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Inhaltsverzeichnis (CONTENTS)

Originalien (ORIGINAL ARTICLES)

Guido Orlandini
Thermograpgic changes after surgery for pain syndromes.....45
(Thermographische Veränderungen nach schmerzchirurgischen Eingriffen)

Mariusz Lipski, Krzysztof Wozniak
Thermographic evaluation of the temperature rise on the outer root surface of teeth during Thermafil, JS Quick-Fill and thermo-mechanical compaction techniques. An in vitro study.....51
(Die thermographische Beurteilung des Temperaturanstiegs an der Wurzeloberfläche der Zähne infolge der Wurzelkanalfüllung mit Thermafil, JS Quick-Fill und thermischer Kondensation. Eine in vitro Studie)

Berichte (REPORTS)

Instruktionen für Autoren.....42

Instructions for authors.....44

15. Thermologisches Symposiumam 27.April 2002, Programm & Kurzfassungen.....58

Physiological measurement of Raynaud´s phenomenon and peripheral microvascular disorders: from research into clinical practice. Programme & Abstracts.....62

Medical Infrared Thermography. Programme & Abstracts.....71

Registration form: 9th European Congress of Medical Thermology.....83

News in Thermology

9th European Congress of Medical Thermology.....79

3rd Asian-Pacific Congress of Thermology.....79

Chinese Society of Thermology..... 79

AAT Mdeeting in Orlando.....79

Veranstaltungen (MEETINGS)

Veranstaltungskalender..... 80

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Thermographic changes after surgery for pain syndromes

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Aim of the investigation - The aim of this investigation was to study the thermographic changes induced by surgical operations for pain. The surgical procedures were neuroablative, specifically Percutaneous Radiofrequency Trigeminal Rhizotomy (PRTR) and Percutaneous Cervical Cordotomy (PCC) and neuroadditive using Spinal Cord Stimulation (SCS).

Patients and methods - A series of seven patients affected by trigeminal neuralgia undergoing PRTR, various type of cancer pain undergoing PCC and chronic nerve root pain undergoing SCS were examined using Infrared Thermal Imaging (ITI) 1-2 days pre and post surgery. Trigeminal neuralgia patients were studied by ITI using one anterior and two lateral (right and left) views. Cancer pain patients were studied using a total body view and also with the body region(s) involved in the pain (thoracic, abdominal, low back, limbs or perineum). In the case of PRTR and PCC, two kinds of thermographic changes were considered: 1) temperature changes directly induced by surgery, regardless of the previous pathologic findings; 2) temperature changes induced by surgery related to the pathologic findings. Patients affected by chronic nerve root pain were studied by ITI with one anterior and one posterior view. Post operative thermal imging was used with stimulation switched on and switched off.

Results and discussion – In those cases treated with PRTR thermographic changes induced by the operation showed a reduction of the cold area which was evident pre-operatively. The thermographic findings in patients with cancer pain were not significantly changed by surgery. If, in the event of nociceptive pain in the superficial tissues, a warm area was found pre-operatively, as an expression of local nociceptor activation, this did not change post-operatively. Similarly, if a cold area was found pre-operatively, it was also observed post-operatively. The paramount appearance of post-operative ITI was that of a warm area diffused to the whole side as the PCC hemisoma. This was more evident at the extremities i.e. the hand and foot. This is the expression of cordotomy-induced sympathetic block on the operated side. Finally, as for post-SCS thermal imaging, it must be noted that thermographic changes do not occur if Spinal cord stimulation is ineffective for the control of pain.

Key words: Percutaneous Radiofrequency Trigeminal Rhizotomy (PRTC), Percutaneous Cervical Cordotomy (PCC),Spinal Cord Stimulation (SCS), Infrared Thermal Imaging (ITI)

Thermographische Veränderungen nach schmerzchirurgischen Eingriffen

Ziel der Untersuchung: Es war das Ziel dieser Studie die Thermographischen Veränderungen nach schmerzchirurgischen Eingriffen zu untersuchen.Neuroablative, speziell die perkutane radiofrequente Trigeminus-Rhizotomie (PRTR) und die perkutane zervikale Chordotomie (PZC) , und neurostimulative chirurgischeVerfahren wie die Rückenmarksstimulation werden besprochen.

Patienten und Methodik: Sieben Patienten, die wegen Trigeminusneuralgie mittels PRTR behandelt worden waren, Karzinom induzierte Schmerzen, die mit PZC therapiert wurden und chronische radikuläre Schmerzsyndrome mit Rückenmarksstimulation wurden 1- 2 Tage vor und nach dem chirurgischen Eingiff mittels Infrarothermographie (IRT) untersucht. Bei den Patienten mit Trigeminusneuralgie wurden Infrarotaufnahmen von vorne und von beiden Seiten (rechtes und linkes Profil) durchgeführt. Bei den Karzinompatienten wurden Ganzkörperaufnahmen gemacht und zusätzlich die schmerzhaften Körperre gionen (Thorax, Abdomen, Rücken, Gliedmaßen, Perineum) thermographisch abgebildet. Beim Einsatz von PRTR und PZC wurden zwei thermographische Veränderungen beobachtet: 1.) Temperaturveränderungen, die unmittelbar durch den chirurgischen Eingriff verursacht wurden, unabhängig von vorangegangenen pathologischen Veränderungen und 2.) chirurgisch bedingte Temperaturveränderungen im Zusammenhang bestehenden pathologischen Befunden. Bei Patienten mit chronischen Nervenwurzelschmer-

zen wurden Aufnahmen von vorne und von hinten angefertigt. Die Bilder wurden sowohl mit eingeschalteter als auch mit ausgeschalteter Rückemmarkstimulation erhoben.

*Ergebnisse und Diskussio*n – Bei Patienten, die mit PRTR therapiert wurden, zeigten sich kühle Areale, die präoperativ thermographisch nachweisbar waren, nach der Operation weniger ausgedehnt. Bei Patienten mit Karzinomschmerzen fanden sich keine typischen Veränderungen nach dem chirurgischen Eingriff. Wenn ein nozizeptiver Schmerz in oberflächlichen Gewebsschichten zu einer präoperativ nachweisbaren Überwärmung als Ausdruck Nozizeptoraktivierung geführt hatte, blieb dieses Phänomen postoperativ unverändert. Analog verhielten sich kalte Zonen. Die wichtigste Veränderungen der Infrarotthermographie nach PCZ war, dass warme Areale sich postoperativ auf die gesamte Halbseite, an der interveniert worden war, ausdehnten. Das war an den Extremitäten besonders an Händen und Füßen deutlicher ausgeprägt und ist Ausdruck des durch die Chordotomie induzierten sympathischen Block an der operierten Seite. Schließlich soll zur Rückenmarkstimulation bemerkt werden, dass im Falle einer unzureichenden Schmerzkontrolle keine thermographischen Veränderungen registriert werden können..

Schlüsselwörter: Perkutane radiofrequente Trigeminus-Rhizotomie (PRTR), perkutane zervikale Chordotomie (PZC)),Rückenmarkstimulation, Infrarot-Thermographie (IRT)

Introduction

The aim of this study was to investigate the changes shown by thermal imaging which can be induced by some surgical operations for pain, particularly Trigeminal Percutaneous Radiofrequency Thermorhizotomy (TPRT) and Percutaneous Cervical Cordotomy (PCC) [1,2].

Patients and methods

A series of patients affected by trigeminal neuralgia undergoing TPRT or those with various types of cancer pain undergoing PCC were tested with Infrared Thermal Imaging (ITI) 1-2 days pre and post surgery.

The trigeminal neuralgia patients were studied with infra red thermal imaging using one anterior and two lateral (right and left) views. The Cancer pain patients were studied using a total body view and with the body region(s) affected by pain (thoracic, abdominal, low back, limbs or perineum).

Two kinds of thermographic changes were considered:
1) changes directly induced by the operations, regardless of the previous pathologic findings and
2) changes induced by surgery based on previous pathologic findings.

Results

Patient 1

Patient 1 was a 76 years old male (MM) with right trigeminal neuralgia of the III branch undergoing a right TPRT. In the preoperative thermal images there was no difference in the skin temperature on the right, and the left side of the face, and postoperatively, only a relatively warm area on the analgesic right III branch, with a right/left difference of 0.6°C was observed.(Figure 1).

Patient 2

Patient 2 was a 61 years old male (MA) with right trigeminal neuralgia of the III branch undergoing a right TPRT. Also in the preoperative image of this patient there was no difference in the skin temperature on the right and the left side of the face. Postoperatively,the thermograms showed no right-left significative differences despite the hypalgesic area and pain relief obtained by the procedure. (Figure 2).

In both the trigeminal neuralgia patients, preoperative ITI did not show any differences in the symmetry of skin temperature comparing the right (affected) side of the face with the left, probably because pain was absent during the investigation. It is important to note that only when the patient is actually experiencing pain will thermal imaging show a cold area which approximatively corresponds to the affected trigeminal branch(es) [3]. On the contrary, during pain-free periods between the paroxisms, thermograms can be normal. Postoperatively, only a relatively warm area on the analgesic right III branch, with a right/left difference of 0.6°C was found in Patient 1 and no right-left significative difference in Patient 2, despite the hypalgesic area and pain relief obtained from treatment. We can argue that when pain is decreased without major denervation there are no significative temperature modifications, comparing the pre and postoperative findings. However, a warm area (due to complete sym- pathetic destruction) can be observed if a deeper lesion is performed, and is potentially the cause of de-afferent post-operative chronic pain.

