing and bone tumors

Thermography is helpful in the evaluation of healing of long bone fractures treated with external fixation devices (e.g. POLFIX) or bioimplants (BIOFIX). External fixation devices are used for treatment of long bone fractures (also open fractures and polytraumas), pseudoarthroses. BIOFIX implants find application in apophyseal fractures and abruptions of small osseous fragments. BIOFIX absorption time amounts up to 1 year and is sufficient for correct bone healing. Thermographic examination of children treated with POLFIX fixation devices or BIOFIX implants resulted in the so called "warm cicatrix". Such a qualification – "warm cicatrix" – from THV examinations applies to those patients whose temperature gradient of the scar and the surrounding tissue was >1°C. (Figure 4, 5) (6).

None of the patients showed a hypothermal area which might have its origin in degenerative lesion of bones.

According to Tauchmannova and Ammer chronic posttraumatic lesions are characterized by significant hypothermia. It results from the cessation of active bone destruction and from secondary muscle changes (7, 8, 9). Inn a patient with bone pain caused by the degenerative process, the location is also cold. Thermography is very usefull in diagnosis of bone pain which may be caused by

Figure 4
Fracture of right femur – stabilization with POLFIX external fixator in a 17 years old boy 6 months after surgery – "warm

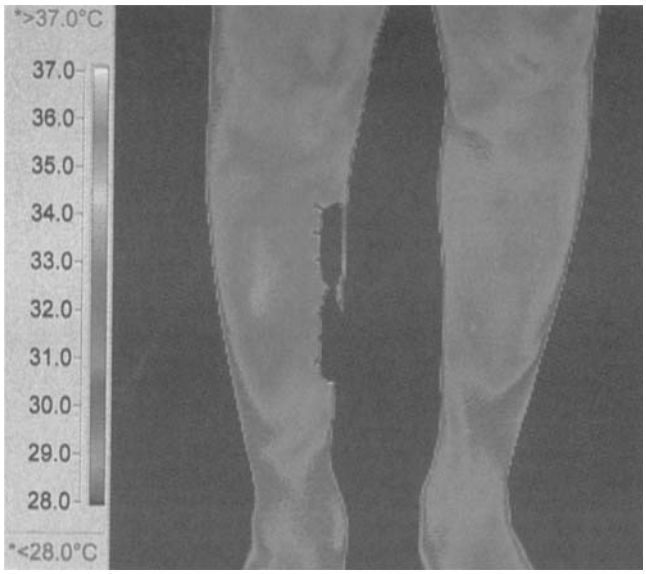

Figure 5
Fracture of right tibia – stabilization with POLFIX external fixator in a15 years old boy 1 week after surgery

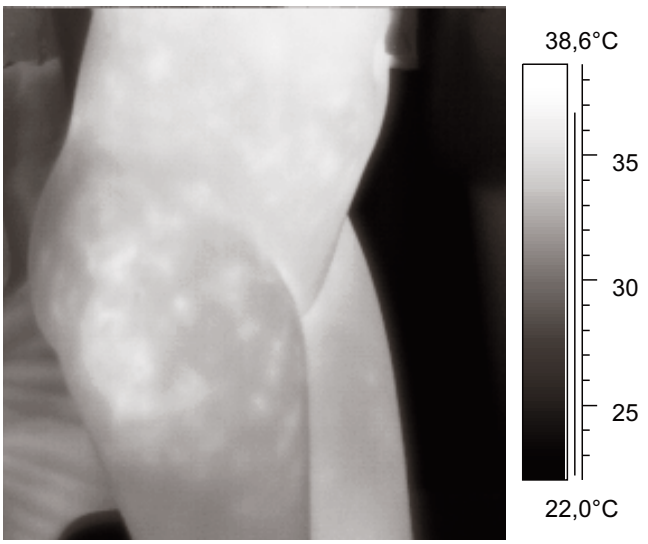

Figure 6
Osteomyelitis of right femur in a 18 months old girl. Such "speckled" image is characteristic for infectious inflammation, frequently caused staphylococci.

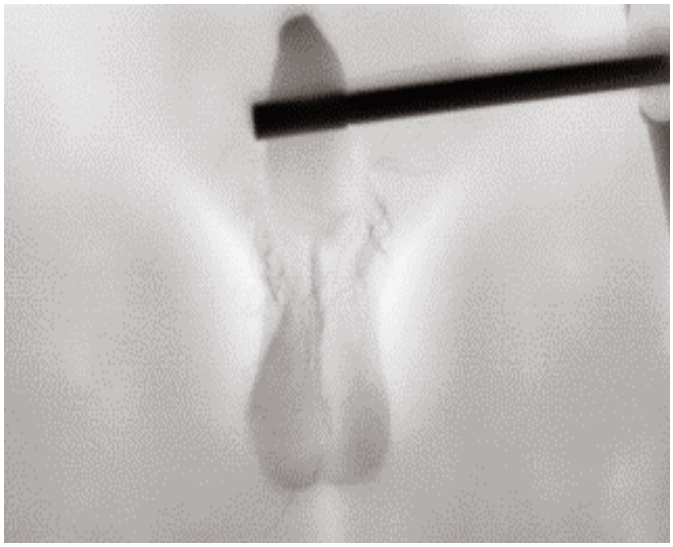

Figure 7a
Torsion of left appendix testis – after operation
15 years old boy – the region of surgery is warmer than the other side

Figure 7b
Torsion of left appendix testis - after operation
16 years old boy – the region of surgery is colder than the other side

a neoplastic process or inflammation. In such cases we can see "hot spots" in the area of the interest. (Figure 6).

Both inflammatory and neoplastic lesions are associated with tissue hypermetabolism and therefore appear warm. Ostealgia caused by a progressive process involving increased osteoclastic activity also shows as warm areas in THV (10, 11).

C. Selected cases – urology

THV is used in pediatric urology in examination of testes: the evaluation of treatment effect in cryptorchidismus, in torsion of testicle appendices and varicoceles.

The results of the correct choice of treatment and correctly performed surgery show no statistically significant temperature differences between temperature of healthy and surgical treated testes. (Figure 7 – 8) (12). Figure 9 shows the genital region of a 16 year old boy admitted to hospital because of testis pain. The surgeon suspected a

Figure 8
Undescended left testicle in an 8 years old boy.- 1 year after

Figure 9
16 years old boy with a neoplasm of the left testicle.

torsion of the left appendix testis. The thermal image suggested a malignant process or inflammation. During the operation it was found that the pain was caused by a neoplasm of the left testicle.

Figure 10
Hydrocephalus – dysfunction of ventriculo – peritoneal shunt

D. Selected cases - neurosurgery

In neurosurgery thermography is used to examine thef function of a ventriculo – peritoneal shunt of a patient with hydrocephalus, meningomyelocoele, myelitis and post traumatic injury of peripheral nerves. Is also used in examinations for brain tumors, vascular diseases, headache and changes in cervical discs. (13, 14, 15, 16, 17, 18)

Figure 10 shows the head of a 2 year old boy admitted to hospital because of symptoms of increased intracranial pressure. Despite the presence of hair on his head a "hot spot" in the area of the Pudenz shunt is visible. This image is caused by the obstruction of the flow of the cerebrospinal fluid resulting in localized heat accumulation.

Figure 11 is the thermal image of the back of an 8 month old boy, who was operated for meningomyelocoele during the neonatal period. The "hot spot" is the result of myelitis caused by fistula.

The assessment of the patency of Pudenz value is a very important functional test in patients, in whom neuroimaging has failed to provide definite answer regarding actual function. In children operated for myelomenigocele THV provides an assessment of the degree of damage to the spine cord or spinal fibres (the image of cold amputation below the lesion or only minor decrease of temperature with the damage involving source of the spinal fibres). The examination is therefore prognostic with regard to the future motor ability of the child. In myelitis THV delineates extension of the regression with therapy. NMR frequently underestimates the area of pathologic signal in comparison with THV and clinical state (personal experience).

Conclusion

- Thermography, when used by an experienced clinician, is of great value both as a screening test as well for the evaluation of treatment effects.
- Thermography helps to localize the organ involved in a pathologic process.
- Thermography can objectify sources of pain reported by the child.

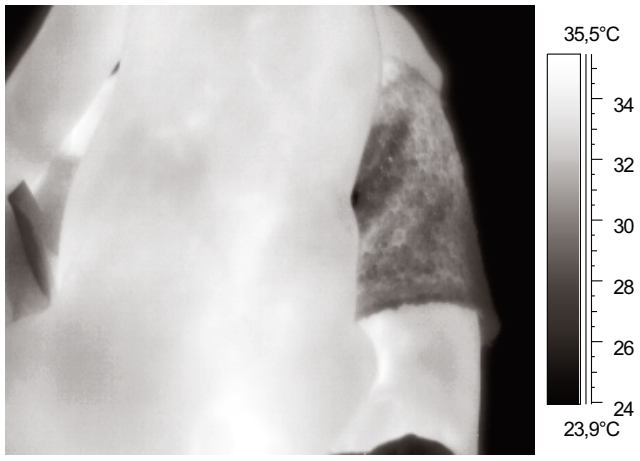

Figure 11
Meningomyelocoele & myelitis in 8 months old boy.

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Serving Humanity-Advancing Technology, First Joint Meeting of BMES & EMBS Annual Fall Meeting of the Biomedical Engineering Society 21st Annual International Conference of the Engineering in Medicine and Biology Society, October 13-16, 1999, Atlanta, Georgia, USA

Session 11.6.1. Digital Infrared Imaging I.,
Saturday October 16-1999, 16:00-18:00, Regency V, oral

DIAGNOSIS OF DEEP VEIN THROMBOSIS WITH NIR SPECTROSCOPY

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The goal of this study is to utilize near-infrared spectroscopy as a non-invasive, inexpensive method of diagnosing deep vein thrombosis. The probe contains two light sources and two filter detectors that record monitor deoxyhemoglobin and oxy- hemoglobin changes via the monitoring of reflected light of wavelengths 760 and 850 mm These changes and the sum of these changes, which corresponds to blood volume changes, are plotted over a time period in which the subject undergoes a series of light exercises. The test protocol is designed to determine the muscle tissue's blood volume capacity, rate of filling and efficiency to promote one-directional venous flow. The subject pool consists of Johns Hopkins Hospital Vascular Surgery patients diagnosed with leg deep vein thrombosis with normal subjects as the control. Abnormal venous systems have distinct characteristics: high blood volume; quick rate of filling; and, the inability to decrease the blood volume during the contraction of the muscle.

Scott FD. Jr.*, Kang KA*, Williams GM.Diagnosis of deep vein thrombosis with NIR spectroscopy. In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc., BMES/EMBS Conference, 1999. Proceedings of the First Joint, p. 1101. vol.2

THE ROLE OF INFRARED THERMAL IMAGING (ITI) IN MANAGEMENT OF NEUROPATHIC PAIN

Hooshmand H, Hashmi M, Phillips EM

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The value of infrared thermal imaging (ITI) is shown to be limited to evaluation of neurovascular dysfunction. It provides useful diagnostic and therapeutic information in the management of neuropathic pain.

Hooshmand H, Hashmi M, Phillips EM. The role of infrared thermal imaging (iti) in management of neuropathic pain. In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1102 vol.2.

DEVELOPMENT OF A HUMAN THERMAL MODEL AND ITS APPLICATIONS FOR THERMOGRAPHIC DIAGNOSIS

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2 Graduate School of Engineering Science, Hokkaido University, Sapporo, Japan

A mathematical model has been developed for the numerical analysis of thermal conditions within the human body. The model is based on a numerical calculation of bio-heat equation and a mathematical model of a thermoregulation system. The internal temperatures, heat fluxes, and blood temperatures of all segments are calculated simultaneously. We try to apply the model to clinical diagnosis by using thermography images. This paper describes the fundamental analysis of the calcu-

lated results and the experimental results. The calculated results compared rather well with the experimental results in some thermal environmental conditions.

Kakuta N, Yokoyama S, MabuchiK. Development of a human thermal model and its applications for thermographic diagnosis. In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1103, vol.2.

INFRARED IMAGING IN THE LONGTERM FOLLOW-UP OF OSTEOMYELITIS COMPLICATING DIABETIC FOOT ULCERATION

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Diabetic foot ulcers are susceptible to secondary infection, when this occurs, there is risk of spread of the infection to adjacent bone, resulting in the serious complication of osteomyelitis, which may be clinically silent in this group of patients. Prompt aggressive treatment with appropriate antibiotics is indicated to prevent even more serious implications ranging from loss of the foot or limb to death. A previous study has shown that infrared imaging is useful in identifyng those patients with diabetic foot ulceration at particular risk of developing clinically silent osteomyelitis. This long-term follow-up study has used infrared imaging to trace the progress of these patients.

Harding JR, BanerjeeD, Wertheim DF, .Williams RJ, Melhuish JM; Harding KG. Infrared imaging in the longterm follow-up of osteomyelitis complicating diabetic foot ulceration. In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1104, vol.2.

UNCOOLED 640X 480 IR CAMERA FOR MEDICAL APPLICATIONS

White T, Leary A,

Lockheed Martin Ill Imaging Systems, Lexington, MA 02421

Uncooled digital infrared focal plane arrays have added a new imaging capability for medical applications. Temperature sensitivity and spatial resolution previously limited to expensive space and military systems applications are now affordable for medical applications and as easy to use as a video camera. This paper presents the results to date obtained moving toward a 640 X 480 camera to be evaluated for medical applications.