Patient 3

Patient 3 was a 57 years old male (BM), with a left chest pain due to a pleural mesothelioma infiltrating the thoracic wall (costopleural syn-

drome), but without evidence of a neuropathic pain component. Preoperative thermograms showed a warm area at the level of the left mammarian, hypochondriac and anterior abdominal wall regions with a left-right thermal difference of 0.6°C (Figure 3A). This patient underwent right PCC and obtained total pain control in the left hemithorax. Postoperatively, ITI showed no reduction of the left-right thermal difference in the site of chest pain (Figure 3B). These findings are not surprising, because PCC controls pain acting on the second neuron and does not influence the delivery of vaso-a ctive metabolites at the level of the nociception source. Postoperatively, the only new finding was a slight increase of the skin temperature on the right side of the face, a cranio-facial expression of the vasodilatation due to the central sympathetic block in the whole hemisoma on the treated side resulting from the cervical cordotomy.

Patient 4

Patient 4 was a 83 years old male (DS), affected by bilateral arm nerve trunk pain (with a left side prevalence) due to cervical spinal canal and nerve root infiltration by secondary lung cancer. Preoperative thermograms showed a cold area on both hands, as an expression of local vasoconstriction due to sympathetic irritation. The patient underwent right PCC and obtained total pain relief in the left arm but without reduction of the cold area of the left hand. Postoperative thermograms showed no modification in the left hemisoma and only a warm area at the level of the right hand (Figure 4). This finding can be explained because local vasoconstriction due to sympathetic irritation is not affected by the lesion at the level of the second neuron within the high cervical spinal cord. On the right side, postoperative thermography showed an increased skin temperature (expecially evident at the level of the hand) which was interreted as the expression of the central sympathetic block in the whole hemisoma of the treated side resulting from PCC. Therefore, the right hand, which was cold before cordotomy (29.6°C), became warm postoperatively (32°C), increasing by 2.4°C.

Patient 5

Patient 5 was a 57 years old woman (SM), with right chest pain due to pleural mesothelioma infiltrating the thoracic wall (costopleural syndrome). Preoperative thermograms (Figure 5) showed: 1) a warm area at the level of the left mammarian and hypochondriac regions (with a left-right thermal difference ranging from 0.5 to 1.1°C) indicating the local delivery of vasoactive metabolites at the level of the nociception source; 2) a cold area on the infra-sc apular region in the posterior surface of the right chest, as an expression of the nerve root and intercostal nerve involvement by the mesothelioma. The patient underwent left PCC and obtained a total pain relief in the right chest. The postoperative images (Figure 6) showed no variation in the skin temperature on the anterior aspect of the right chest, a slight reduction of the cold area in its posterior aspect, and a diffuse increase of skin temperature along the whole left hemisoma, which was particularly evident at the face, the hand and the foot.

Patient 6

Patient 6, a 67 years old male (CL) had right leg deep nociceptive pain due to bone infiltration from lung cancer metastasis. Preoperative ITI showed a cold area on the posterior surface of the right leg, apart from the site of pain, which was either a reflex painless vasospasm induced by the hip nociception or the effect of an initial involvement of the L5 and S1 nerve roots (Figure 7A). This patient underwent a left PCC and obtained the total pain control in the right leg, without reduction of the left-right thermal difference on the posterior surface of the legs (Figure 7B1). Percutaneous Cervical Cordotomy does not influence the reflex vasospasm and the local vasocostriction due to sympathetic irritation in nerve trunk pain is not affected by the lesion on the second neuron. In this patient, the major finding of the postoperative thermography was a diffuse increase in skin temperature along the whole area ipsilateral to the treated emisoma, which was particularly evident on the face and foot (Figure 7B2).

Patient 7

Patient 7 was a 65 years old female (VN), with severe incident right leg neurogenic and prevailing nociceptive pain. This extended to nerve trunk pain mixed with a neuropathic pain component relating to tumor infiltration of the lumbo-sacral plexous pelvic secondaries from metastatic lung cancer (lumbosacral plexopathy). The physical examination showed severe motor deficit of the right leg and sensory distortion (deep allodynia evoked by firm pressure and passive movement of the leg). Pre- operative thermography (Figure 8A) showed a

slight increase of the temperature on the anterior surface of the right thigh compared to the corresponding controlateral area, and a reduced temperature in the remaining portion of the right leg (28°C on the right side and 28.9°C on the left at the level of the knee, 29°C on the right side and 27.7°C on the left at the level of the dorsal surface of the foot). This patient underwent a left PCC and obtained total pain relief in the right leg. Postoperative ITI showed a further increase in skin temperature at the knee and a decrease at the associated foot. In addition there was a diffuse increase in skin temperature along the whole of the treated side. (Figure 8B).

Conclusions

Infra red thermal imaging is not substantially modified in the analgesic area of the face following percutaneous radiofrequency trigeminal rhizotomy or in the analgesic emisoma following percutaneous cervical cordotomy. In the case of TPRT, at least in the two patients of this series, postoperative thermography did not show any right-left significant temperature differences, despite the hypalgesic area and clinical pain relief obtained from treatment. We can postulate that after TPRT when pain is reduced in the absence of major denervation, changes in the thermal image are not significant, i.e. when comparing the preoperative with the postoperative findings. A warm area (due to complete sympathetic destruction) was observed only if after a deeper lesion is performed, which potentially causes deafferent postoperative chronic pain.

Similarly, in percutaeous cervical cordotomy, thermograms do not show significant changes in the analgesic emisoma, despite the impressive clinical results. This can be explained because local vascular tone under sympathetic control, and local supply of vasoactive metabolites at the level of nociception are not affected by the lesion of the second neuron within the high cervical spinal cord. Therefore the cold or warm areas found on the preoperative thermograms are not altered postoperatively, because the procedure does not act on the intrinsic mechanisms regulating the thermal patterns on the skin.

It was only possible to find significant postoperative modifications in skin temperature related to specific pain areas in the one case of sympathetic block. In this specific case only sympathectomy acted at the level of the intrinsic mechanism regulating the skin temperature recorded by thermal imaging [4,5, 6, 7,8, 9, 10].

Finally, infra red thermal imaging has been found to be a reliable instrument to predict the outcome of TPRT and PCC only if the preoperative examination, a diffuse warm area in the same site of the pain, which can be clinically correlated to a severe neuropathic pain condition. This finding, in the case of facial pain, suggests a deafferent pain syndrome where TPRT is not indicated. In the case of arm, trunk and leg pain it suggests a severe neuropathic pain condition which potentially will not be controlled by cervical codotomy.

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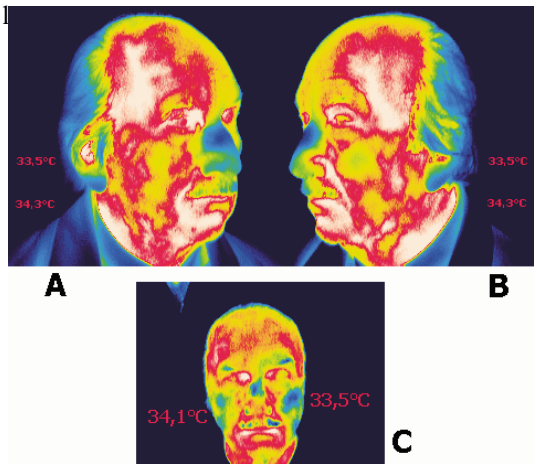

Figure 1 - Thermal images of a patient with a right trigeminal neuralgia of the III branch preoperatively (A and B) and postoperatively (C). Note that the preoperative images were normal (there were no differences in the skin temperature comparing the right and the left side of the face, because pain was absent during the ITI-scan) and that postoperatively only a relatively (insignificant) warm area was found on the analgesic right III branch.