White T, Leary A. Uncooled 640x 480 ir camera for medical applications.In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1105, vol.2.

ATHEROSCLEROTIC PLAQUE TEMPERATURE MEASUREMENTS WITH INFRARED FIBER OPTIC IMAGING

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[3,] ANE Image, Pasadena, CA

Rupture of atherosclerotic plaque-the main cause of heart attack and stroke-is not predictable. Fatal plaques are found at autopsies to be associated with active inflammatory cells. Classically, inflammation sites have been characterized by heat, swelling, red color and pain (calor, tumor, rubor and dolor). We have demonstrated in vitro that heat accurately locates the dangerous plaques that are significantly warmer then those plaques without inflammation. In order to develop a non-surgical method of locating these plaques, an infrared fiber optic imaging methodology has been developed in our laboratory to evaluate the causes and effect of heat in atherosclerotic plaques. The temperature heterogeneity of atherosclerotic plaques developed in the arterial of the experimental animal models is under study with the new device. The preliminary experimental results fkom the animal model are encouraging The potential of using this new technology in diagnostic evaluation of the vulnerable plaques is considerable.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1106, vol.2.

SYSTEM DYNAMICS ANALYSIS OF DYNAMIC FAR INFRARED IMAGES IN MEDICINE

Fujimasa I, Miyasaka E, Nakazawa H, Matsuura H.

Nat. Graduate Inst. for Policy Studies, Tokyo;

The objectives of the report are to develop a simulation model for thermal convection near the skin surface, to make an application software for analyzing dynamic far infrared images, and to establish a new analysis system of dynamic thermography for clinical medicine. Firstly, dynamic thermal images were taken by a FIR camera (Thermal Vision LAIRD 3A, Nikon) and stored in a digital-videotape. Secondary, the images were sent to a Macintosh computer using DVCap software (Canon) and converted to a QT movie. Thirdly, the QT movie was processed with a simulation model in the NIH image system. In order to analyze the dynamic images a thermal convection model was developed using system dynamics software (STELLA, High Performance Systems Inc.). After thermal and mechanical stresses were applied to a human body, the dynamic changes of skin temperature were observed by the system. Blood flow rate distribution of cutaneous tissue and sympathetic control factors were detected using the system

Fujimasa I, Miyasaka E, Nakazawa H, Matsuura HSystem dynamics analysis of dynamic far infrared images in medicine. In:Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint, p.1107, vol 2

Session 11.6.2. Digital Infrared Imaging II.,

Saturday October 16-1999, 16:00-18:00,
Grand Hall East, Poster

ADVANCED THERMAL, VISUAL AND RADIOLOGICAL IMAGE PROCESSING FOR CLINICAL DIAGNOSTICS

B. Wiecek*, S. Zwolenik*, A. Jung**, J. Zuber**

*Technical University of Lodzi, Institute of Electronics, Poland
** Military School of Medicine, Warsaw, Poland

This paper presents multi-channel system with for advanced image processing for thermal, visual and radiological images. Novel methods mainly based on statistical data processing and 3D reconstruction are implemented. The system was successfully used for pneumonia treatment.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1108, vol.2.

NUMERICAL ANALYSIS OF CP-MCT AND IMAGE RESTORATION BY THE COMPUTED PROJECTION

M. Miyakawa*, K. Orikasa*, N. Ishii*, M. Bertero+ P. Boccacci+

*Dept.Biocybernetics,Faculty of Eng.,Niigata Univ, Japan
+Dept.Inform.& Inform.Sci., Univ.Genova,, Italy

A method for FD-TD based field analysis of the chirp radar-type microwave tomography (CP-MCT) has been developed. By taking the computed projection of a thin cylinder to be the point spread function (PSF) of CP-MCT, image restoration has been attempted.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1109, vol.2.

FAN BEAM –MIKROWAVE SCANNER FOR HIGH SPEED TEMPERATURE IMAGING

M. Miyakawa*, H. Itoh*, M. Takabayashi, M. Bertero+, P. Boccacci+
* Dept. Biocybemetics, Faculty of Eng., Niigata Univ., Japan
+ Dept, Inform. & Inform. Sci., Univ. Genova,V Italy

For high-speed imaging of the chirp radartype microwave computed tomography(CP-MCT), a fan beam-type microwave scanner which works at 1-2 GHz has been developed. By introducing the electronic scan into the microwave scanner with the receiving antenna consisted of 43 small dipole antennas,data acquisition is completed within 200 seconds.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1110, vol.2.

IMPROVEMENT OF THERMAL PROPERTIES IMAGING SYSTEM OF SKIN BY CHANGING AMBIENT RADIATION TEMPERATURE IN STEPWISE FASHION

H. Saito *, Y. Kimura *, HMD Moinudin *, K.Otsuka *, A. Shimase **, S. Okada **, K. Tsuchiya ** T. Togawa *
** Inst .of Biomat. and Bioeng., Tokyo Med. and Dent. Univ., Japan.
** Sch.of Sci. and Eng., Waseda univ., Tokyo, Japan.

This paper proposes a system to make images on skin thermal properties such as emissivity, thermal inertia and emissivity-corrected thermography. The properties are estimated to measure the time course of temperature during changing ambient temperature in stepwise fashion. Discharge from huge capacitances to electrical heater which is controlled by their temperature can heat the ambient radiation from 20 to 40 ‘C within 0.2 sec. The time course of temperature on skin surface is almost linear against square root of time, which fits the theory. We can conclude that the system is practically applicable.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1111, vol.2.

DESIGN AND TESTING OF A NEAR-INFRARED COMPUTED TOMOGRAPHY DEVICE FOR BREAST TUMOR CHARACTERIZATION

KD Paulsen, BW Pogue, TO McBride, UL Osterberg
Thayer School of Engineering, Dartmouth College, Hanover New Hampshire

The design of a frequency-domain near-infrared scanning device is considered in order to determine how the source-detector geometry affects the resulting reconstruction of the tissue images. The measurements are processed by a finite element-based algorithm which reconstructs the interior image map of the absorption and scattering coefficients. This reconstruction is achieved by matching the light fluence measurements to calculated values based upon the assumption that light diffuses in tissue, and is predicted by the diffusion equation. An initial series of computer simulations have been used to evaluate the source detector geometry, and predict how the measurement geometry affects the reconstruction accuracy and image quality. A physical device has been realized, using the optimal design, and is currently in a clinical trial to characterize the optical properties of breast tissues and tumors in vivo. The device uses 16 source and 16 detector locations alternating in a circular array, which can be attached to the breast tissue during a patient exam. Initial phantom and tissue studies indicate that quantitatively accurate images of the absorption coefficient can be obtained at multiple near infrared wavelengths.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1112 vol.2.

MICROWAVE RADIOMETRIC IMAGING (MWI)

B, Bocquet, S. Mouty, R. Ringot, Y. Leroy, N. Rocourt*, Y. Robert*, P. Devos* *, R. Beuscart**
University des Sciences et Technologies de Lille, France
*CHRU de Line, H6pital Jeanne de Flandre
**Centre d’Etude et de Recherche en Informatique Medicale (CERIM)

We have developed a fast MicroWave radiometric Imaging system (MWI) which realizes thermal images with a good spatial resolution.We are making at the present time,a large clinical evaluation for the breast tumor characterization in an early stage. A ReceivedOperatingCurve (ROC) statistical analyze in an intermediate stage of 60 patients, gives a sensibility and a specificity up to 80%.We show here that this technique could complete the non-invasive radiological outcome in terms of benign-malignant characterization.

Moreover,t he use of an inverse problem technique in the spatial frequency domain gives a quantitative measurement of cancer temperature. It is now possible to consider in a new application such as the followed of the temperature during a chemotherapy treatment.

In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc, BMES/ EMBS Conference, 1999. Proceedings of the First Joint, p. 1113 vol.2.

Session 11.6.3: Digital Infrared Imaging III

Friday October 15 1999, 13:30-15:30, Chicago EF, Oral

STRUCTURAL AND FUNCTIONAL TISSUE ANALYSIS UNDER SKIN USING NEAR INFRARED SPECTRAL IMAGING

Fujimasa I, Nakazawa H.
Nat. Graduate Inst. for Policy Studies, Tokyo;

The infrared imaging technique will become a typical non- invasive measurement method in clinical medicine. However, the pathophysiological meaning of infrared imaging has not been analyzed schematically. The authors have developed an infrared imaging system, which can detect spectroscopic images from near infrared images to far infrared thermography. Near infrared images are taken by a cooled charge-couple-device (cooled CCD) applying an active light source such as a halogen light and laser diodes in reflecting and transparent mode. Middle infrared images are measured by an infrared camera, which can detect short wavelengths less than 3.0 microns. Far infrared images are taken by a dynamic thermographic instrument to measure radiated rays. Using projected infrared rays of 880 nm, the vascular network in subcutaneous tissue has been observed in transparent and reflective mode. Using infrared rays of 760 nm and 800 nm, blood volume and oxygenation images of subcutaneous tissue have been obtained in dynamic mode. A near infrared image of subcutaneous tissue combined with a thermal image of skin surface which was simultaneously taken by an image overlapping method, and the pathophysiological function of cutaneous tissue was analyzed .

Fujimasa I, Nakazawa H. Structural and functional tissue analysis under skin using near infrared spectral imaging. In: [Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint Meeting; 1999, p. 1114 vol.2.

OBJECTIVE DETECTION OF BREAST CANCER BY DYNAMIC AREA TELETHERMOMETRY (DAT)

Anbar M, Brown C, Milescu L.
Sch. of Med. & Biomed. Sci., State Univ. of New York, Buffalo, NY

Classical thermology involves visual localization of abnormalities in the spatial distribution of temperature over human skin. Dynamic area telethermometry (DAT), on the other hand, which extracts diagnostic information from temporal changes in skin temperature, yields quantitative information on the detailed structure of skin temperature modulation including the underlying frequencies and their corresponding relative amplitudes. Significantly abnormal values of these parameters, which quantitatively describe the dynamics of skin perfusion, can be of great diagnostic importance. DAT is typical of the new trend in thermology to focus on dynamic physiological rather than on anatomical thermal manifestations of disease. DAT focuses on rapid periodic changes in skin temperature, caused by cardiogenic pulsatile hemodynamics as

well as by neuronal regulation of blood flow in the vasculature. Quantitative analysis of these changes can reveal pathology in the cardiovascular or neuronal systems, as well as pathologies that affect the function of the latter. Using this methodology, the authors were able to demonstrate high significant differences between cancerous breasts and breasts with no known pathology or breasts with benign abnormalities.

Anbar M, Brown C, Milescu L. Objective detection of breast cancer by dynamic area telethermometry (DAT).In: [Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint Meeting, 1999, p. 1115 vol. 2.

COMPARISON OF MAMMOGRAPHY AND BREAST INFRARED IMAGING: SENSITIVITY, SPECIFICITY, FALSE NEGATIVES, FALSE POSITIVES, POSITIVE PREDICTIVE VALUE AND NEGATIVE PREDICTIVE VALUE

Head JF, Lipar, CA, Elliott RL.

Mastology Res. Inst., Elliott Mastology Center, Baton Rouge, LA;

Breast infrared imaging (IRI) for detection of breast cancer has been unfairly maligned as having unacceptably high false positive and false negative rates. IRI actually has statistical performance characteristics that are similar to mammography. The false positive rate of 14% is about twice as high as mammography but surgical intervention is not possible (no increase in invasive procedures). Also, the false negatives of IRI do not hinder the detection of breast cancer by physical exam, mammography and ultrasound. Finally, the ability of IRI to predict who will develop breast cancer is not appreciated and IRI results should be used to select patients for prevention trials

Head JF, Lipari CA, Elliott RL.Comparison of mammography and breast infrared imaging: sensitivity, specificity, false negatives, false positives, positive predictive value and negative predictive values. In: Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc., BMES/EMBS Conference, 1999. Proceedings of the First Joint Meeting, 1999, p. 1116 vol.2

DIAGNOSIS OF NERVE ENTRAPMENT SYNDROMES BY THERMAL IMAGING

Ammer K

Ludwig Boltzmann Res. Inst. for Phys. Diagnostics, Vienna;

Thermal images of 154 hands were studied to show that patients suffering from thoracic outlet syndrome or carpal tunnel syndrome can be differentiated from healthy subjects by the occurrence of a thermal asymmetry between the index and the little finger. A temperature difference between these fingers higher than 0.5°C was regarded as a pathological finding. With respect to clinical, neurographic and thermographic criteria, hands were allocated into four groups: healthy controls, carpal tunnel syndrome, thoracic outlet syndrome and the combination of carpal tunnel with thoracic outlet syndrome. A discriminant analysis of grouping with respect to the temperature difference between index and little finger, found correct classification in 44,8% of cases. After transfer of the combined syndrome to the thoracic outlet group, the number of correct classifications increased to 63,3%. The calculation for sensitivity and specificity of pathological temperature differences for the diagnosis of thoracic outlet syndrome yielded values of 71,60 and 42,9%. The determination of the temperature distribution on the hand seems to be a valuable test for the detection of patients with thoracic outlet syndrome

Ammer K.Diagnosis of nerve entrapment syndromes by thermal imaging. In: [Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint Meeting ;1999, p 1117 vol.2

VISIBLE AND INFRARED HYPERSPECTRAL VISUALIZATION OF NORMAL AND ISCHEMIC TISSUE

Zuzak K J *, Schaeberle MD.*Levin IW.*, Lewis EN*, Freeman J**, McNeil JD *** , Cancio LC.****

*Laboratory of Chemical Physics, NIDDK, NIH, Bethesda, MD
** Chesnut Hill, MA 02467
***Wilford Hall Medical Center, Lackland, TX
****U.S.Army Institute of Surgical Research, Houston, TX

We have developed a new in-vivospectroscopic imaging system (IVIS) for real-time biomedical applications. IVIS visualization produces images that are acquired non-invasively during clinical procedures. This paper describes data collected from tissue to determine the efficacy of this type of hyperspectral imaging modality for measuring changes in the spatial distribution of regional tissue oxygenation during vascutar occlusion and reperfusion.