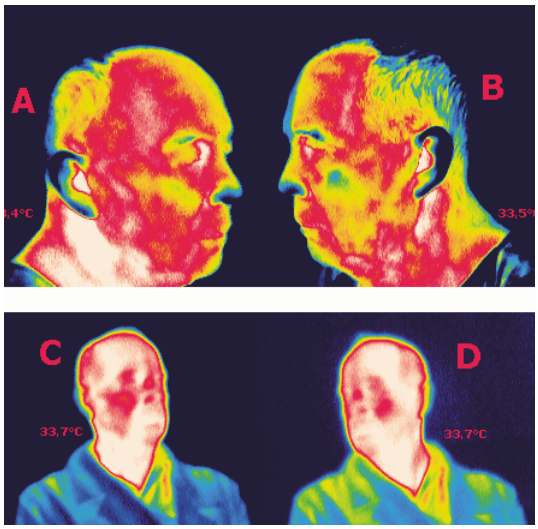

Figure 2 – Left trigeminal neuralgia of the III branch. A and B: preoperative thermograms. Note the absence of abnormality, because the pain was absent during the ITI investigation. C and D: postoperative images. There is no difference in the skin temperature comparing the right and the left side of the face

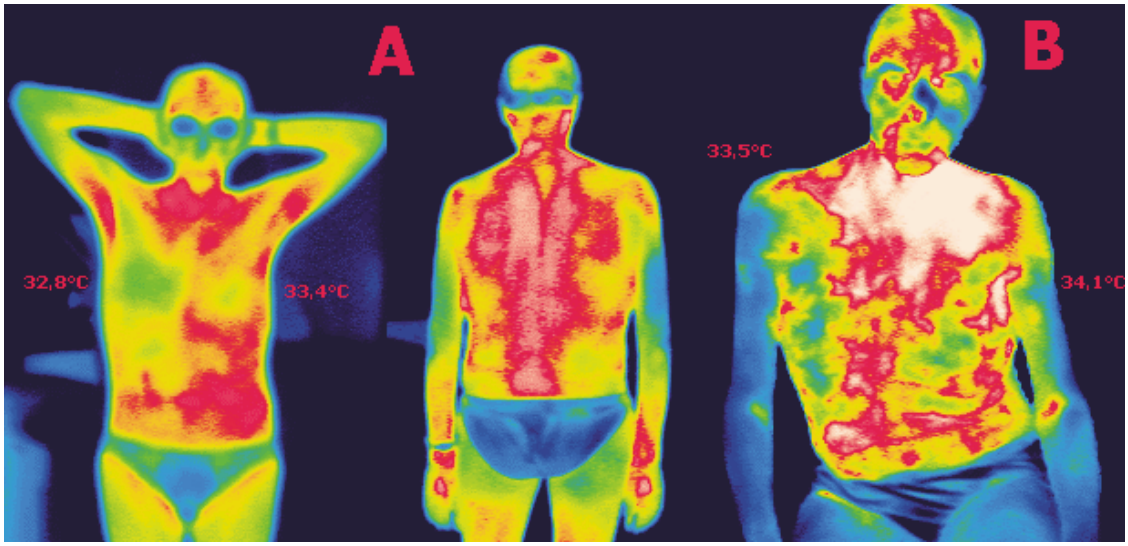

Figura 3 - Left chest pain due to pleural mesothelioma, treated by right PCC.
A: preoperative thermogram; B: postoperative thermograme TTG

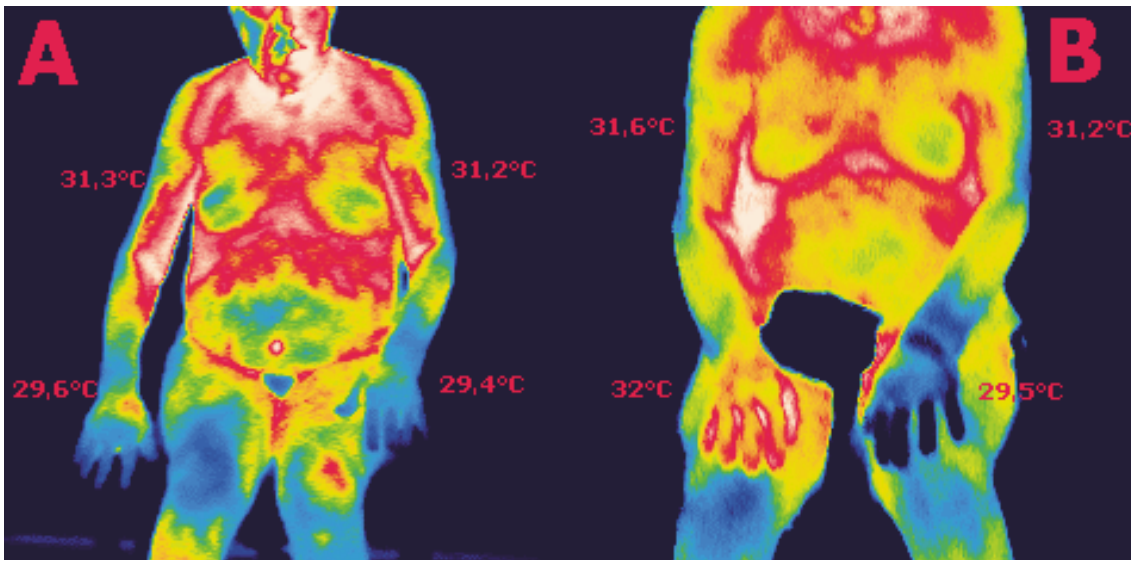

Figure 4 - Left-arm pain due to lung cancer, treated by right PCC.
A = preoperative ITI; B = : postoperative ITI, after right PCC TTG, after right PCC

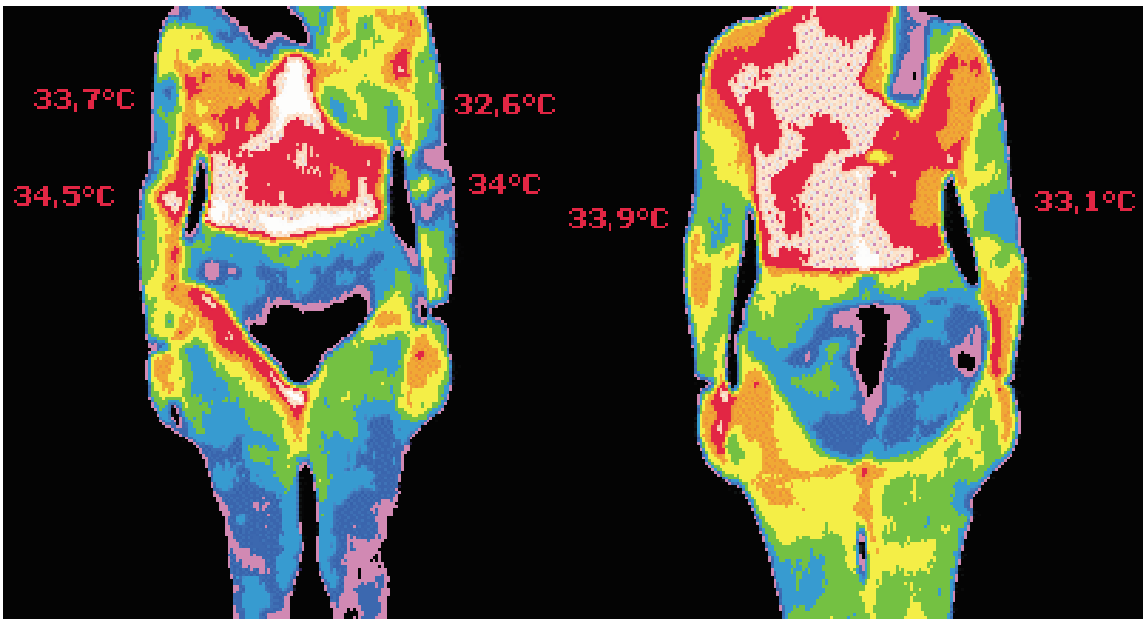

Figure 5 – Right chest pain due to pleural mesothelioma, treated by left PCC: preoperative ITI

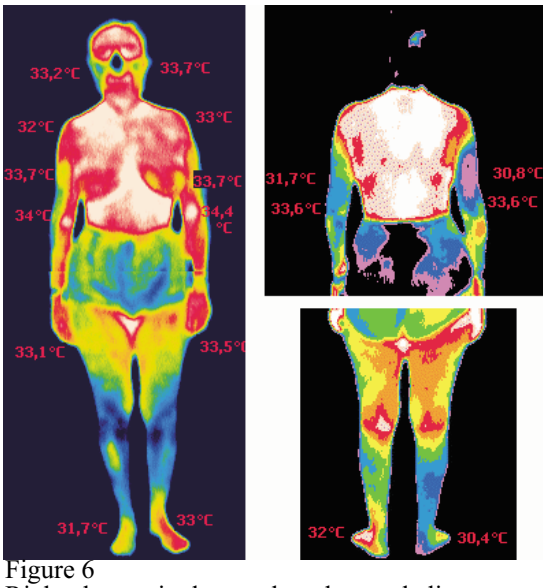

Figure 6
Right chest pain due to pleural mesothelioma: postoperative ITI, after left PCCC

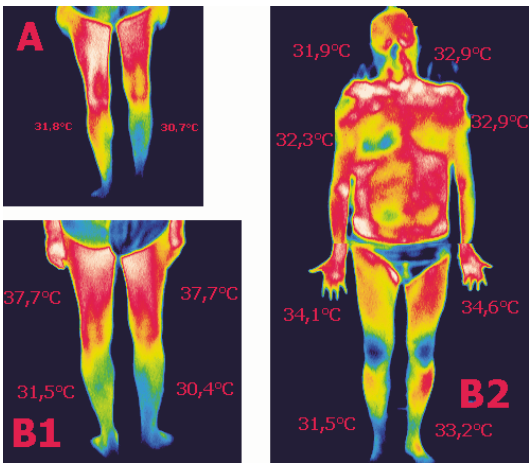

Figure 7
Right leg pain due to lung cancer metastasis at the hip, treated by left PCC. A: preoperative ITI; B1 and B2: postoperative ITI

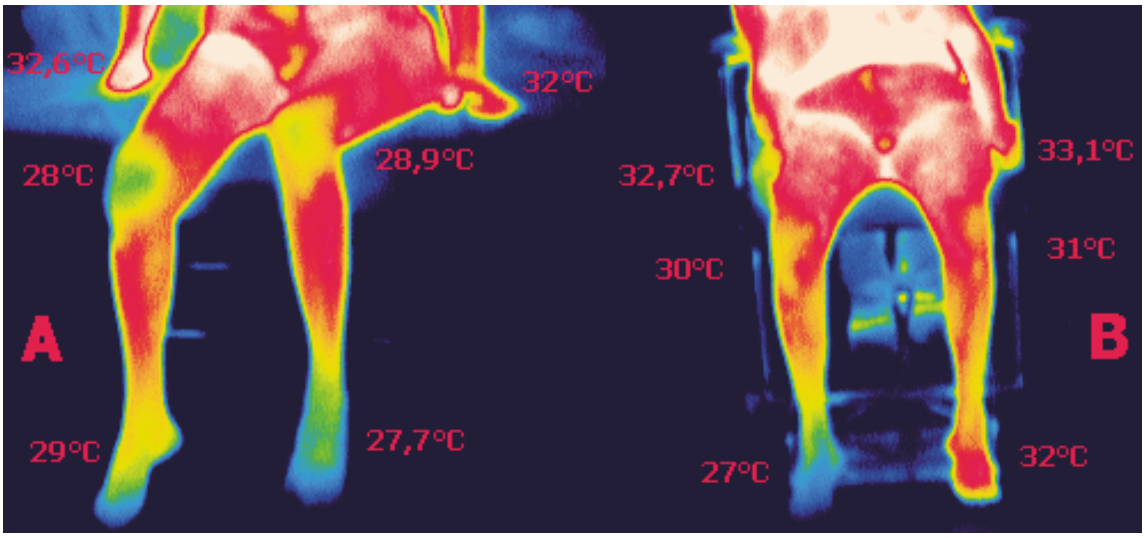

Figure 8 – Right leg pain due to lumbosacral plexopathy in lung cancer metastasis of the pelvis, treated by left PCC. A: preoperative ITI; B: postoperative ITI

Thermographic evaluation of the temperature rise on the outer root surface of teeth during Thermafil, JS Quick-Fill and thermo-mechanical compaction techniques. An in vitro study

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Summary

This in vitro study compared root surface rises during: titanium and plastic carrier Thermafil oburation techniques, JS Quick-Fill obturation technique and thermo-mechanical compaction with Engine Plugger.

Forty extracted human premolars with a single canal were used. After cleaning and shaping to an apical size 40 file, the teeth were divided into 4 groups of 10 teeth. Each of which was mounted in a wooden slate and obturated with titanium or plastic carrier Thermafil obturators, JS Quick-Fill technique and thermo-mechanical compaction with Engine Plugger at 10000 rpm. Temperature changes on the external root surface during root canal filling were measured using thermal imaging camera.

The results of this in vitro study showed that during Thermafil and JS Quick-Fill technique the temperature rise does not reach a level that is a danger to the periondontal tissues. In contrast, the thermomechanical compaction generated a relatively high temperature rise 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 infolge der Wurzelkanalfüllung mit Thermafil, JS Quick – Fill und thermischer Kondensation. Eine in vitro Untersuchung.

In dieser Studie wurden Temperatursteigerungen an der Wurzeloberfläche nach Wurzelkanalfüllung mit Thermafilstiften mit Plastik -oder Titanträger, JS Quick – Fill and thermische Kondensation mit Hilfe von Engine Plugger verglichen.

Die Untersuchung wurde an 40 Prämolaren mit einem Wurzelkanal durchgeführt. Nach dem Wurzelkanalaufbereitung, apikal bis zur Feilen-Größe 40, wurden die Zähne in 4 Gruppen á 10 Zähne geteilt, in einen Holzständer verankert und mit Thermafilstiften mit Plastik - und Titanträgern, JS Quick – Fill und thermischer Kondensation mit Engine Plugger bei 10000 U/min 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 Thermafilstiften und JS Quick – Fill nur zu geringen Temperaturerhöhungen an der Wurzeloberfläche führt, die für das Periodontium nicht gefährlich sind. Im Gegensatz dazu, ist die thermische Kondensation von einer relativ großen Temperaturerhöhungen an der Wurzeloberfläche begleitet, die eine Schädigung der Zahnumgebung wahrscheinlich macht.

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

Introduction

Complete filling of the root canal system is an important aspect of a successful endodontic treatment. The use of laterally condensed gutta-percha cones in conjunction with sealer has been accepted as one of the most popular procedures for root canal obturation. However, according to some authors, lateral condensation has not resulted in a homogenous mass of gutta-percha that could be closely adapted to the root canal walls [1,2,3,4,5,6]. They preferred obturation techniques utilising thermo-plasticised gutta-percha or heat–induced compaction of gutta-percha [5,6]. Thermo-mechanical compaction is one of these methods. This technique, first introduced by McSpadden (1978), uses a compactor which resembles a converted Hedstrom's file mounted on a contra angle. The compactor uses rotary friction between gutta-percha and dentinal walls to produce heat which thermoplasticises the gutta-percha and forces it laterally and apically [6]. Thermomechanical condensation can be also performed with application of Engine Plugger (VDW, Munich, Germany), which resembles a converted K file, rather than McSpadden Compactor. According to the manufacturer, Engine Plugger is much more safe, since it has been less frequently broken within the root canal [7].

Another variation of thermo-mechanical compaction, JS Quick-Fill (Losser/JS Dental, Leverkusen, Germany), provides a gutta-percha coated on the titanium compactor by the manufacturer. The JS Quick-Fill obturator is inserted into the canal until it binds the contra angle as actuated, and the gutta-percha is thermoplasticised and transported laterally and apically as the compactor rotates. Following obturation, the compactor can be separated and left in a canal, but it is possible to remove the instrument immediately after the filling, as rotation continues [8].

In 1978, Johnson [9] described a technique of carrying thermo-plasticised gutta-percha with a metal carrier to the full extent of the prepared canal. This obturation technique was commercialised as Thermafil Endodontic Obturators (Tulsa Dental Products, Tulsa, OK, USA). It involves the use of flexible titanium or plastic carriers that are coated with α-phase gutta-percha. When warmed, the gutta-percha becomes thermo-plasticised and adheres to the carrier which becomes the transporter of the gutta-percha to the working length in the root canal [10].

Dentine has a low thermal conductivity [11], but the heat produced by the obturation techniques utilising thermo-plasticised gutta- percha or heat-induced compaction of gutta- percha may pass on the external root surface. This is a potential insult to the cementum, periodontal ligament and alveolar bone [11].

The aim of this *in vitro* investigation was to measure the temperature changes on the external root surface during:
(a) titanium and plastic carrier Thermafil obturation techniques;
(b) JS Quick-Fill obturation technique; and
(c) thermo-mechanical compaction with Engine Plugger.

Material and methods

Forty extracted human premolar teeth with single patent canal and with a completely formed apex were selected and stored in a 0,9% NaCl solution until use. Access cavities were prepared using high-speed diamond stones and water spray. After pulp extirpation, a size 10 K file was introduced into the canal of each specimen until it was seen just at the apical foramen. The working length was determined to be 1 mm short of that position. The canals were instrumented to a size 40 using K file and constant irrigated with 1% sodium hypochlorite solution. Following the apical preparation, the canals were flared using Gates- Glidden drills, sizes 2 through 4.

The teeth were allocated to four groups of 10 teeth each and their crowns were fixed in wooden slat with the entire root surface exposed to the air. The canals were obturated with the titanium carrier Thermafil obturator (group 1), plastic carrier Thermafil obturator (group 2), JS Quick-Fill technique (group 3) and thermo-mechanical compaction using Engine Plugger (group 4).

The canals in group 1 and 2 were obturated with a size 40 titanium carrier Thermafil obturator and a size 40 plastic carrier Thermafil obturator, respectively. Before obturation the walls of coronal part of canals were coated with a small amount of sealer using K file. Each Thermafil obturator was warmed in the Therma-Prep Oven (Tulsa, Dental Produkts, Tulsa, OK,

USA) for 5 min and inserted with firm apical pressure to working length.

Group 3 used the JS Quick-Fill technique. Obturation was performed with a size 30 JS Quick-Fill according to the instructions of the manufacturer. The carrier was dipped into sealer to lightly coat the apical 1/3 and inserted into the canal until resistance was felt. It was rotated at 4000 rpm and then advanced apically until reaching working length (duration of total root canal filling was 4 s). The titanium core was then backed up slowly, still rotating.

The canals in group 4 were obturated by thermo-mechanical compaction using Engine Plugger. The filling was carried in accordance with the method described by Tagger [12]. The gutta-percha cone was dipped in the appropriate sealer and a size 50 Engine Plugger was used at 10000 rpm during 6 s.

In all groups Apexit root canal sealer (Vivadent, Lichtenstein) was used.