BLOOD FLOW IMAGING ALGORITHM FOR INFRARED THERMOGRAPHIC SYSTEMS

K. Kondo*, H. Ishigaki*, Y. Konishi*, K. Mabuchi**

* Dept. Mechanical & Intelligent Eng., Himeji Institute of Technology, Japan
** Center for Collaborative Research, The University oj Tokyo, 4-6-1, Japan

The most important information obtained by thermographic teats is not the absolute value of the temperature itself, but rather its distribution on space or time variables. In this paper, we propose an effective imaging method for infrared thermographic systems. Especially, it is applied to the change detection of blood flow in the infrared images. The purpose is achieved by using image-subtraction technique and spatiotemporalfilter for motion enhancement. Through simulation result, it is shown the change of blood flow is detected clearly.

A FOCAL PLANE ARRAY SYSTEM FOR CLINICAL INFRA RED IMAGING

Ring EFJ, Minchinton MAB, Elvins DM

R. Nat. Hosp. for Rheumatic Diseases, Bath

Thermal infrared imaging (IR) in medicine has been dependent on single element detectors with mechanical scanning systems for four decades. Modern IR systems now offer high speed, high resolution. This paper reports a study made during an upgrade from a cooled single element Agena 782M imager to a new uncooled focal plane army Thermovision (Flir systems Inc.). The results show spatial resolution to be higher with the new Thermovision, resolving skin vasculature. The autocalibration of this camera can produce some temperature measurement variability

Ring EFJ, Minchinton MAB, Elvins DM. A focal plane array system for clinical infra red imaging.In:Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc. BMES/EMBS Conference, 1999. Proceedings of the First Joint Meeting , 1999, p. 1120 vol.2.

World Congress on Medical Physics and Biomedical Engineering Chicago, July 23-26, 2000

TU-G3003 Track 01: Infrared Imaging in Medicine, 5:00 –6.00, Room 303

Chairs: Jasper Lupo, Office of the Under Secretary of Defense (Science & Technology) Pentagon, Washington DC

William Sander,
U.S.Army Research Office, Research Triangle Park, NC

STANDARDIZATION OF THERMOGRAPHIC BREAST CANCER DETECTION-ROLE OF QUALITATIVE FINDINGS AND QUANTITATIVE FINDINGS

Usuki H, Maeta H, Maeba T, Wakabayashi H, Goda F, Karasawa Y, Misawa A, Mori S, Okano K.
Dept. of Surgery, Kagawa Med. Univ, Japan

In previous studies, thermographic findings of breast disease were compared with histological findings for evaluating thermographic usefulness. Some researchers tried to create criteria for thermographic diagnosis of breast disease using many kinds of findings. These trials improved the thermographic accuracy rate, but the criteria became too complex. The first purpose of this study is establishing the standard of thermographic breast cancer detection, which is as simple as possible for commonly used thermography. For this purpose, it is clarified which thermographic findings contributed to breast cancer detection. Then, a diagnostic tree for breast thermography is created. In the second part of this paper, the role of several thermographic findings in breast cancer treatment, is discussed.

Usuki H, Maeta H, Maeba T, Wakabayashi H, Goda F, Karasawa Y, Misawa A, Mori S, Okano K. Standardization of thermographic breast cancer detection-role of qualitative findings and quantitative findings
In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 2000, p. 1219-1222 vol.2

DATA-PROCESSING METHOD FOR STANDARDIZATION OF THERMOGRAPHIC DIAGNOSIS

Wakamiya J, Mabuchi K, Fujimasa I, Nakagawa S, Miyake H, Anmura K, Osame M, Igata A, Takizawa Y.
Clinical Dept., Nat. Inst. for Minamata Disease, Kumamoto;

In previous papers, areas of temperature change were analyzed using the average temperature of frames or the differences between different shaped thermograms of the affected side and the normal side. But, by this method, it is impossible to accurately evaluate temperature differences. Therefore, we have developed a method by which thermograms could be converted to a uniform shape. The appropriateness of the program was evaluated using fifty normal subjects and ten patients with lumbar radiculopathy. It was concluded that thermograms could be converted to different shapes accurately, that the conversion method reflected anatomical structure. Also, through differences between two thermograms with a uniform shape, it was possible to show precisely not only areas of temperature change but also the distribution and degree of temperature change in the areas. It can be concluded that this method is useful in studies on thermography and clinical application and that thermography can be standardized by this method

Wakamiya J, Mabuchi K, Fujimasa I, Nakagawa S, Miyake H, Anmura K, Osame M, Igata, A, Takizawa Y. Data-processing method for standardization of thermographic diagnosis. In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE Meeting; 2000; p. 1432-1435 vol. 2.

DYNAMIC AREA TELETHERMOMETRY (DAT)

Anbar M.
Dept. of Physiol. & Biophys. & Surgery, Buffalo Univ., NY

The tutorial describes this novel objective infrared imaging methodology and its clinical applications. Use of DAT in the detection of breast cancer illustrates the potential of this non-invasive diagnostic technique

Anbar M. Dynamic area telethermometry (DAT) In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 2000, p. 1635-1638 vol.3

DIAGNOSIS OF BREAST CANCER WITH INFRARED DYNAMIC AREA TELETHERMOMETRY (DAT)

Anbar, M. Milescu, L. Brown, C. Carty, C. Naumov, A. Bachman, E. AlDulaimy, K. Geronimo, C. Button, T.
Dept. of Physiol. & Biophys., Buffalo Univ.

Breast cancer was shown to affect the modulation of skin perfusion in subareas of cancerous breasts. This is probably due to the vasodilatory effect of nitric oxide (NO), generated by cancerous cells. By saturating NO endothelial receptors, extravascular NO interferes with neuronal control of perfusion. DAT can quantitatively assess this effect of cancer and be used to detect breast cancer. This noninvasive diagnostic test involves the acquisition of 1024 consecutive infrared images of a breast at a rate of 100 Hz. The DAT test yields several diagnostic parameters, including: (1) the average modulation amplitude of the breast; (2) the average modulation of a subset of spots with the lowest modulation amplitudes; and (3) the spatial distribution of that subset of spots. The frequency dependence of each of these three parameters constitutes three additional diagnostic parameters. Modulation of the spatial homogeneity of skin temperature offers another analogous set of diagnostic parameters. Our clinical study involved testing breasts found by X-ray mammography to show suspicious microcalcification warranting biopsy. We compared breasts with pathologically established malignant lesions, breasts containing benign lesions, and breasts with normal X-ray mammograms (the contralateral breast). The DAT findings of the two latter groups were indistinguishable. Preliminary tests have demonstrated that cancerous breasts can be identified with a sensitivity >90% at a specificity of 95%

Anbar M, Milescu L, Brown C, Carty C, Naumov A, Bachman E, Al Dulaimy K, Geronimo C, Button T. Diagnosis of breast cancer with infrared dynamic area telethermometry (DAT). In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE Meeting, 2000, p. 1215-1218, vol.2.

INFRARED IMAGING IN THE DETECTION AND EVALUATION OF TUMOR ANGIOGENESIS

Li WW, Head JF
Inst. for Adv. Studies, MEDIRIM Program, Cambridge, MA;

Recently, the authors have reexamined the potential for adapting high sensitivity IR imaging techniques to detect pathological features of disease (tumor angiogenesis), in order to fulfil an unmet scientific and clinical need in cancer research and therapy. Data from early preclinical studies is presented and discussed. They conclude that the infrared sensor is an a important new research tool for exploring the biological and clinical correlates of tumor angiogenesis. Advances can be made by integrating the current knowledge and efforts of specialists in the multiple disciplines of engineering, molecular and cellular biology, oncology, radiology, and biotechnology

Li WW, Head JF. Infrared imaging in the detection and evaluation of tumor angiogenesis. In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE Meeting, 2000, p. 1931-1932 vol.3

DETECTING BREAST CANCER FROM INFRARED IMAGES BY ASYMMETRY ANALYSIS

Qi H, Snyder WE, Head JF, Elliott RL.
Dept. of Electr. & Comput. Eng., Tennessee Univ., Knoxville, TN;

Infrared imaging of the breast (also called thermography) has shown effective results in both risk assessment and prognostic

determination of breast cancer. This paper proposes an automated approach to detect asymmetric abnormalities in thermograms. Canny edge detector is first used to derive the edges from the original image. Hough transform is then applied to the edge image to recognize the four feature curves, which include the left and the right body boundary curves, and the two parabolic curves indicating the lower boundaries of the breasts. Segmentation is conducted based on the intersection of the two parabolic curves and the body boundaries. Bezier histogram is then derived from each segment. Curvature information is finally computed from the histogram to be used to easily indicate the asymmetry

Qi H,Snyder WE, Head JF, Elliott RL. Detecting breast cancer from infrared images by asymmetry analysis. in: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 2000, p.1227-1228 vol.2.

THERMAL-CORONARY-ANGIOGRAPHY (TCA) FOR INTRAOPERATIVE EVALUATION OF GRAFT PATENCY IN CORONARY ARTERY BYPASS SURGERY

Falk V, Kitzinger H, Walther T, Diegeler A, Mohr FW.
Univ. fur Herzchirurgie, Leipzig, Germany.

Despite the evolution of surgical techniques, coronary artery bypass graft surgery is complicated by early and late graft failure. While late graft failure is usually due to progression of the underlying disease, early graft failure can be caused by technical mistakes at the level of anastomoses. Thermal Coronary Angiography (TCA) has been developed to detect intra- operative graft failures. The method is based on the small temperature gradient that is produced by the inflow of blood into the graft and can be detected using an infrared scanner. TCA is a non-invasive method that requires no ionizing radiation or contrast documents. It allows to demonstrate graft patency of venous and arterial grafts and allows evaluation of perfusion after revascularization. It is also helpful detect distal stenoses in native coronary arteries. With the development of total endoscopic coronary artery bypass graft procedures using robotic assistance endoscopic TCA may prove to be a valuable tool for quality control in an endoscopic setting. Its value in the field of pediatric cardiac surgery for congenital disease involving reimplantation of coronaries needs yet to be explored. In summary, TCA is a valuable tool for intraoperative quality control in coronary artery bypass graft procedures and helps to minimize the risk of postoperative complications following myocardial revascularization

Falk V, Kitzinger H, Walther T, Diegeler A, Mohr FW. Thermal-coronary-angiography (TCA) for intraoperative evaluation of graft patency in coronary artery bypass surgery. In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 2000, p. 1933-1941 vol.3.

TAU IMAGE:
A DIAGNOSTIC IMAGING TECHNIQUE BASED ON THE DYNAMIC DIGITAL TELETHERMOGRAPHY

Merla A, Di Donato L, Romani GL
Dipt. di Sci. Cliniche e Bioimmagini, Universita di Chieti, Chieti; Italy

A new diagnostic imaging technique based on the dynamic digital telethermography is described. Using all the functional information related to the local thermoregulatory process, this technique seems able to detect and to classify the stage of some disorders that alter the normal displays of the local thermoregulatory system. The presence of these altering pathological factors can be enhanced by means of an induced thermal stress and recorded by the different dynamics of the thermal recovery exhibited by healthy or damaged area. The recording of these different recovery dynamics-performed by means of digital thermographs characterised by a very short acquisition time-can provide a new useful imaging tool, especially to validate and to follow up specific rehabilitative processes.

Merla A,Di Donato L, Romani GL.Tau image: a diagnostic imaging technique based on the dynamic digital telethermography. In: Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 2000, p. 3272

Building New Bridges at the Frontiers of Engineering and Medicine 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, Istanbul, Turkey

5.5.1: IR Imaging Techniques
Friday, October-26-2001, 17:00-19:00 Marmara, oral

NEW DIFFERENTIAL DATA ANALYSIS METHOD IN ACTIVE THERMOGRAPHY

Ruminski J, Kaczmarek M, Nowakowski A.
Dept. of Med. & Ecological Electron., Tech. Univ. Gdansk;

A new method for parametric image synthesis in active thermography is proposed. Based on experimental results, the thermal model of an observed object is defined. Images of reconstructed model parameters are formed allowing clear visualization of object thermal properties. Studies made on phantoms and in-vivo measurements are presented. Possible applications of the method are discussed.

Ruminski, J,Kaczmarek M, Nowakowski A. New differential data analysis method in active thermography. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2801- 2804 vol.3.

ADVANCED THERMAL IMAGE PROCESSING FOR MEDICAL AND BIOLOGICAL APPLICATIONS

Wiecek B, Danych R, Zwolenik Z, Jung A, Zuber J.
Inst. of Electron., Tech. Univ. Lodz;

In this paper, new image processing tools are presented for conversion thermal and visual images, mainly for application in medicine and biology. A novel method for area and distance evaluation based on statistical differencing is discussed. In order to increase the measurements accuracy, the interpolation and subpixel bitmap processing are chosen.

Wiecek B, Danych R, Zwolenik Z, Jung A, Zuber JAdvanced thermal image processing for medical and biological applications. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2805- 2807 vol.3.

THERMAL RHYTHMOGRAPHY-TOPOGRAMS OF THE SPECTRAL ANALYSIS OF FLUCTUATIONS IN SKIN TEMPERATURE

Kondo K, Kakuta N, Chinzei T, Nasu Y, Suzuki T, Saito T, Wagatsuma A, Ishigaki H, Mabuchi K.
Fac. of Eng., Himeji Inst. of Technol, Japan

It has been reported that skin blood flow and, consequently, skin temperature exhibit several periodic fluctuations. Although the mechanisms and physiological basis underlying these fluctuations are not yet well understood, it is thought that the fluctuations originate in the periodic rhythms of the autonomic nervous system. In this study, a program for a far-infrared thermal imaging system was developed which is capable of displaying topograms of the power spectra of an arbitrary frequency range with respect to changes in skin temperature (i.e. thermal rhythm). Thermographic images were taken using a high-speed far-infrared thermal camera. The change in

the skin temperature with respect to time at every pixel was obtained from the time series of the thermograms, and the power spectrum was calculated by the FFT method using the personal computer. The amplitude of the power spectrum at an arbitrary frequency range was changed into pseudo-colors at each pixel, and a 2-dimensional or 3-dimensional color image of the amplitude mapping of the power spectrum at each frequency range was obtained. We are now analyzing differences between healthy subjects and patients with Raynaud's syndrome in the distribution of the rhythms of skin temperature using this system

Kondo K, Kakuta N, Chinzei T, Nasu Y, Suzuki T, Saito T, Wagatsuma A, Ishigaki H, Mabuchi K. Thermal rhythmography-topograms of the spectral analysis of fluctuations in skin temperature.In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2002, p. 2812- 2815 vol.3

EVALUATION OF INFRARED IMAGES BY USING A HUMAN THERMAL MODEL.

Kakuta N, Yokoyama S, Suzuki T, Saito T, Mabuchi K.
Center for Collaborative Res., Univ. of Tokyo; Japan

In order to evaluate IR images obtained under various thermal environmental conditions, we proposed a human thermal model that can be used for converting IR images into those under a standard condition. The developed model was based on a numerical calculation of bio-heat transfer equations that express heat transfer phenomena within the human body and a mathematical model of the thermoregulation system. A comparison of an IR image which was converted under the standard condition (30/spl deg/C) with the original one at 30/spl deg/C indicated that the method using our model was effective to eliminate the influence of the thermal environmental condition.

Kakuta N, Yokoyama S, Suzuki T, Saito T, Mabuchi K. Evaluation of infrared images by using a human thermal model. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2816- 2819 vol.3.

MODALITIES AND CLINICAL APPLICATIONS OF DYNAMIC INFRARED IMAGING

Anbar M.
Sch. of Medicine & Biomed. Sci., State Univ. of New York, Buffalo, NY, USA

Dynamic infrared imaging (DIRI), the most effective modality of dynamic area telethermometry (DAT), involves the acquisition of hundreds to thousands of consecutive thermal images, deriving information from the modulation of temperature and of thermal spatial distribution of small subareas. Four groups of clinical applications of dynamic infrared imaging are reviewed from the standpoint of their data processing following FFT analysis of temperature modulation and modulation of perfusion of the cutaneous capillary bed.

These include: 1. Visual assessment of spatial abnormalities in perfusion kinetics that can be used in diagnosis of joint disease and of advanced cancer, as well as visual identification of abnormalities in subcutaneous circulation.

2. Objective computerized diagnosis of systemic chronic neuronal disorders that may affect modulation amplitudes and their spatial distribution.

3. Objective computerized detection of cancer, breast and skin cancer in particular, by their effect on the spatial distribution of attenuated subareas at specific frequencies of modulation.

4. Objective assessment of transient mental stress (psychological testing) and of exposure to neurotoxic agents that may affect modulation amplitudes and their distribution over limited periods of time. Following time-dependent changes in temperature modulation at specific frequencies one can assess the severity of functional perturbation of the autonomic nervous system.

Anbar M. Modalities and clinical applications of dynamic infrared imaging. Iin: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2820- 2822 vol.3

DETERMINATION OF MEAN TEMPERATURES OF NORMAL WHOLE BREAST AND BREAST QUADRANTS BY INFRARED IMAGING AND IMAGE ANALYSIS

Head JF, Lipari CA, Elliott RL.
Mastology Res. Inst., Baton Rouge, LA;USA

In clinical testing it is standard to determine the normal ranged and then to determine if a test can differentiate normal from diseased patients. Now with the advent of uncooled staring array digital infrared imaging systems (Prism 2000; Bioyear Group, Houston, TX) and image analysis, numerical results (mean temperatures of the whole breast and quadrants of the breast) can be used to determine the normal range and cutoff temperatures for risk assessment and detection of breast cancer. In this study we determined mean temperatures of whole breast and breast quadrants of women being screened for breast cancer. The mean temperatures for the right breast, left breast, right upper outer quadrant (UOQ), left UOQ, right upper inner quadrant (UIQ), left UIQ, right lower outer quadrant (LOQ), left LOQ, right lower inner quadrant (LIQ), and left LIQ were 32.79, 32.65, 32.60, 32.46, 32.91, 32.69, 32.28, 32.12, 33.29, and 33.00/spl deg/C, respectively. Temperature differences were calculated between the right and left breasts and quadrants, and temperature differences greater than 0.5/spl deg/C for whole breasts and 1.00/spl deg/C for breast quadrants were considered asymmetric and abnormal. This resulted in 4 (17%) patients with differences in whole breast temperatures and 3 (13%) patients with quadrant differences from the 23 screened patients. These results are consistent with our previous results with both objective image analysis and subjective visual analysis (15% of screened patients have asymmetric breast infrared patterns). Further objective infrared measurements in breast cancer patients are needed to determine the sensitivity and specificity of this objective method for risk assessment and detection of breast cancer.

Head JF; Lipari CA; Elliott RL. Determination of mean temperatures of normal whole breast and breast quadrants by infrared imaging and image analysis: in: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE; 2001, 2823- 2825 vol.3.

MONITORING OF PERIORBITAL BLOOD FLOW RATE THROUGH THERMAL IMAGE ANALYSIS AND ITS APPLICATION TO POLYGRAPH TESTING

Pavlidis I, Levine J.
Honeywell Labs., Minneapolis, MN;USA

In the present paper we describe a novel method for scoring polygraph tests using thermal image analysis. Our method features three stages: image acquisition, physiological correlation, and pattern classification. First, we acquire facial thermal imagery using an accurate mid-infrared camera. Then, we transform the raw thermal data to blood flow rate data through thermodynamic modeling. Finally, we classify the subject as deceptive or non-deceptive based on the nearest-neighbor classification method. We perform our analysis on the peri-o rbital area of the subjects' faces. Our previous research has indicated that the periorbital area is the facial area affected the most from blood flow redistribution during anxious states. We present promising experimental results from 18 subjects. We henceforth anticipate that thermal image analysis will play an increasingly important role in polygraph testing. as an additional scoring channel. Our ultimate objective is to increase the accuracy and reliability of polygraph testing through the fusion of traditional invasive 1D physiological measurements with novel non-invasive 2D physiological measurements.

Pavlidis I, Levine J. Monitoring of periorbital blood flow rate through thermal image analysis and its application to polygraph testing. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2826- 2829 vol.3

5.5.2: Clinical Applications of IR Imaging I
Saturday, October-27-2001, 15:30-17:00 Rumeli, Poster

DYNAMIC ANALYSIS OF INNER METABOLIZING STATUS BASED ON THE SURFACE TEMPERATURE DISTRIBUTION OF BODY

Shang Z; Jiang G.
The Coll. of Life Sci. & Med. Eng., Tongji Univ., Shanghai; China

This paper presents a new method to analyse dynamically the metabolizing status of the inner body on the basis of the body's surface temperature distribution. The authors applied cold stimulation to the human body in a special place. They recorded the surface temperature distribution by infrared thermography in the process of temperature restoration after stimulation, and calculated the temperature time sequence data obtained from thermography. They used the system identifica tion method of system control theory to define the pulse response sequence of body temperature control system. They then judged the inner metabolism function as normal or abnormal by analyzing that pulse response sequence.

Shang Z; Jiang G.Dynamic analysis of inner metabolizing status based on the surface temperature distribution of body. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2830- 2835 vol.3

VISUALIZING SKIN TEMPERATURE BEFORE, DURING AND AFTER EXERCISE FOR DYNAMIC AREA TELETHERMOMETRY

Wang JG. Toh HL.
Sch. of Electr. & Electron. Eng., Nanyang Technol. Univ., Singapore

The dynamic behavior of human skin temperature has potential clinical diagnosis values. The method and material for acquiring and implementing thermal data plays an important role for obtaining a confirmed thermographic, diagnosis. High resolution, both temperature and spatial, is required in order to see a dramatically different behavior between the data obtained in a group of patients and the one observed in a group of normal subjects. In this paper, a specific exercise is designed; we visualize the skin temperature before, during and after the exercise. Over 2000 frames during the period were captured, and the skin temperature of the regions of interest is analyzed statistically. In order to visualize the FFT to yield the relative contributions of its underlying frequency over the series of frames, the average temperature of the region of interest is obtained in order to average out some of the spurious noise. The subareas of interest are detected automatically using region-growing technique. The results are obtained using an infrared imaging system at a frame rate 30 frames per second.

Wang JG, Toh HL. Visualizing skin temperature before, during and after exercise for dynamic area telethermometry. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2831- 2835 vol.3

CONTOUR PICK-UP AND REGISTRATION OF INFRARED IMAGES OF PALM

Liu X, Shang Z, Jiang G
Coll. of Life Sci. & Med. Eng., Tongji Univ., Shanghai, China

In this thesis an approach for contour pick-up and image registration is presented for infrared images of the palm. Contour pick-up is based on Gauss-Laplace kernel and image registration is implemented by their cross-correlation function. In order to use the temperature variation obtained from the infrared images for diagnoses of metabolic diseases, one used to have to obtain the temperatures at different times for a certain area artificially point by point. It always wastes time and the data cannot be very accurate. This thesis gives a method that avoids these disadvantages. First, the contour is picked up from the environment by using the convolution of the Gauss-Laplace kernel. Then we filled inside the edge with darkness. Counting the maximum value of their cross-correlation function realized registration of the infrared images of the palm. The results of experiments prove this method to be feasible.

Liu X, Shang Z, Jiang G . Contour pick-up and registration of infrared images of palm. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2836- 2839 vol.3.

DEVELOPMENT OF A NON-INVASIVE OPTICAL IMAGING METHOD FOR TRACKING VASCULAR GENE EXPRESSION

Chen HH, Kumar A, Yang Y, Wang D, Maouyo D, Fried NM, Yang, X.
Dept. of Biomed. Eng., Johns Hopkins Univ., Baltimore, MD;USA

Gene therapy is an exciting frontier in modern medicine. To date, no imaging modalities are available for monitoring vascular gene therapy. Green fluorescent protein (GFP) has become an increasingly common marker for gene therapy. We have developed an optical imaging method to track vascular gene expression by detecting fluorescence emitted from GFP or red fluorescent protein (RFP) in arterial walls following gene transfer. We surgically transferred GFP- and RFP-vectors into the femoral and carotid arteries of three New Zealand white rabbits. Excitation light was transmitted through a fiber-optic ring-light (Nevoscope) and GFP and RFP fluorescence was detected by a charge coupled device (CCD) camera. Direct contact images of the target arteries demonstrated that this method was capable of both discriminating between normal and transferred arterial tissues and mapping fluorescent protein localization. Subsequent measurements by confocal microscopy showed statistically significant differences in average fluorescent signal intensity between the control and transferred tissues. This result was corroborated by immunohistochemical staining. These preliminary results are encouraging evidence that the optical imaging,method can be developed further to be performed non-invasively and in vivo in a clinical setting.

Chen HH, Kumar A, Yang Y, Wang D, Maouyo D, Fried NM, Yang, X. Development of a non-invasive optical imaging method for tracking vascular gene expression. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p.2840- 2843 vol.3

INITIAL EXPERIENCE WITH A MICROWAVE IMAGING SYSTEM FOR MONITORING TEMPERATURE CHANGE IN AN ANIMAL MODEL

Meaney PM, Fanning MW, Fang Q, Paulsen KD.
Thayer Sch. of Eng., Dartmouth Coll., Hanover, NH; USA

We are developing a microwave system for non-invasively monitoring temperature distributions in human tissue during thermal therapy. Central to our approach is a microwave antenna array and switching matrix which allows tomographic data collection over a wide range of frequencies (300 Mhz-1GHz). The measured field values are processed by a reconstruction algorithm that creates electrical property maps which vary with temperature and show changes in temperature as a function of time through difference imaging. Initial phantom investigations suggested that our imaging device was sufficiently sensitive to thermally induced electrical property changes to expand the studies to animal models. The results presented here are from our initial experiments conducted with a saline-coupled microwave imaging system on a 5-day old live piglet. The heating was accomplished using a heated tube of water surgically implanted in the piglet's abdomen. Fiber optic temperature sensors were inserted at various positions for comparison with recovered conductivity values and the entire experiment was performed in a CT scanner to facilitate localization of the probes with respect to the heating tube, piglet geometry and microwave antenna array.