Temperature changes on the external root surface during and after root canal filling were recorded using a ThermaCam SC 500 (Flir, Danderyd, Sweden). The thermal imaging camera was mounted on a stand perpendicular to the mesial root surface and 0.15 m away. The results were monitored and processed by the support Thermal Image Computer TIC 8000 System. The maximum highest temperature rises were tabulated from the whole (mesial) root surface. The temperature elevation was measured every 1 s for a period of 150 s. Additionally, thermal images were displayed on a video monitor and were recorded on video tape. The experiment was carried out in a specifically designed room under controlled environmental conditions (Ta=19^0C ± 0,5°C, RH=50 ± 5% and air flow rate below 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 0.91 using the method described by Kells et al. [13].

Statistical analysis

Wilcoxon signed rank test for pairs and U-Mann-Whitney test for independent samples were used in the statistical analysis.

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 1.

The lowest temperature rise was recorded in the titanium and plastic carrier Thermafil groups with mean temperature rise of 4.8 $\pm$ 1.6°0C and 4.5 $\pm$ 1.5°C and with a range of 2.0-7.0°C and 2.1-7.2°C, respectively. The JS Quick-Fill technique had the greater temperature rise with a mean of 7.7 $\pm$ 2.5°C and a range between 2.4 and 12.2°C. The greatest temperature rise was obtained in thermo-mechanical compaction groups, with a mean rise of 22.8 $\pm$ 10.0°C and a range of 12.0-37.2°C.

When compared, differences between mean temperatures in all studied groups were found to be statistically significant in all cases, except for the difference between plastic Thermafil and titanium Thermafil groups (Table 1).

The number of teeth that the root surface temperature rise was elevated by more than 10^0C, 20°C or 30°C , are shown in Table 2. In plastic

Table 1.
The maximal temperature rise including mean temperature rise, the standard deviation and the range recorded on the outer root surface during root canal filing

Group	Obturation technique	Number of teeth	Maximal temperature rise (°C) Mean ± SD (Range)
I	Titanium carrier Thermafil obturator	10	4.8 ± 1.6 (2.0 to 7.0)
II	Plastic carrier Thermafil obturator	10	4.5 ±1.5 (2.1 to 7.2)
III	JS Quick - Fill	10	7.7 ±2.5 (2.4 to 12.2)
IV	Thermo-mechanical compaction	10	22.8 ± 10.0 (12.0 to 37.2

Group I vs group II ns

Group I vs group III $p < 0.01$

Group I vs group IV $p < 0.001$

Group II vs group III $p < 0.01$

Group II vs group IV $p < 0.001$

Group III vs group IV $p < 0.001$

Figure 1
The temperature rise on the outer root surface during root canal filling by titanium and plastic carrier Thermafil obturation technique, JS Quick – Fill technique and thermo-mechanical compaction..

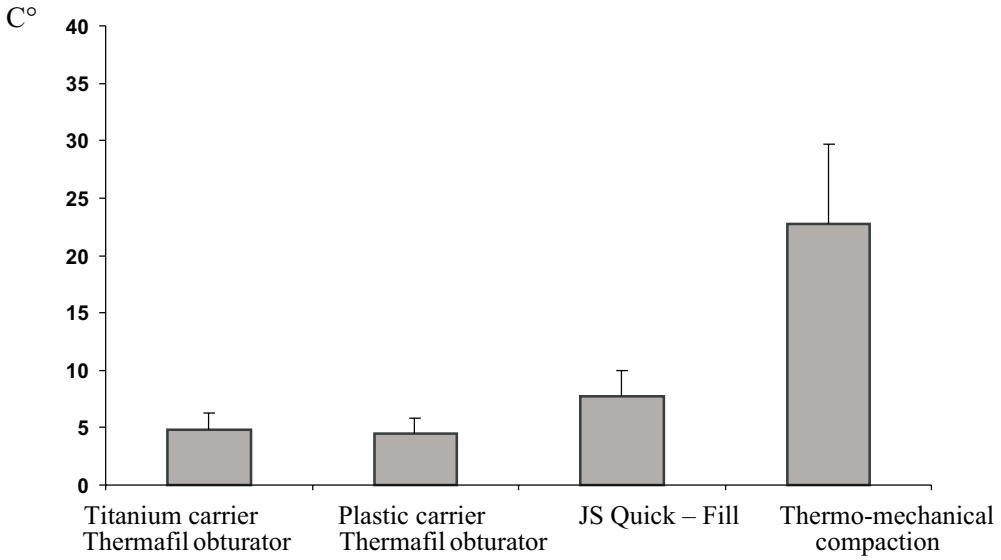

Table 2.
The number of teeth, that the root surface temperature rise was elevated by more than 10^0C, 20^0C or 30^0C.

Group	Obturation technique	Number of teeth	Number of teeth, in which the root surface temperature rise was elevated by more than		
			10°C	20°C	30°C
I	Titanium carrier Thermafil obturator	10	0	0	0
II	Plastic carrier Thermafil obturator	10	0	0	0
III	JS Quick - Fill	10	1	0	0
IV	Thermo-mechanical compaction	10	10	5	2

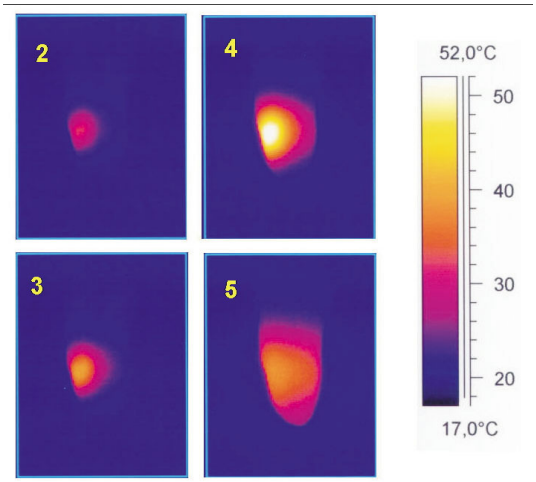

Figure 2. Thermal image at 2s after starting obturation by thermo-mechanical compaction using Engine Plugger (group 4). The maximum temperature rise was 12,8°C.

Figure 3. Thermal image at 3s after starting obturation. The maximal temperature rise was 20,8°C.

Figure 4.Thermal image at 5s after starting obturation .The maximal temperature rise was 33,9°C

Figure 5. Thermal image at 12 s after starting obturation (6 s after withdrawal of Engine Plugger). The maximal temperature rise was 18,6°C.

and titanium carrier Thermafil groups the temperature rise was less than 10°C in all cases. JS Quick-Fill technique resulted in root temperature rise of more than 10°C in one case out of 10 studied teeth, and thermo-mechanical compaction- in all cases (maximum length of time that the root surface temperature was elevated by more than 10°C was 47s). In the thermo-mechanical compaction group the temperature rise exceeded 20°C in 5 cases and 30°C in 2 cases.

Figures 2 – 5 demonstrate the typical colour images displayed by the thermal imaging software during root canal filling by thermo-mechanical compaction using Engine Plugger (group 4).

Discussion

It is generally accepted that a 10°C elevation in temperature on the root surface can irreversibly damage the periodontium [14, 15]. The present study showed that among the studied procedures only thermo-mechanical compaction by Engine Plugger resulted in temperature rise exceeding 10°C. In this method the mean temperature rise was 22.8°C with the minimal temperature rise of 12.0°C and maximum - 37.2°C. Somewhat higher figures were reported by Fors et al. [16], who applied McSpadden compactor at 8000 rpm during 4s for condensation. These authors also reported a higher temperature elevation in canals enlarged apically to 80 (32°C), when compared with teeth with canals enlarged to 40 (38°C).

Elevation in temperature due to the filling of the root canals using the thermo-mechanical method was studied by Hardie [17], who applied McSpadden compactor at 8000 rpm during 4 s. She observed a temperature rise of 14.63°C and 13.45°C, (both with and without the sealer) in the central part of root canal, and of 4.81°C and 5.54°C in the apical part of root canal. In the consecutive study Hardie investigated the temperature rise during thermo-mechanical compaction with the Engine Plugger rotating at 8000 rpm, 16000 rpm, and 16000 rpm after cold lateral condensation of gutta-percha in apical part of canal ("hybrid technique") [18]. Statistical analysis of the final results revealed no differences in temperature rise in the central part of the root between the studied methods (elevation from 15.19°C to 16.08°C). In the apical part of the root canal the temperature rises differed significantly and were as follows: 7.5°C (8000 rpm), 12.88°C (16000 rpm) and 2.48°C (16000 rpm after lateral condensation).

In the present study the temperature rise on the external surface of the root canal during root canal obturation using the JS Quick-Fill technique has also been studied. The recorded temperature rise in this technique was less than 10°C. Mean temperature rise was 7.7°C, and in only one case out of 10 studied teeth the temperature slightly exceeded 10°C. A significantly lower temperature rise in the JS Quick-Fill technique than in the conventional thermo-mechanical condensation with application of Engine Plugger may be explained by the shorter time of filling of the root canal in the JS Quick-Fill technique. In fact, the time of filling of the root canal, i.e. time of friction between compactor and gutta-percha or canal walls is half that of the thermomechanical condensation technique. Furthermore, in thermo-mechanical condensation with the application of Engine Plugger, the applied rotation rate was 10000 rpm, while in the JS Quick-Fill method the condenser rotation rate was only 4000 rpm, i.e. twice as slow as Engine Plugger.