Meaney PM, Fanning MW, Fang Q, Paulsen KD. Initial experience with a microwave imaging system for monitoring temperature change in an animal model. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 12844-2847 vol.3.

THE DESIGN OF MAMMARY GLAND TUMOR PHANTOM FOR MICROWAVE RADIOMETERS

Lee JW, Lee SM, Eom S.J, Kim KS.

M&I.bar;Application Project Team, Samsung Adv. Inst. of Technol., Yong-In, Korea

Microwave radiometry is the spectral measurement technique of resolving the electromagnetic radiation of all matter whose temperature is above absolute zero. This technique utilized the electromagnetic noise field generated by a thermal volume similar to a mechanism existing in biological tissues. One particular application of microwave radiometry is for analyzing the temperature differentials inside the human body to detect and diagnose some crucial pathologic conditions. For general evaluation of radiometers, we propose a new mammary gland tumor phantom simulating the heat diffusion propagated by tissues around tumors. Theoretical researches of human tumors have revealed the fact that the temperature distribution of tissues around a tumor forms gaussian statistics. To comply with this physiological property, we built a tumor imitator composed of two parts, pseudo-tumor and thermo-anomaly, and observed the temperature distribution of the tumor imitator inside a phantom. Our experimental results showed that the thermal properties of the tumor imitator well agreed with heat transfer properties of a real tumor.

Lee JW, Lee SM, Eom S.J, Kim KS. The design of mammary gland tumor phantom for microwave radiometers.In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2848- 2851, vol.3.

ASSISTANCE TO SURGERY BY MEANS OF INFRARED FUNCTIONAL IMAGING: PRELIMINARY RESULTS

Merla A, Di Donato L, Romani GL.

Dipt. di Sci. Cliniche e Bioimmagini, Universita di Chieti, Chieti Scalo, Italy

Infrared functional imaging (IRFI) was used in microsurgery and cardio-surgery operation to assess correct blood re-perfusion after de-clamping of anastomoses. Arm reimplantation, local sympathectomy and coronary bypass were considered. Moreover, IRFI was used to follow up the restoration of the neurovascular functions thanks to the study of the changes in the thermoregulatory capabilities of the treated district. The study has proved that IRFI can be advantageously used in these fields thanks to its features - non-invasiveness, high temperature, spatial and time resolution and real time availability of data.

Merla A, Di Donato L, Romani GL. Assistance to surgery by means of infrared functional imaging: preliminary results. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2852- 2855 vol.3

STUDY OF RAYNAUD'S PHENOMENON BY MEANS OF INFRARED FUNCTIONAL IMAGING

Merla A, Di Donato L, Farina G, Pisarri S, Proietti M, Salsano F, Romani GL.

Dipt. di Sci. Cliniche e Bioimmagini, Universita di Chieti, Chieti Scalo;Italy

Infrared functional imaging was applied to the study of Raynaud's Phenomenon obtaining a simultaneous assessment of the thermal properties of all five fingers of both hands of a group of patients with respect of a control group. The method is based on the use of high-resolution telethermography imaging and allows identification of objective parameters from the re-warming curves of finger immediately after a 2 min cold stress. The evaluation of the area under the temperature versus time curve, namely the temperature integral INT, provides a figure particularly effective in describing the thermal properties of the finger. 18 healthy volunteers, 20 Secondary Scleroderma and 20 Primary Raynaud's Phenomenon patients were studied subsequently to clinical evaluation and nailfold capillaroscopy. This new approach highlighted a quite different behaviour between patients with Primary Raynaud's Phenomenon and those with early diagnosed Systemic Sclerosis This new method, compared with other existing techniques, seems to be useful tool to discriminate between PRP and RP secondary to SSc.

Merla A, Di Donato L, Farina G, Pisarri S, Proietti M, Salsano F, Romani GL. Study of Raynaud's phenomenon by means of infrared functional imaging. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2856- 2859 vol.3

FURTHER DISCUSSION FOR THE TEMPERATURE RECOVERY RATE METHOD IN INFRARED THERMOGRAPHY DIAGNOSIS.

Xu G, Shang Z, Jiang G.

Coll. of Life Sci. & Med. Eng., Tongji Univ., Shanghai, China

This paper deduces the characteristic equation of the body surface temperature change according to the classic bio-heat transfer equation, and attains the theoretic equation for calculating temperature recovery rate. By comparing the temperature recovery rate method generally used in infrared thermography diagnosis with this method, we analyses the shortage of the former in actual diagnosis, and propose a new concept of temperature recovery trend coefficient. At the last of this paper, the analyses result for some diabetes cases with temperature recovery rate method and temperature recovery trend coefficient is given.

Xu G, Shang Z, Jiang G. Further Discussion For The Temperature Recovery Rate Method In Infrared Thermography Diagnosis. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2860 vol.3.

5.5.2: Clinical Applications of IR Imaging II

Saturday, October-27-2001, 17:00-19.00, Marmara, oral

RELIMINARY EVALUATION OF PREOPERATIVE CHEMOHORMONOTHERAPY-INDUCED REDUCTION OF THE FUNCTIONAL INFRARED IMAGING SCORE IN PATIENTS WITH LOCALLY ADVANCED BREAST CANCER

Keyserlingk JR, Yassa M, Ahlgren P, Belliveau N.

Ville Marie Oncology Center, St. Mary's Hosp., Montreal, Quebec.Canada

20 successive patients who received preoperative chemohormonotherapy (PCT) for locally advanced breast cancer underwent high resolution digital infrared imaging (IR) both before and after PTC and prior to surgery. The images were graded using a new scale. Initial pre-PCT IR imaging revealed obvious and often dramatic angiogenesis-related findings in all our patients. Following PCT, there was a significant decrease in both the IR score and in the clinical size of those with measurable disease. Four of the six patients with complete pathological response also saw their IR revert to normal. In nine patients, the elevated pre-PCT IR score lingered longer than the clinical findings. IR provides a very safe and convenient alternative functional imaging modality to monitor PCT. Further study and follow-up is required to assess whether the IR changes that reflect the effect of PCT on tumor vascularity also provide an additional valuable prognostic indicator for this subset of patients with aggressive tumors.

Keyserlingk JR, Yassa M, Ahlgren P, Belliveau N. Preliminary evaluation of preoperative chemohormonotherapy-induced reduction of the functional infrared imaging score in patients with locally advanced breast cancer. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2861- 2863 vol.3

ASYMMETRY ANALYSIS USING AUTOMATIC SEGMENTATION AND CLASSIFICATION FOR BREAST CANCER DETECTION IN THERMOGRAMS

Qi H, Head JF.

Dept. of Electr. & Comput. Eng., Tennessee Univ., Knoxville, TN;

Thermal infrared imaging has shown effective results as a diagnostic tool in breast cancer detection. It can be used as a complementary to traditional mammography. Asymmetry ana-

lysis are usually used to help detect abnormalities. However, in infrared imaging, this cannot be done without human interference. This paper proposes an automatic approach to asymmetry analysis in thermograms. It includes automatic segmentation and pattern classification. Hough transform is used to extract the four feature curves that can uniquely segment the left and right breasts. The feature curves include the left and the right body boundary curves, and the two parabolic curves indicating the lower boundaries of the breasts. Upon segmentation, unsupervised learning technique is applied to classify each segmented pixel into certain number of clusters. Asymmetric abnormalities can then be identified based on pixel distribution within the same cluster. Both segmentation and classification results are shown on images captured from Elliott Mastology Center.

Qi H, Head JF. Asymmetry analysis using automatic segmentation and classification for breast cancer detection in thermograms. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, 2866- 2869 vol.3

THERMAL IMAGING OF SKIN CHANGES ON THE FEET OF TYPE II DIABETICS

Ammer, K. Melnizky, P. Rathkolb, O. Ring, E.F.
Thermal Physiol. Lab, Univ. of Glamorgan, Pontypridd;

Skin changes such as callosities and mycosis may be regarded as a risk factor for severe structural impairments including ulcers and osteomyelitis in patients suffering from diabetes. Increased temperature of the feet of diabetics is another frequent finding. We investigated the relationship between skin changes and areas of increased skin temperature recorded with an Infrared Scanner AGEMA 870. 76 patients who had type 2 diabetes longer than 5 years, were studied. A physical examination of their feet and nerve conduction tests were performed. Thermal images were taken from both legs in the anterior view, the foot from an anterior view and the soles. 230 sites of high temperature (hot spots) were detected on the thermal images of 75 soles. Toe deformities or deformity of the anterior foot arch, skin callosities, onychomycosis were not related to hot spots on the sole. We confirm that about half of type II diabetes patients present with increased temperatures of their feet. However, no relationship with skin changes and areas of elevated skin temperature could be established. Thermal imaging does not identify the common skin changes found in the feet of diabetics.

Ammer K, Melnizky P, Rathkolb O, Ring EF. Thermal imaging of skin changes on the feet of type II diabetics.In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2870- 2872 vol.3

INFRARED THERMOGRAPHY AND DIABETIC FOOT

Shikano M, Murakami K, Tomita M, Hasegawa M, Hasegawa H, Sugiyama S, Sobajima H.
Dept. of Nephrology, Fujita Health Univ., Toyoake; Japan

The purpose of this study was to identify and quantify the neurovascular risk factors for diabetic foot using infrared thermography, compared with other unusual neurological examinations. The subjects were 504 Japanese patients with type II diabetes and 150 normal subjects. Among the diabetic patients 28 had a history of diabetic foot. We preformed the cold stress test using ice-cold water. We observed the time course of the hand temperature and calculated the recovery rate. The hand temperature at rest and recovery rate was significantly lower in the diabetic patients compared with the normal. The patients with diabetic foot had significantly lower temperature and lower recovery rate compared with the patients without diabetic foot. These differences (especially the recovery rate) were the most specific findings in patients with diabetic foot compared with other neurological examinations. The cold stress test using computer-assisted thermography provides much information about the microcirculation of the skin in patients with diabetic foot. It will be helpful to detect high-risk patients.

Shikano M, Murakami K, Tomita M, Hasegawa M, Hasegawa H, Sugiyama S, Sobajima H. Infrared thermography and diabetic foot. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2873 vol.3.

THERMOGRAPHIC AND ELECTRICAL MEASUREMENTS FOR CARDIAC SURGERY INSPECTION

Nowakowski A, Kaczmarek M, Wtorek J, Siebert J, Jagielak D, Roszak K, Topolewicz J, Stojek, W
Dept. of Med. & Ecological Electron., Tech. Univ. Gdansk

The aim of this paper is to analyze the validity of new methods applicable for cardiac surgery intraoperation inspection. In vivo measurements on pigs using passive and active thermography as well as electroimpedance spectroscopy applied to investigation of the heart tissue properties during open chest cardiac surgery are related. The measurement results clearly show that each of proposed modalities is giving different information valuable for evaluation of the heart muscle biological properties. This information may have very high importance in terms of intra-operation inspection as well as for decisions of proper medical interventions. A series of cardiac operations on anaesthetized pigs involving a controlled heart infarct followed by extensive histopathologic study allowed the authors to make an objective evaluation of the value of the discussed methods.

Nowakowski A, Kaczmarek M, Wtorek J, Siebert J, Jagielak D, Roszak K, Topolewicz J, Stojek, W. Thermographic and electrical measurements for cardiac surgery inspection. In Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2874- 2877 vol.3.

DIAGNOSIS OF SUB-CLINICAL VARICOCELE BY MEANS OF INFRARED FUNCTIONAL IMAGING

Merla A,Ledda A, Di Donato L, Romani GL
Dept. of Clinical Sci. & Bioimaging, Univ. of Chieti, Chieti Scalo, Italy

Infrared functional imaging (IRFI) was used to detect subclinical varicocele. The evaluation of varicocele related hyperthermia and the different thermal properties of healthy and unhealthy testicles were used to detect the presence of the disease. A mild cold thermal stress performed on the scrotal region highlighted differences in the thermal recovery between the contralateral testicles and pampiniform plexuses. Mismatches in the equilibrium temperatures and in the recovery curves were used as objective parameters to infer the presence of varicocele, in a subclinical stages. 60 subjects, without any previous varicocele related symptoms, underwent the IRFI. 22 subjects out of the 60 showed abnormal values of the chosen parameters; clinical and echo-color-Doppler examination confirmed the presence of a subclinical first or second degree varicocele.

Merla A, Ledda A, Di Donato L, Romani GL. Diagnosis of sub-clinical varicocele by means of infrared functional imaging. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2878- 2881 vol.3

INVESTIGATION OF SKIN BURNS BASING ON ACTIVE THERMOGRAPHY

Kaczmarek M, Nowakowski A, Renkielska A, Grudzinski J, Stojek W.
Dept. of Med. & Ecological Electron., Tech. Univ. Gdansk

Use of dynamic thermography for assessment of burns is discussed. Animal in-vivo experiments are presented. Sets of burns were inflicted on the backs of eight domestic pigs. Thermographic measurements of burns with different depths of affected tissue (from first to third-degree burns) were correlated with histopathologic analysis of lesions. The results show that dynamic thermography might be applied as a simple, noninvasive and nonstressful tool for patient diagnosis. Further analysis of dynamic pictures gives the first estimate of the depth of a lesion.

Kaczmarek M,Nowakowski A, Renkielska A, Grudzinski J, Stojek W. Investigation of skin burns basing on active thermography. In: Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2001, p. 2882- 2885 vol.3.

Bioengineering-Integrative Methodologies, New Technologies Second Joint EMBS-BMES Conferenece 2002 24th Annual International Conference of the Engineering in Medicine and Biology Society Annual Fall Meeting of the Biomedical Engineering Society, 23-26 October 2002, Houston, Texas, USA

Session 5.3.1. Mini-symposium: Infrared Imaging
Friday October 25-2002, 8:00-10:00, Galleria II, oral

ADVANCES IN INFRARED SENSOR TECHNOLOGY AND SYSTEMS

Balcerak RS, Lupo, J.
Electro-Opt. Center, Penn State Appl. Res. Lab., Kittanning, PA, USA;

The imaging technology available for medical research and diagnosis has progressed from early systems using single detector scanners to full two-dimensional arrays. The initial emphasis on visible and low light level arrays has expanded dramatically to include the long wave infrared with spectral cut-off as long as twenty-five microns, the short-wave infrared and multispectral arrays. Image enhancement features, originally controlled manually at each channel, are now integral to the sensor. Advanced signal processing, both at the output of the array and at the pixel level, enhances image contrast, automatically recognizes features and controls gain globally and in local areas. Advances in detector and packaging technology have significantly reduced sensor size and weight, opening new applications for imaging technology previously restricted to large platforms. In addition, the innovations in detector and electronics technology have had a large impact on cost reduction, making high performance imaging systems available to a wide variety of users. These significant advances in imaging technology can lead the way to a new era in affordable medical imaging systems, widely available in both the laboratory and physician's office.

Balcerak RS, Lupo, J.Advances in infrared sensor technology and systems. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society EMBS/ BMES Conference, 2002. Proceedings of the Second Joint, 2002; p. 1124-1125 vol.2

OVERVIEW OF FUNCTIONAL INFRARED IMAGING AS PART OF A MULTI-IMAGING STRATEGY FOR BREAST CANCER DETECTION AND THERAPEUTIC MONITORING

Keyserlingk JR, Ahlgren P, Yassa M, Belliveau N.
Ville Marie Oncology Center, St Mary's Hosp., Montreal, Que., Canada

To assess infrared imaging as a first line detection strategy, we retrospectively reviewed the relative ability of our preoperative clinical exam, mammography, and infrared imaging to detect 100 new cases of ductal carcinoma in situ, Stage I and II breast cancer. While the false-negative rate of infrared imaging was 17%, at least one abnormal infrared sign was detected in the remaining 83 cases, including 10 of the 15 patients, a slightly younger cohort, who had nonspecific mammograms. The 85% sensitivity rate of mammography alone thus increased to 95% when combining both imaging modalities. Access to infrared information was also pertinent when confronted with the relatively frequent contributory but equivocal clinical exam (34%) and mammography (19%). The average size of those tumors undetected by mammography or infrared imaging was 1.66 cm and 1.28 cm, respectively, while the false-positive rate of infrared imaging in a concurrent series of 100 successive benign open breast biopsies was 19%. Our initial experience would suggest that, when done concomitantly with clinical exam and mammography, high-resolution digital infrared imaging can provide additional safe, practical, first-line and objective information. To assess infrared imaging as a therapeutic monitoring tool, 20 successive patients who received preoperative chemohormonotherapy (PCT) for locally advanced breast cancer underwent high resolution digital infrared imaging (IR) both before and after PTC and prior to surgery. The images were graded using a new scale. Initial pre-PCT IR imaging revealed obvious and often dramatic angiogenesis-related findings in all our patients. Following PCT, there was a significant decrease in both the IR score and in the clinical size of those with measurable disease. Four of the six patients with complete pathological response also saw their IR revert to normal. In nine patients, the elevated pre-PCT IR score lingered longer than the clinical findings. IR provides a very safe and convenient alternative functional imaging modality to monitor PCT. Further study and follow-up is required to assess whether the IR changes that reflect the effect of PCT on tumor vascularity also provide an additional valuable prognostic indicator for this subset of patients with aggressive tumors.

Keyserlingk JR, Ahlgren P, Yassa M, Belliveau N. Overview of functional infrared imaging as part of a multi-imaging strategy for breast cancer detection and therapeutic monitoring. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, 1126- 1128 vol.2.

BREAST CANCER IDENTIFICATION THROUGH SHAPE ANALYSIS IN THERMAL TEXTURE MAPS

Qi H, Liu Z, Wang C.
Dept. of Electr. & Comput. Eng., Tennessee Univ., Knoxville, TN, USA;

Proposes an automated approach to the study of metabolic activities within a human body using thermal infrared (TIR) imaging. It uses early detection of breast cancer as an example to show the effectiveness of the approach. Different shape analysis parameters are employed in the development. Some preliminary results show the effectiveness of using shape analysis to automate the detection of half power point and thus the depth of the heat source.

Qi H, Liu Z, Wang C. Breast cancer identification through shape analysis in thermal texture maps. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1129- 1130 vol.2

SYNTHETIC PICTURES IN THERMOGRAPHIC DIAGNOSTICS

Nowakowski A, Kaczmarek M, Ruminski J.
Dept. of Med. & Ecological Electron., Tech. Univ. Gdansk, Poland;

Main advances in terms of the quality of thermal imaging are recently due to digitalization of the data and enhancing of specific features possible in this case. Here we summarize the state of the art of data treatment methods in thermography and development of so called synthetic pictures. The practical significance of using such presentations is shown in phantom experiments and for evaluation of skin injuries but other applica-

ti ons are also studied. This approach may be regarded as the first attempt to open new frontiers of thermal tomography in medical imaging. Knowledge of correlation between synthetic parameters and physiological data is here of the highest importance.

Nowakowski A, Kaczmarek M, Ruminski J. Synthetic pictures in thermographic diagnostics. Iin: [Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1131- 1132 vol.2.

THERMAL WAVE METHOD - LIMITS AND POTENTIALITIES OF ACTIVE THERMOGRAPHY IN BIOLOGY AND MEDICINE

Wiecek B, Zwolenik S

Inst. of Electron., Tech. Univ. Lodz, Poland;

In biology and medicine active thermography methods can be used for measuring skin thickness, inflammation regions, density of tissues, blood flow, etc. We present the basis and preliminary application of lock-in and pulse thermography for non destructive testing (NDT). 3D modelling is presented to confirm usefulness of simple analytical solutions, and to set up the experiments. As an example, the thickness of thin film coatings is briefly described.

Wiecek B, Zwolenik S. Thermal wave method - limits and potentialities of active thermography in biology and medicine. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1133- 1134 vol.2.

Session 5.3.2. Infrared Imaging

Friday October 25-2002, 13:30-15:30, Galleria II, oral

ADVANCES IN INFRARED TECHNOLOGY - QUANTUM WELL VERSUS THERMAL DETECTORS

Wiecek, B.

Inst. of Electron., Tech. Univ. Lodz, Poland;

The comparison of uncooled thermal and deeply cooled QWIP (quantum well infrared photodetector) detectors are briefly presented. Different types of QWIP detectors have been mentioned. The limits of detectivity both for thermal and photon detectors are discussed.

Wiecek B. Advances in infrared technology - quantum well versus thermal detectors. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1135- 1136 vol.2

HEATING OR COOLING TO INCREASE CONTRAST IN THERMOGRAPHIC DIAGNOSTICS

Nowakowski A, Kaczmarek M, Renkielska A, Grudzinski J, Stojek J

Dept. of Med. & Ecological Electron., Tech. Univ. Gdansk, Poland

The aim of this paper is to discuss the possibility of enhancement of contrast in thermographic investigations directed towards medical diagnostics. Results of in vivo experiments on pigs are shown for evaluation of skin injuries inflicted by burns introduced in a controlled way. Use of cooling procedures by ice or a cooling fan as well as heating using optical irradiation is discussed. The heating procedureseems to be more comfortable in practical use while cooling gives better contrast, due to a bigger acceptable temperature span.

Nowakowski A, Kaczmarek M, Renkielska A, Grudzinski J, Stojek J. Heating or cooling to increase contrast in thermographic diagnostics. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1137- 1138 vol.2.

NON-INVASIVE MULTI-MODALITY TECHNIQUE TO STUDY ANGIOGENESIS ASSOCIATED WITH KAPOSI'S SARCOMA

Hassan M, Hattery D, Chernomordik V, Aleman K, Wyvill K, Merced F, Little R, Yarchoan R, Gandjbakhche AH.

Nat. Inst. of Child Health & Human Dev., Nat. Inst. of Health, Bethesda, USA

In this on going study, we are investigating the usefulness of thermography and laser Doppler imaging techniques to study vascularity and vascular changes associated with Kaposi's sarcoma. Both techniques are useful for observing the lesions associated with Kaposi's sarcoma. A comparative image analysis of thermography, between the lesion and the contra- lateral, lesion free sites, shows that lesions are a different temperature than the contralateral side. Similar relationships are also observed in laser Doppler images. The present data supports further study of these imaging modalities to assess Kaposi's sarcoma.

Hassan M, Hattery D, Chernomordik V, Aleman K, Wyvill K, Merced F, Little R, Yarchoan R, Gandjbakhche AH. Non-invasive multi-modality technique to study angiogenesis associated with Kaposi's sarcoma. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1139- 1140 vol.2.

INFRARED FUNCTIONAL IMAGING: ANALYSIS OF SKIN TEMPERATURE DURING EXERCISE

Merla A, Di Donato L, Romani GL.

Dept. Clinical Sci. & Bioimaging, "G.d'Annunzio" Univ., Chieti, Italy;

Thigh skin temperature was studied during bicycle ergometry graded exercise by means of infrared functional imaging (IRFI). Executing graded exercise determined the decreasing skin temperature throughout the exercise period, while it increased during the after-exercise recovery. Skin cooling and warming processes depended on the fitness level of the subjects, as estimated by the maximal oxygen consumption. IRFI permitted skin temperature time evolution of different regions involved in the exercise to be recorded. IRFI may provide indirect complementary information about the hemodynamic recruitment by the muscular masses and the thermal processes associated with the exercise.

Merla A, Di Donato L, Romani GL. Infrared functional imaging: analysis of skin temperature during exercise. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1141- 1142 vol.2

THERMAL FACIAL SCREENING FOR DECEPTION DETECTION

Pavlidis I, Levine J.

Honeywell Labs., Minneapolis, MN, USA;

Our group has been conducting advanced research in deception detection (DD) for the last three years. The conclusion from our effort is that facial thermal screening is a very promising method for DD. It can be used as an additional information channel to enhance traditional polygraph examination for investigative purposes. Because of the unique advantages of the method (non-invasive, real-time, and highly automated), it can also be used for mass screening in airport, border, and other critical checkpoints. Checkpoint agents are already asking travelers certain questions. A familiar example is the question: "Did you pack your own bags?" The difference under our proposal is that these questions will become much more meaningful and both an agent and a machine will evaluate the travelers' responses. The machine's recommendation will serve as an additional data point to the traveler's on-line record. Its weight will be commensurate with how well the machine proves itself in actual practice.

Pavlidis I, Levine J.Thermal facial screening for deception detection. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1143- 1144 vol.2

INFRARED SPECTROSCOPIC IMAGING. LOOKING FOR DIAGNOSTIC CHEMICAL MARKERS

Marcott C, Story GM, LowerEE, Yassin RS, Johnson BL, Dukor RK.

Miami Valley Labs., The Procter & Gamble Co., Cincinnati, OH, USA

Infrared (IR) spectroscopic imaging is growing in popularity as a technique for distinguishing tissue types and diagnosing disease states, including breast cancer. The combination of an IR focal-plane array detector and a Fourier transform infrared (FT-IR) microscope provides the researcher with chemical information in each pixel of the image detected. IR spectroscopic images are collected in reflectance from tissue biopsies mounted on inexpensive IR-reflective glass microscope slides that are still transparent in visible light. These slides allow us to perform FT-IR microspectroscopic imaging studies on samples that can be evaluated by conventional pathology. A chemical marker in stroma near epithelial cells has been discovered based on its IR spectroscopic signature. This marker may be useful for classifying a tissue as cancerous or non-cancerous.

Marcott C, Story GM, LowerEE, Yassin RS, Johnson BL, Dukor RK. Infrared spectroscopic imaging. Looking for diagnostic chemical markers. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1145- 1146 vol.2.

DIGITAL INFRARED THERMAL IMAGING AS BIOFEEDBACK TOOL: MONITORING CHEMOTHERAPY RESPONSE IN A YOUNG FEMALE WITH BREAST CANCER MEDIASTINAL SECONDARIES

Boyd AS, Maloney SK.