In the present study we also evaluated the rise of the temperature on the external surface of the root caused by filling of root canals with solid core carrier coated with gutta-percha. Titanium and plastic carriers Thermafil obturators were applied in the present study. Both types of obturators caused a temperature rise significantly lower than 10°0C, namely 4.8°C and 4.5°C, respectively. A similar temperature rise was observed in the previous study, in which thermocouples were applied for measurements of temperature changes [19, 20]. In this report the temperature rise was also significantly lower than 10°C, ranging between 2.7°C and 6.2°C in the titanium carrier Thermafil obturator group, and between 2.4°C and 5.9°C in the plastic carrier Thermafil group. Low temperature rises were also observed by other authors who thermo-plasticised gutta-percha outside the oral cavity and then introduced it into the root canals [18,21,22]. Barkordar et al. [21] applied Ultrafil and Obtura injection systems and found the elevation of temperature on the external surface of the root to be 2-3°C. When a sealer was not used, the temperature rise recorded was greater for both systems (3-5°C). Somewhat higher temperature rises were observed by Hardie [18], who injected thermo-plasticised gutta-percha by Obtura

system and recorded temperature rise of 9.65°C in the central part of the root canal, and 6.03°C in the apical part of the root canal. Low temperature increase after injection of thermo-plasticised gutta-percha into the root canals observed in *in vitro* studies, confirm to some extent the results of *in vivo* studies performed in dogs by Gutmann et al. [22]. A maximum temperature rise recorded on the bone overlying the roots obturated with thermo-plasticised gutta-percha ranged from 0.2^0C to 1.1^0C.

The temperature rise on the outer root surface following the root canal obturation with thermo-plasticized gutta-percha was studied by Mc Cullagh et al. [23]. The authors compared the thermocouple and infrared thermographic analysis of temperature rise on the root surface during the continuous wave of condensation technique. They found that the above result in high temperatures on the external root surface. However, higher values were recorded when using the infrared thermal imaging system rather than the thermocouple. The value of infrared thermography as a technique for analysing patterns of temperature change was observed in this study [23].

The destructive effect of temperature elevation of more than 10°C on the bone is significantly influenced by time. To produce irreversible changes within tissues surrounding the tooth, the temperature elevation of more than 10^0C should last for at least 1 minute [9,10]. In the current study the temperature rise of more than $10^{\circ 0}$C was recorded only in case of thermo-mechanical condensation. Although that temperature elevation was not maintained more than 1 minute in any case, it is likely that *in vivo* it might resulted in damage of the surrounding tissues. This was proved by results of Sanders [24], who had found harmful effect of canal obturation by thermo-mechanical compaction of gutta-percha on the cementum on the lateral surface of the root and adjacent periodontal membrane and alveolar bone of the ferret caninum after time intervals of 20 days and 40 days. Twenty days after root canal filling 20% of the experimental teeth showed evidence of surface resorption of cementum and 40 days after thermo-mechanical compaction 28% of experimental teeth were affected by surface resorption and of these 22% exhibited ankylosis of alveolar bone to cementum. It should be underlined that Sanders [25] found the temperature rise on the external surface of root canal of 18.31^0C, the figure being lower when compared with the results of the current study.

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 thermo-mechanical compaction technique in root canal obturation.

Conclusions

Within the parameters of this in vitro study, the following conclusions can be drawn.

1.Thermomechanical compaction of gutta-percha using Engine Plugger generated a relatively high temperature rise on the outer root surface, at which damage to the periodontal tissues may occur.

2.The temperature rises produced during JS Quick-Fill and titanium or plastic carrier Thermafil techniques are below the critical level and there fore should not cause damage to the supporting structures of teeth.

3.The Thermafil carrier had no influence on the temperature rise on the outer root surface.

Acknowledgement

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15.Thermologischen Symposium am 27. April 2002

veranstaltet von der
Ludig Boltzmann Forschungsstelle für Physikalische Diagnostik und Österreichischen Gesellschaft für Thermologie

Wir danken der Fa. Schlumberger
für die freundliche Unterstützung der Veranstaltung

Programm

Standards in Thermal Imaging

Chair. Prof Dr. O.Rathkolb *(Wien),* Prof. Dr. F. Ring *(Pontypridd)*

9.00 Francis Ring *(Pontypridd)*
Protocol and sources of errorr in thermal imaging

9.20 Diskussion

9.25 Kurt Ammer *(Wien/Pontypridd),*
Reproducibility of standard positions used for image capturing within the standard protocol for thermal imaging

9.45 Diskussion

9.50 Piotr Murawski, Anna Jung, Francis E.J. Ring, Peter Plassmann, Janusz Zuber, Boleslaw Kalicki *(Warsaw/Pontypridd)*
*"*Image ThermaBase" - A Software Tool to Capture and Analyse Thermal Images

10.10 Diskussion

10.15 Kurt Ammer *(Wien/Pontypridd)*
Reliability of temperature readings from seleceted standard views for thermal imaging

10.30 Diskussion

10.35 -11.05 Kaffeepause

Recent Advances in Thermal Imaging

Chair: Prof DDr.K.Ammer *(Wien),* Prof. Dr.B.Wiecek *(Lodz*)

11.05 Boguslaw Wiecek, Slawomir Zwolenik *(Lodz)*
The Thermal Wave Method – Fundamentals and otential Applications in Medicine

11.25 Diskussion

11.30 T.Maca *(Wien)*
Infra red thermal imaging of arterial steal phenopmenon
11.50 Diskussion

11.55 Krzysztof Siniewicz, Boguslaw Wiecek, Jan Baszczynski, Slawomir Zwolenik *(Lodz)*
Thermal imaging before and after physical exercises in children with orthostatic disorders
12.15 Diskussion

12.20 Anna Jung, Boleslaw Kalicki, Janusz Zuber, Lech Gawron, Radoslaw Rówycki, Andrzej Stankiewicz *(Warsaw)*
Thermographic monitoring of ophthalmic surgery –extraction of cataract
12.40 Diskussion

13.00 Ende der Veranstaltung

Kurzfassungen der Vorträge

PROTOCOL AND SOURCES OF ERROR IN THERMAL IMAGING

EFJ Ring,

Thermal Physiology Lab, School of Computing,
University of Glamorgan, UK

Infra red thermal imaging is a powerful tool for the study of human body temperature. Modern thermal imaging systems are highly developed, and produce a digital two-dimensional image of skin temperature. In clinical practice there are a number of essential steps to apply the technique to the examination of the human body. There are now a number of factors recommended for clinical practice, which are needed for reliable and reproducible thermal imaging. Ignoring any one of these steps leaves the investigation open to error, and thus reducing the clinical acceptance and understanding of thermal imaging for medical applications. A knowledge of normal thermal patterns and temperatures is required, and awareness of clinical causes for those patterns to be changed, with increased or decreased temperatures.

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

The equipment must be of proven stability and accuracy, with the IR camera mounted on a parallax free stand. The examination room must be at a controlled temperature, usually from 20°C (used for inflammatory studies) to 24°C (used for vasomotor studies). Standard views of each required area of the body are essential, and the angle between camera and patient should be around 90° whenever possible. Standard distances are also advisable, since resolution (thermal and spatial) are usually decreased as scanning distance increases.

Image analysis must also be standardized. Regions of interest are frequently chosen on subjective parameters, which have been shown to be irreproducible even by the same investigator on the same image with repeated analysis. A protocol for defined regions of interest based on anatomical limits is the only sure way to minimize inter operator variation.

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

Examples will be given of false results in thermal imaging from failure of the investigator to understand the essential factors for the patient examination. Inadequate camera settings, or unproven stability after starting the camera have been found to significantly alter the final image. Errors resulting from subjective sizing and placement of regions of interest also show significant variations, all of which can be avoided. The importance of standardized reporting is evident when comparisons over time are required. In medical-legal issues, each image must be clearly identified, and shown to be taken under comparable conditions. No less a standard is required for normal clinical work with this technique. Knowledge of the normal patterns, and causes of hyperthermia or hypothermia are also important to both the technician and the physician using this technique.

Under correct conditions good reproducible images are obtained from which reliable thermal data can be extracted. Poor technique results in avoidable errors and artifacts, which confuse and even invalidate the clinical findings. A good knowledge of

thermal physiology is important, but is not enough, if protocols for image capture and analysis are not carefully followed. Modern hardware and software have transformed this technique in recent years, the limitations are more subjective than objective. User-friendly software can provide prompts to help the inexperienced user of thermal imaging.

REPRODUCIBILITY OF STANDARD POSITIONS USED FOR IMAGE CAPTURING WITHIN THE STANDARD PROTOCOL FOR THERMAL IMAGING

Kurt Ammer

Ludwig Boltzmann Forschungsstelle für Physikalische Diagnostik, Wien & School of Computing, University of Glamorgan, Pontypridd, UK

We have established a protocol for capturing a series of images that covers the whole body of a healthy subject. The protocol defines a healthy subject as someone who has had no problems with mobility, no difficulty in caring for himself, no restrictions in performing normal activities, experienced no pain or discomfort and was not suffering from anxiety or depression. A total of 24 views of the body were specified and within these views, a total of 87 regions of interest (ROI) were defined. The consistency of the standard views "Face", "Anterior Left Arm" and "Dorsal Hands" have been evaluated. The distance, measured in pixels, from the upper or the lower edge of the image to anatomical landmarks was used for evaluation. The cross section tool of Ctherm was used for the determination of distances.

Positioning for the face varied in very narrow way. However, any tilting of the head which may be an important source in defining reference values , was not assessed in this procedure, but can easily performed by flipping the region of interest (half of the face) of one side to the contralateral.

Hand views varied in a wider range as the positioning of the face. This might be caused by a higher varibility of hands between subjects. A different degree in spreading fingers may also contribute to this variation, as one definitions of positioning "middle fingers are parallel, thumbs do not touch" was not always followed

Related to the difficulty of positioning the arm, where 3 landmarks must be placed within the image, repeatability of this view was slightly better than the positioning of hands. Bending of the elbow at 90 degrees was not always performed and this may contribute to the variation of temperature readings.

The repeatability of standard views varies by the body regions investigated. However, standards views can be reproduced within a narrow range by different investigatiors. Reference values for the surface temperature of body regions based on images captured according to our protocol will mainly reflect the individual temperature variation.

"IMAGE THERMABASE" – A SOFTWARE TOOL TO CAPTURE AND ANALYSE THERMAL IMAGES

Piotr Murawski[1], Anna Jung[1], Francis E. J. Ring[2], Peter Plassmann[2], Janusz Zuber[1], Boleslaw Kalicki[1]

1 Thermology Laboratory, Paediatrics and Nephrology Clinic Military Medical School of Medicine in Warsaw, Poland

2 Thermal Physiology Laboratory, School of Computing, University of Glamorgan, UK

„*Image ThermaBase*" is a software package that was designed and implemented at the Thermology Laboratory of the Paediatrics and Nephrology Clinic, Military Medical School of Medicine in Warsaw, Poland. Its underlying concept is to enable the acquisition, processing and collection of examination results of medical thermal imaging. For that purpose, the package produces and stores thermal images together with medical data to allow the correct interpretation of images. The design of the system is aided by the Power Designer 7.5 CASE software tool and implementation is achieved in the Borland Delphi 5 Client / Server RAD environment. Sybase SQL Anywhere 6 was used as a database engine. First experiences suggest that "Image Therma Base" is as useful in every day medical practice as originally intended.

In this paper we show also a portion of the data requirement analysis. This analysis was made during the design period of the application. Its main goal was to include patient related data that are not usually considered to be part of a thermological examination. However, this additional information may be useful for clinicians involved in the evaluation and assessment of thermal images. Functionality and coefficients, which are computed by "*Image ThermaBase" software,* are also included.

In the last part of this paper an outline of ongoing and future work in collaboration with the Thermal Physiology Laboratory, School of Computing, University of Glamorgan, UK, is presented.

RELIABILITY OF TEMPERATURE READINGS FROM SELECETED STANDARD VIEWS FOR THERMAL IMAGING

Kurt Ammer

Ludwig Boltzmann Forschungsstelle für Physikalische Diagnostik, Wien & School of Computing, University of Glamorgan, Pontypridd, UK

Definition of regions of interest for temperature measurements must meet two challenges. Firstly, the region must capture as much information from the body area of interest, and secondly, positioning of the region must show a high degree of reproducibility. Together with the use of standard views reproducible temperature readings from regions of interest will reduce the variability of temperature to individual features of the subjects investigated.

Inter operator reliability of temperature measurements of 3 regions of interest on the view "Anterior Arm" was evaluated for 5 newly trained investigators-. In this experiment one thermal image of the anterior arm was given to these five people, who evaluated the thermal image twice following the protocol on standard views and definition of regions of interest. This evaluation resulted in deviations from the mean temperature of the region of interest between 0.001 and 0.10 °K at the elbow, between 0.06 and 0.27 at the upper arm and between 0.02 and 0.1 at the upper arm. Mean difference between 1st and 2nd measurement of individual investigators was 0.024.

In another experiemt, a circle, a square and an hourglass shaped area were applied to the same image in the standard view "Anterior Knee" by three newly trained investigators. Using the hourglass shape revealed a better precision of temperature readings than the other shapes. The reason for that might be that the alignment of the region of interest is easiest to perform with the hourglass shape.

Interrater reliability coefficient alpha and ICC of the ROI "Lower Arm", and the hourglass shaped ROI at the anterior knee confirmed excellent repeatability of ROI placement. The investigated regions of interest show high reliability and therefore reference values created in such way are highly credible.

THE THERMAL WAVE METHOD – FUNDAMENTALS AND POTENTIAL APPLICATIONS IN MEDICINE

Boguslaw Wiecek, Slawomir Zwolenik

Technical University of Lodz , Institute of Electronics , Computer Thermography Group , Poland

This paper shows the basis and preliminary applications of lock-in and pulse thermography for Non Destructive Testing (NDT). 3D thermal modelling is presented to confirm the usefulness of the simple analytical solutions, and to setup the experiments. For example, the thickness of thin film coatings is briefly described.

The proposed method is based measuring the thermal response as a result of delivering power to the investigated body. Human skin or the internal layer of tissues can be investigated by this method. According to the theoretical background, with this method we can penetrate inside of the body, not very deeply, but deep enough for many applications. We emphasize that the thermal process is dynamic, and in many cases very fast. Authors are aware that thermoregulation existing in the living body can reduce the thermal effect of irradiation, but as soon as modelling is added into the investigations, it seems that we can detect inhomogeneous parts of the human body on the skin or just below.

INFRA RED THERMAL IMAGING OF ARTERIAL STEAL PHENOMENON

T.H. Maca.

Departmentof Medical Angiology, University and General Hospital of Vienna, Austria.

Introduction: Peripheral arterial steal syndromes may be coexistent with cerebrovascular insufficiency in case of a subclavian artery stenosis. Post occlusive steal syndromes are of importance in the microcirculation. Further clinically relevant steal phenomena are seen in patients with haemodialysis shunts (HDS) or arterio-venous-fistulas (AVF), respectively.

Aim of the Study: To evaluate the clinical impact of infrared tele-thermography in various peripheral arterial steal phenomena.

Patients and Methods: We prospectively screened 30 persons: 10 patients with known subclavian artery stenosis/occlusion, 10 patients with HDS and compared them to 10 control subjects. The peripheral arterial perfusion of the upper extremity was measured by following techniques: Blood pressure and oscillometry, colour coded duplex scan (Acuson XP 128) and infrared imaging (Thermo Tracer TH1100, NEC, San-ei).

Results: Patients with subclavian artery stenosis or occlusion present usually with low mean arm temperature differences < 1.0 °C less compared to the contra-lateral extremity and show stable temperature gradients after stress tests (candle stick manoeuvre). A moderate temperature difference of 1.0-2.0 °C or a severe distal hypo-perfusion (difference > 2.0 °C) is more often diagnosed in HDS patients. The finger temperature distal to the AVF may increase or remain stable after stress tests (compensated) or show a further decline (de-compensated).

Conclusion: Infra red imaging of the upper extremity may be helpful in detecting patients at risk for critical peripheral arterial hypo-perfusion or ischaemia caused by arterial steal phenomenon

THERMAL IMAGING BEFORE AND AFTER PHYSICAL EXERCISES IN CHILDREN WITH ORTHOSTATIC DISORDERS OF THE CARDIOVASCULAR SYSTEM

Krzysztof Siniewicz[1] , Boguslaw Wiecek[2], Jan Baszczynski [1], Slawomir Zwolenik [2]

[1]Department of Pediatrics Military medical University of Lodz , Poland (Director : Professor Jan Baszczynski , M.D., Ph.D., F.I.C.A.)

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Orthostatic disorders of the cardiovascular system in children are frequently caused by transient disturbances of resistive and venous blood vessels . The purpose of this work was to estimate the usefulness of thermography in children with orthostatic

disorders of the cardiovascular system . The analysis was carried out of 30 children with orthostatic disorders. The control group consisted of healthy children.

The new generation Inframetrics 760 thermographic camera was used in this study. Every child with orthostatic disorders was subected to physical training for a period of 1 year to improve cardiovascular reactions. Thermal imaging was repeated after the period with exercises.

These studies showed confirmed differences in temperature distribution in children with orthostatic cardiovascular disorders compared to healthy children used as controls. Both the clinical symptoms of the orthostatic disorders and the temperature changes disappeared after physical exercises. Thermal imaging is a new, non-invasive method for examination of the cardiovascular system, which is very useful for the diagnosis of orthostatic disorders in children.

THERMOGRAPHIC MONITORING OF OPHTHALMIC SURGERY – EXTRACTION OF CATARACT

Anna Jung[1], B. Kalicki[1], J. Zuber[1], L. Gawron[2], R. Rówycki[2], A. Stankiewicz[2]

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2 Central Hospital Military School of Medicine, Clinical Ophtalmology

Aim: To follow the decay of the surface temperature of the eye during the stages of cataract surgery.