Australian Res. Council of Med. Eng., Univ. of Western Australia, Perth. , Australia

Data obtained from infra-red thermography (IRT) of a 36 year old female with proven breast cancer secondaries in her mediastinum shows how infrared imaging could be used as a feedback tool to monitor both growth of a tumor as well as its response to treatment. IRT scans have been obtained seven months prior to confirmatory CT scans and weekly during chemotherapy treatment. From the outset the thermal pattern overlying the tumour has remained identifiable, and significantly different from the pattern observed in asymptomatic control subjects.

Boyd AS, Maloney SK.Digital infrared thermal imaging as biofeedback tool: monitoring chemotherapy response in a young female with breast cancer mediastinal secondaries. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1147- 1148 vol.2

Session 5.3.2. Infrared Imaging

Friday October 25-2002, 10:30-12:30, Woodway II, Poster

TOTAL BODY INFRARED IMAGING AND POSTURAL DISORDERS

Merla A, Romano V, Zulli F, Saggini R, Di Donato L, Romani GL

Dept. of Clinical Sci. & Bioimaging, "G. d'Annunzio" Univ., Chieti, Italy

Agonist-antagonist and contralateral musculatures of lower extremities, abdomen, pelvis, trunk, and back, co-work to maintain unaware antalgic orthostatic positions caused by postural disorders. Such positions involve a different activity of the several muscular groups. This results in their different working loads and metabolic rates, which may produce specific skin temperature patterns. In this study, comparison of total body infrared imaging and clinical-orthopedic findings was attempted on 150 subjects, to individualise antalgic orthostatic positions due to postural disorders and their effects on the skin temperature distributions. Total body infrared imaging detected specific disorder-related thermal patterns and provided functional information on the adaptation of the agonist-antagonist and contralateral musculature to the specific disorder.

Merla A, Romano V, Zulli F, Saggini R, Di Donato L, Romani GL. Total body infrared imaging and postural disorders.In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1149- 1150 vol.2

ASYMMETRY ANALYSIS IN BREAST CANCER DETECTION USING THERMAL INFRARED IMAGES

Kuruganti, PT. Qi H.

Dept. of Electr. & Comput. Eng., Tennessee Univ., Knoxville, TN, USA

Automated diagnostic tools always provide the doctors with the very valuable second opinion during disease diagnosis. This paper discusses an automated approach for breast cancer detection using thermal infrared (TIR) images. Breast cancer is a disease in which only early diagnosis increases the survival hope. The cancer cells with their higher metabolic rate are hotter than the normal cells and this property makes the cancerous tumors appear as hotspots in the TIR images. The existence of asymmetry in the temperature distribution indicates the existence of a tumor. In this paper, we initially segment the breast part of the TIR image using the Hough transform of a parabola. Upon segmentation, different features are extracted from the breast segments. Comparison of these features is done to detect any asymmetry and thus classify the image as cancerous or non-cancerous. The segmentation and feature extraction are performed on images obtained from Bioyear Inc.

Kuruganti PT, Qi H. Asymmetry analysis in breast cancer detection using thermal infrared images.In: [Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002,
1155- 1156 vol.2

DIGITAL PROCESSING TECHNIQUES FOR THE ASSESSMENT OF PAIN WITH INFRARED THERMAL IMAGING

Dept. of Syst. & Comput. Eng., Carleton Univ., Ottawa, Ont., Canada

Herry CL, .Frize M.

The assessment of pain is a difficult topic that may be facilitated by the quantification of some of the phenomena usually involved in the sensation of pain, such as thermal abnormalities. Digital thermal imaging is a technique that records the skin temperature distribution of the body and thus can provide some insight in thermal dysfunction associated with pain. In this paper, we propose several digital processing steps to analyze thermal images of pain patients and summarize the results with a computer-aided decision-support system. Results from our analysis are expected to be validated by a statistical comparison with actual medical outcomes for the pain patients considered in the study.

Herry CL, .Frize M. Digital processing techniques for the assessment of pain with infrared thermal imaging. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p.1157- 1158 vol.2

PROCESSING OF THERMAL IMAGES TO DETECT BREAST CANCER: COMPARISON WITH PREVIOUS WORK

Frize M, Herry C, Roberge R

Dept. of Syst. & Comput. Eng., Carleton Univ., Ottawa, Ont., Canada

In the early 1980s, thermography began to be used to detect pain and breast cancer. However, the images were interpreted through the naked eye, and thus subtle differences were difficult to identify. More recently, widespread use of PCs led to the application of computer processing to the analysis of thermal images. For example, Head et al. (1997) reported three meth-

ods to calculate temperature differences between the right and left breast to help detect and diagnose breast cancer. Their analysis of 13 patients had better results with their 3/sup rd/ method than with their methods 1 and 2, but still showed 3 false positives out of 10 patients who were diagnosed as "normal" and 1 false negative out of 3 patients diagnosed with cancer. We applied these authors' three techniques to nine of our patients (6 with a diagnosis of normal and 3 with cancer) and found that only method 3 provided reliable results. With the lower threshold of 1/spl deg/C suggested by Head et al., we had 2 false positives. However, when we raised the threshold to of normalcy to 1.5/spl deg/C (instead of 1), we found no false negatives or false positives on this sample of nine patients. Future work should focus on improving the third approach and find new ways of enhancing differences, which would be significant for a correct diagnosis. These preliminary results are encouraging but a properly designed prospective clinical trial needs to be done to show if this technique can play a useful role in the future or not.

Frize M, Herry C, Roberge R. Processing of thermal images to detect breast cancer: comparison with previous work.In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1159- 1160 vol.2

RADIOMETRIC INFRARED MICROBOLOMETER ARRAYS FOR SURGICAL ABLATION

Gibson PL, Havey GD, Seifert GJ, Hoey MF, Kalpin SL

Adv. Med. Electron. Corp., Fridley, MN, USA;

Experiments comparing radiometric infrared tissue surface temperature measurement techniques during surgical ablation procedures to contact-probe measurements demonstrated substantial correlation between the measurement modalities. Thermal monitoring during surgical ablation guides therapy and prevents tissue damage in adjacent structures. RF ablation procedures on a canine kidney were monitored concurrently with a radiometric microbolometer array and fiber-optic thermal probe. Comparative analyses at select monitoring points established a substantial correlation between the recorded temperature values.

Gibson PL, Havey GD, Seifert GJ, Hoey MF, Kalpin SL. Radiometric infrared microbolometer arrays for surgical ablation. In: Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1151- 1152 vol.2

THE AUTOMATIC APPLICATION OF DIAGNOSIS OF DIABETES BASED ON THERMOGRAPHY

Liu XW, Jiang GT

Coll. of Life Sci. & Med. Eng., Tongji Univ., Shanghai, China

A new method for diagnosis of diabetes using thermographs is introduced, then its automatic application by means of digital image processing is discussed. Here a Laplacian-Gaussian kernel is used to extract the contour and thinning is used to obtain the corresponding temperature distribution of the hand-s hape images. After this the temperature data is applied to the diagnosis model and the patients in the experiments are classified.

Liu XW, Jiang GT. The automatic application of diagnosis of diabetes based on thermography. In:Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, p. 1153- 1154 vol.2

News in Thermology

7th Congress of the Polish Society of Thermology

The Polish Society of Thermology made the first announcement for ther 7th Congress.

The congress takes place in Zakopane, the venue of the congress is the Pension "HYRNY", Pilsudskiego Str.20, 34-500 Zakopane.

Deadline for abstracts ist 15.12.2003. Abstracts should be submitted in English on a floppy disk or by email to the adress: ajung@wim.mil.pl

Deadline for registration is 15.03.2004. Registration fee is 100€ and will be paid on site. The fee includes:

Accomodation in the HYRNY pension (double room) from 3.04.2004 (dinner) to 5.04.2003 (breakfast), meals, participation in all scientific sessions, congress materials and participation in the social progranmme. Participation in the congress will be confirmed by certificate.

For registration, please fill in the registration form, and send it for confirmation to the Organizing Committee at

Klinika Pediatrii i Nefrologiii Dzieciecej
Wojskowego Instytutu Medycnego
00-909 Warszawa, ul.Szaserow 128
Phone: +48 22 6817-236 Fax: +48 22 6816-763
emai: ajung@wim.mil.pl

31st Annual Meeting of the American Academy of Thermology

Greetings Fellow Thermologist;
We (your local hosts: Ram C. Purohit and David D. Pascoe) would like to personally invite you to participate in the 31st Annual Meeting of the American Academy of Thermology and the Conference on International Standards for Thermology in Human and Animal Research and Medicine. With 28 years of thermography experience in human and veterinary medicine we are very proud to be your host for this very important conference.

The meeting will be held on the Auburn University College of Veterinary Medicine campus in Auburn, Alabama from April 15-18, 2004. We have developed and planned sessions (scientific papers, tutorials, standards symposium, and special interest group discussions) that will be informative and enhance the participant's understanding of the scientific basis and use of infrared thermography. Our objective for this meeting is to encourage scientific dialogue between conference participants that represent thermologists from all countries and disciplines.

In conjunction with the Academy meeting, we have developed conference symposiums which seek to develop a better understanding and review of thermal imaging standards for human and veterinary medicine. We strong ly believe these sessions will lead us towards common guide- lines for the use of infrared thermography in medical practice and scientific research.

Please make plans now to attend this meeting. We will be finalizing the meeting schedule after the December 1, 2003 deadline for abstract submission. For those who have submitted abstracts and/or registered, we will use your email address to provide you with a program updates and the final conference schedule. Again, we are looking forward to this meeting and your participation. See you at Auburn in April!!

6th International Congress of Thermology (ICT)

Dear Colleagues, on behalf of the organizing committee of the and the 13th Annual Meeting of the Korean Academy of Medieal Thermology (KAMT) which will be held in Seoul on June 5-6, 2004. lt is a great honor and pleasure tu host the 6th ICT. We will do our very best as to host you cordially throughout the meeting with every means of convenience.

In the congress, we can get more understanding about a modern knowledge made since the last ICT and more information about new technologies with vigorous, stimulating and fruitful discussion.To every attendees, may I once again extend warm greetings, and hope that this Symposium nourish you with the latest information to meet the demands of your profession and also provide many unforgettable pleasant memories of Korea to bring home with you.Finally, 1 would like to extend my sincere appreciation to each and every one who has given their assistance and support in many ways in preparing this 6th ICT and 13th KAMT.

Professor Young Soo Kim MD., Ph.D.
President of ICT and KAMT

Main topics of this conference are thermal physiology and thermal regulation, thermal imaging and related technique, clinical application of thermology in neuro-musculo-skeletal disease, pain medicine. CNS, complex pain syndrome, peripheral vascular disease, deep vein thrombosis, pediatric disease, rheumatology, oriental medicine, dermatology, oncology, sports medicine and, of course, infrared technology.

Deadline for abstract submission is : March 15, 2004,

Abstracts can be submitted by E-mail to the Congress secretariat. Secretary General Yong-Eun Cho, M.D., Ph.D.,

Department of Neurosurgery, Yongdong Severance Hospital, Yonsei University College of Medicine, Seoul, Korea, Tel : +82-2-3497-3390, Fax +82-2-3461-9229, E-mail:ydnscho@yumc.yonsei.ac.k

The preferred form for submissions is by electronic means with E-mail to ydnscho@yumc.yonsei.ac.kr. If electronic submission is not possible, two hard copies of the paper should be sent to:Yong-Eun Cho, MD., Ph.D, Department of Neuro surgery, Yongdong Severance Hospital, Yonsei University College of Medicine, 146-92 Dogok-dong, Gangnam- gu, Seoul 135-720, Korea, Tel : +82-2-3497-3390, Fax : +82-2-3461-9229

Deadline for registration is May 8, 2004. The conference language is English.

The venue of the congress is the New Millennium Hall at Konkuk University, #l Hwayang-dong Gwangjin-gu, Seoul 143-701, Korea Tel +82-2-455-1896-7, Fax +82-2-455-4084 http://www.konkuk.ac.kr

UK Symposium on Medical Thermal Imaging II

Paul Campell

St Andrews University and Ninewells Hospital, Dundee

Overview

Following on from the previous year's inaugural event at the Royal Free Hospital, London, the Second UK Symposium on Medical Thermal Imaging was held on September 18th 2003, at the University of Bath, England. The meeting was again organised by Paul Campbell (St Andrews University and Ninewells Hospital, Dundee) and Kevin Howell (Royal Free Hospital), and was themed with an emphasis on *self-help* within the medical thermal imaging community. To that end, speakers were invited from the spectrum of clinical activities and encouraged to identify areas with distinct collaboration potential: the ultimate aim being to form a dedicated UK network for medical thermology that will hopefully be supported by the research councils. In the event, 29 people attended, representing the majority of the UK academic and clinical community, as well as several industrially related figures who also demonstrated the latest generation thermal imaging hardware in a parallel manufacturers exhibition.

Self Help

The self-help aspect of the meeting was underscored by the attendance of several key speakers. The first of whom was **Dr Peter Plassman** (Glamorgan University). Peter advised the audience on the procedures for upgrading older (and often discarded) Agema camera systems so that their performance can compete with many of the latest generation systems. Peter explained the electronic principles behind the camera design and illustrated the physical and software approaches needed to improve resolution with these older systems: an invaluable lesson for those wishing to breathe new life into old kit. The marked enhancement in performance is illustrated by the images shown in figure 1 below.

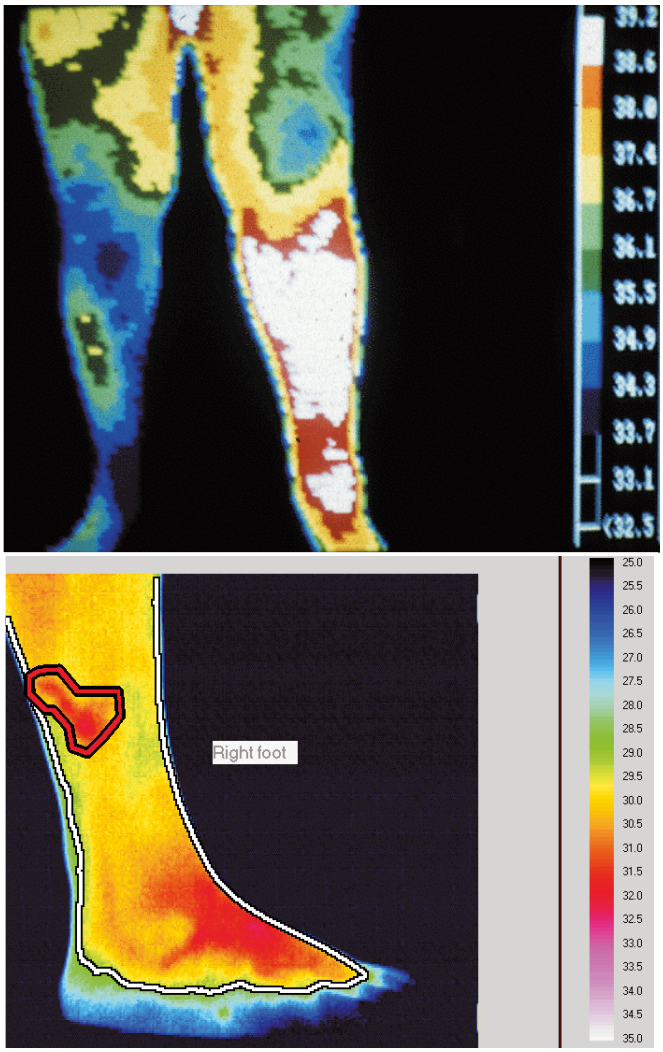

Figure 1.
Upgrading the Agema 780 Series. The initial image quality was a mere 140 x 140 pixels/12 colour, as shown above left (courtesy Dr Richard Harding). After upgrading, the system now boasts a 256 x 256 pixel/128 colour image that can be displayed at 1098 x 756. The improvement in resolution is obvious.

Information on the CTHERM code used as the software core, and developed by the Glamorgan group can be found at:

http://www.comp.glam.ac.uk/pages/staff/pplassma/

In the afternoon session, Peter also described his involvement in developing a bid to the EU for a Multi-Spectral Imaging Consortium. Not only was Peter's talk interesting and indeed entertaining, but it was also highly informative in detailing the application procedure, with its many potential stumbling blocks, when constructing a proposal to the EU. Details of the MUSIC bid can be found at:

http://ltg4.comp.glam.ac.uk/music/

The committee for the UK Symposium wish Peter and his colleagues and collaborators every good fortune with this application.

Also within the self-help category, **Mr Rob Simpson** (NPL) showed the initial results that have been obtained with a new black body calibration source developed specifically for use within the medical thermography community. This device allows medical thermographers to have traceable [to ITS-90] and manufacturer independent calibration of their cameras, thus ensuring that temperature measurement, and subsequent diagnostic assessments based thereon, are of the highest integrity. Initial tests undertaken at NPL and the Royal Free indicate that the source is highly stable and well within the tolerances specified at the design stage. The calibration source is currently undergoing a second trial at Ninewells Hospital after which it will have a final test under the auspices of Professor Ring at Glamorgan. It is hoped that the black body calibration source will be available for general use within the community within next twelve months.

Computer modelling methods represent a valuable complimentary aspect to thermal imaging work, especially when the predictive capabilities of the model can be used to optimise protocols that may be either expensive or unsafe to undertake on a trial and error basis. **Dr Charlie Song** (University of Dundee) gave an overview of the application of finite-element (FE) methods as a computational adjunct to thermal imaging. Dr Song's talk made use of animated models showing the calculated temperature field in the vicinity of heated-activated surgical staples and also illustrated how real thermography data is used to validate computational models of such dynamic events. Elements of the talk are featured in two recently published articles [1,2].

The final talk in this category was delivered by **Adrian Walker** and **Peter Anthony** (Rutherford Labs) who described the facilities available at the Engineering and Physical Sciences Research Council (EPSRC) equipment loan pool: a facility which most attendees were not aware even existed! The freely available kit includes several Agema systems and a latest generation FLIR SC3000 thermal imager, among a myriad other useful (and usually prohibitively expensive) types of specialised imaging instrumentation. The procedure for application to the loan pool was also detailed and the waiting times outlined. An interesting overview of a previous thermographic application of the on-loan instrumentation was also provided.

Clinical Aspects

The clinically related talks were concentrated on topical issues where the employment of thermal imaging is making a tangible impact.

Professor Francis Ring gave a fascinating address on complex regional pain syndrome (CRPS), a condition that often presents with patient sensations of severe burning or aching pain, increasing with the slightest touch or breeze (type 1 CRPS). Initial thermographic analysis showed a limb temperature asymmetry of up to 2.7°C. In developing a therapy, Professor Ring's group took a cue from the seminar work of Ramachandran [3] which showed that phantom limb pain results from disruption of the normal interaction between motor intention to move the limb, and the absence of sensory feedback (proprioceptive). When a mirror was introduced to provide visual feedback of a healthy (reflected) limb, then sensation of pain was reduced.visual feedback using a mirror image of the healthy limb might interrupt the pathological cycle. re-establishes pain free relationship between sensory feedback and motor action. Further, the subjective assessment of pain [reduction] was complimented with infrared thermal imaging objectively indicating the normalisation of temperature in these patients after visual feedback therapy. Further details are now available in published form [4].

Lasers are now established as the preferred method of treatment for a range of clinical skin disorders including vascular lesions and it is a common requirement to deliver the laser energy to a sub-dermal region such as a blood vessel, while minimising the temperature rise at the skin surface**. Dr Roderick Thomas** (Swansea Institute) delivered a beautifully illustrated talk showing how infrared thermography is being used to optimise laser therapy both empirically, and via the use of computer models. Rod also outlined the challenges and rationale for adopting laser approaches as opposed to alternative

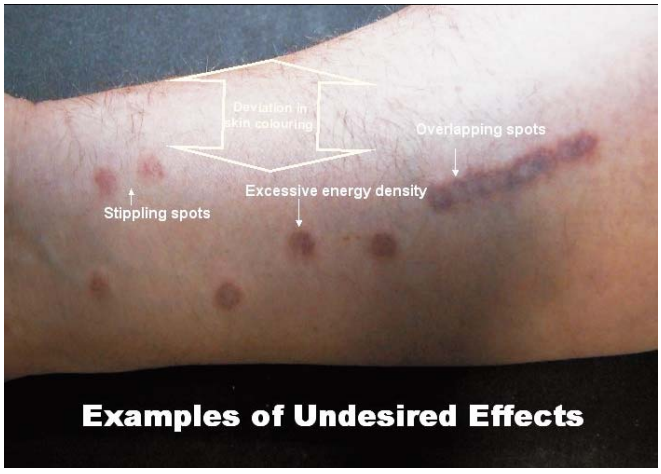

Figure 2
Examples of undesired effects of laser Therapy

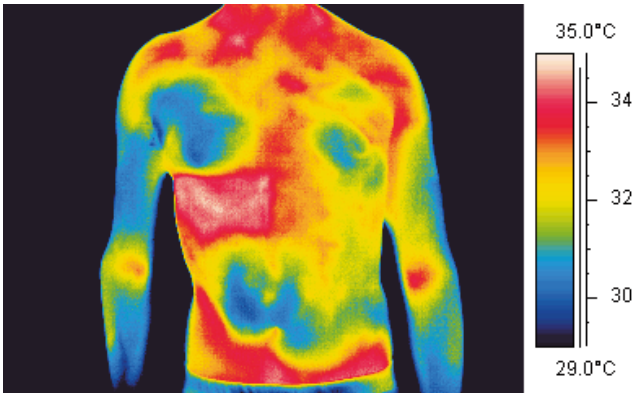

Figure3
Infrared thermogram showing inflammation of active morphoea plaques at the chest and abdomen (Royal Free Hospital)

techniques such as cryosurgery or excision. The undesirable effects of non-optimised treatment were also reviewed (as pictured below), as well as the successful case studies drawn from the range of applicability of laser treatments. Rod also described the development of computational models to predict radiative and thermal transport through the tissue, and validated these models against real thermography based data.

Kevin Howell (Royal Free Hospital) presented a review of thermography for the assessment of morphoea. He explained that the disease was the most common connective tissue disorder in children, causing fibrosis of the dermis in localized skin areas, often along with atrophy of the subcutis and underlying musculature. Thermography has been shown to be effective for assessment of the inflammatory early stage of morphoea, and is the subject of ongoing research at the Royal Free and Great Ormond Street Hospitals (5).

Other speakers included **Drew Heusch** (Effect of body fat on skin temperature), **Gary Chamberlain** (SARs detection), **Carl Jones** (Image Registration and Overlay) and **Steve Hollock** (Inexpensive IR detectors and applications).

The meeting was generously sponsored by both the UK Thermography Association (UKTA) through a reduced registration fee to their attending members, and also the Institute of Physics (IoP) by provision of travel bursaries to Dr Paul Campbell & Dr Maria Teresa Visentin.

References

[1] C Song, P A Campbell, T G Frank, A Cuschieri. *Smart Materials and Structures* 11(3), 1 (2002)

[2] Y, Ng, C. Song,.. & P A Campbell. 83, 1884 *Applied Physics Letters* (2003)

[3] VS Ramachandran & D. Rogers- Ramachandran *Proc. R. Soc. Lond.* 1996

[4] McCabe, Haigh, Ring, Halligan, Wall, Blake et al *Rheumatology* 2003; 42:97-101

[5] Martini G, Murray KJ, Howell KJ et al *Rheumatology* 2002; 41: 1178-1182

Citations

Please cite this paper as

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This paper was cited by

1. Ammer K.Thermology 2003 - A computer-assisted literature survey with a focus on non medical applications of thermal imaging. Thermology International 2004; 14 (1) 5-360

Veranstaltungen (Meetings)

2004

March 15-18, 2004

The Multiple Applications of Infrared Thermography, a Tool for Measurement, Characterization and Monitoring, a 3.5 - Day Short Course to be held at the Continuing Education Dept of Eco1e Normale Superieure of Cachan, Paris, France

Information: Ecole Normale Superieure de Cachan
Service Formation Continue et Developpement
61 avenue du Präsident Wilson
94235 Cachan Cedex, France

Tel. :33 (0)147407500 ; Fax:33 (0)1 4740 75 10
e-mail: fcd@ens-cachan.fr

April 3-4, 2004

7th Congress of the Polish Association of Thermology in Zakopane, Poland

Venue: „HYRNY"; ul. Pilsudskiego 20, 34-500 Zakopane
Deadline for abstracts: 15.12.2003.
Organising office:
ATAS Sp. z o.o. Pl. Konstytucji 4/17 Warszawa

Information: ATAS: Malgorzata Slawińska
tel. 022 - 875 04 40, 022 - 825 74 77, fax 022 - 825 74 77
e-mail: atas@atas.com.pl**,** atas@atas.pl

or Prof. Dr. Anna Jung
Klinika Pediatrii i Nefrologii Dzieciêcej
Wojskowego Instytutu Medycznego
00-909 Warszawa, ul. Szaserów 128
tel. (0-22) 6817-236, tel./fax (0-22) 6816-763
e-mail: a jung@wim.mil.pl

April 15-18, 2004

31st Annual Meeting of the American Academy of Thermology and the Conference on International Standards for Thermology in Human and Animal Research and Medicine in Auburn, Alabama, U.S.A.

Chairman, Scientific Program: Dr. David D. Pascoe

Chairman, Standards Symposium: Dr. Ram C. Purohit

Program Organizer: Dr. Richard Herrick

Information:
David D. Pascoe2050
Memorial ColiseumAuburn University, AL 36849. U.S.A

phone: (334) 844-1479
emaila: Pascodd@auburn.edu

June 5-6, 2004

The **6th International Congress of Thermology** combined withl3th Annual Meeting of the Korean Academy of Medical Thermology

Venue: Konkuk university, New Millennium Hall
#l Hwayang-dong Gwangjin-gu, Seoul 143-701, Korea
Tel +82-2-455-1896-7, Fax +82-2-455-4084
http://www.konkuk.ac.kr

Information;
Secretary General Yong-Eun Cho, M.D., Ph.D.
Department of Neurosurgery, Yongdong Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

Tel : +82-2-3497-3390, Fax +82-2-3461-9229
E-mail:ydnscho@yumc.yonsei.ac.kr

25.-27 Juni .2004

Jubiläumskongress der Deutschen Gesellschaft für Thermographie und Regulationsmedizin in München, Deutschland
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An der Steig 6, D-88483 Burgrieden-Rot,
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