Method: The cataract operation was performed using phaco emulsification. Several phases of the surgical procedure were defined: topical anaesthesia, the pulsed emulsification of the nucleus lens, the irrigation and the aspiration of the cortical masses, the implantation PC – IOL and the first hour after the operation.

Research thermography was performed with the Inframetrics S. C. 1000 camera throughout all phases of surgery maintaining the standard conditions for thermal imaging.

Results were analysed by our own programme Image ThermaBase.

Results: After the topical anaesthesia and humidification of the cornea, the temperature on the eye surface decreased in the range of mean, minimal and maximal temperatures by 4,2 C. During the thermo-coagulation a localised increase of the temperature up to 64 C , lasting a few seconds was observed. In the next phase of the operation. the phaco-emulsification probe reached 34,8 C resulting in a very slight increase of the local temperature of 0,6 C. The measurement of the phaco- emulsification probe temperature in a test had produced a temperature increase of 3,3 C.

The changes of the temperature after the implantation (attachment) PC – IOL were insignificant and did not exceed 0,2 C. 15 minutes after the end of the operation, the surface of the eye warmed up by 1,2 C, and returned to baseline values one hour later.

Conclusion: 1.An increase of temperature during the cataract operation was only observed during diathermy. The change was local and persisted for few seconds.

2.The temperature of the probe increased by 0,6 C during the phaco-emulsification and was at a similar temperature level as the surrounding tissue.

Physiological measurement of Raynaud's phenomenon and peripheral microvascular disorders: from research into clinical practice

Friday 17th May 2002

&

Medical Infrared Thermography

Saturday 18th May 2002

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FRIDAY 17TH MAY 2002

PHYSIOLOGICAL MEASUREMENT OF RAYNAUD'S PHENOMENON AND PERIPHERAL MICROVASCULAR DISORDERS: FROM RESEARCH INTO CLINICAL PRACTICE

8.50 - 9.15 Registration and coffee, Sheila Sherlock Centre common room

9.15 WELCOME

SESSION 1: THE CLINICAL PICTURE.

Chair: AJ MacGregor

9.20 **The microvasculature in Rheumatology**
AL Herrick

9.40 **The clinical presentation and natural history of Raynaud's phenomenon**
N Kumar

10.00 **The epidemiology of Raynaud's phenomenon**
AJ MacGregor

10.20 **Vibration white finger**
T Lees

10.40 - 10.55 Coffee and exhibitors: common room

SESSION 2: PROVOCATION STUDIES

Chair: K Ammer

10.55 **Thermal and mechanical provocation tests for Raynaud's phenomenon and Vibration White Finger**
EFJ Ring

11.15 **Primary, secondary Raynaud´s phenomenon and vibration induced white fingers: Are they all the same ?**
K Ammer

SESSION 3: THERMOGRAPHIC TECHNIQUES AND TEMPERATURE MEASUREMENT 1

Chair: EFJ Ring, JM Engel

11.35 **The 'distal-dorsal difference': a thermographic parameter by which to differentiate between primary and secondary Raynaud's phenomenon**
ME Anderson

11.55 **Mean relaxation velocity after cold challenge - a selective parameter for diagnosis in peripheral vascular diseases**
JM Engel

12.15 **Assessment of Raynaud's phenomenon with a hand held infra-red scanner**
JR Harding

12.35 **The use of portable radiometry to assess Raynaud's phenomenon: a practical alternative to thermal imaging.**
KJ Howel

12.55 – 1.45 Buffet lunch and exhibitors: common room

SESSION 4: THERMOGRAPHIC TECHNIQUES AND TEMPERATURE MEASUREMENT 2

Chair: EFJ Ring, JM Engel

1.45 **The use of thermographic criteria to identify Raynaud's phenomenon in a population setting**
L Cherkas

2.05 **Vibration disease - thermological proof of vibration induced vasospasm**
JM Engel

SESSION 5: OPTICAL TECHNIQUES 1

Chair: F Khan, N Harris

2.25 **Image analysis of nailfold capillary patterns from video sequences**
TL Moore

2.45 **Photoplethysmography as a tool for assessing the microcirculation**
J Allen

3.05 **Iontophoresis and factors affecting responses measured by laser Doppler**
R Gush

3.25 **Laser Doppler flowmetry in the assessment of Raynaud's phenomenon**
F Khan

3.45 – 4.00 Tea and exhibitors: Common room

SESSION 6: OPTICAL TECHNIQUES 2

Chair: F Khan, N Harris

4.00 **Comparison of microvascular blood flow changes in the fingertips of Raynaud's phenomenon patients and normal subjccts following cold challenge**
MD Aldridge

4.20 **A laser Doppler imaging protocol for patients with connective tissue disease**
N Harris

4.40 **Variable wavelength laser Doppler imaging (LDI) in Raynaud's phenomenon (RP) – A new technique by which to study microvascular pathophysiology**
ME Anderson

SESSION 7: CLINICAL TRIALS

Chair: AL Herrick

5.00 **Topical application of a novel nitric oxide generating system in patients with severe Raynaud's syndrome**
A Tucker

5.20 SESSION 8: OPEN FORUM DISCUSSION

Standardisation of measurement protocols for study of the peripheral microcirculation

Chair: EFJ Ring, N Harris

5.40 CLOSE OF MEETING

THE CLINICAL PRESENTATION AND NATURAL HISTORY OF RAYNAUD'S PHENOMENON

N Kumar

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Raynaud's Phenomenon is a common condition that affects around 5% of the population. Patients may consult their General Practitioners, Rheumatologists or even Vascular Surgeons for help and advice. Of particular interest to Rheumatologists is the association of Raynaud's with the autoimmune rheumatic diseases.

This brief session will look at the clinical presentation and natural history of Raynaud's Phenomenon. Associated conditions will be outlined with potential hazards if unrecognised by the clinician. Finally an overview of treatments available will be given.

THE EPIDEMIOLOGY OF RAYNAUD'S PHENOMENON

AJ MacGregor

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Raynaud's phenomenon (RP) has a worldwide distribution. However, problems of definition and classification present a major challenge to accurately characterising its occurrence. Estimates of prevalence vary widely, ranging between 1 and 15%. Most studies show a consistent female excess. Although the prevalence of RP is reported to be higher in colder climates, temperature variation does not fully explain the observed geographical variation, and other risk factors are implicated. Genetic variation has an important contribution to susceptibility, as evidenced by an increased recurrence risk among relatives of affected cases and by concordance studies in twins which have indicated a heritability for the disease of around 50%. A range of constitutional and environmental risk factors have also been associated with the disease including body mass index, the presence of underlying cardiovascular diseases, and alcohol consumption. These effects may be modified by sex. RP is a common manifestation of a range of inflammatory and non-inflammatory diseases and can result from mechanical stresses (such as those caused by pneumatic equipment) and from the use of drugs. The proportion of subjects presenting with RP in isolation who progress to develop systemic disease is small and has been estimated to be as low as 0.2% per year. The risk of autoimmune disease rises in the presence of antinuclear antibodies and in those with nailfold capillary changes. RP itself may be a specific manifestation of a more widespread vasospastic process that includes migraine, atypical angina and pulmonary hypertension.

VIBRATION WHITE FINGER

T Lees

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Vibration white finger is a common clinical condition amongst manual workers who are exposed to the use of hand held vibrating tools. It is a prescribed disease within the Social Security Regulations (1985) and workers with the condition may claim disability payments from the Department of Social Security or may pursue litigation against their employers.

There are three components to the condition of vibration white finger, (or more accurately named as hand-arm vibration syndrome). These are vascular, neurological and musculo-skeletal, with the commonest symptoms being intermittent finger blanching due to vasospasm, tingling and numbness of the fingers and loss of manipulative dexterity.

The diagnosis of this condition is difficult and is based largely on patient history and examination. There are two common scales of disability used to grade patients with this condition and these are the Taylor Pelmear Scale and the Stockholm Workshop scale. The differential diagnosis includes primary Raynaud's disease, carpal tunnel syndrome, other neurological conditions e.g. diabetic neuropathy, and cervical spondylosis.

Many neurological and vascular tests exist that have the potential to aid the diagnosis of this condition but many of these require the subjective response of the patient and have a low sensitivity and specificity. Tests include thermal aesthesiometry, vibrotactile threshold, cold provocation, and the Purdue Peg Board Test. The use and benefits of these investigations remain controversial although more data relating to their use may soon be available from the widescale testing of miners currently claiming compensation.

THERMAL AND MECHANICAL PROVOCATION TESTS FOR RAYNAUD'S PHENOMENON AND VIBRATION WHITE FINGER

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Medical Imaging Research Group, School of Computing, University of Glamorgan, Pontypridd. CF37 1DL. UK

Provocation tests to induce a thermal challenge to the extremities have been developed by a number of investigators who require an objective assessment of the response to a thermal stress. Skin temperature can be monitored by contact and non contact methods. Thermocouples fixed to the skin have been used to monitor fingertip temperature. Infrared thermal imaging or infrared radiometry allows the skin temperature to be measured without contact. This is efficient as the skin is a highly efficient black-body radiator.

All thermal detection techniques require the subject to be stabilized in a temperature controlled environment. The imaging technique has advantages in the speed by which the temperature distribution can be captured. It also provides possibilities for dynamic recording of thermal reactions as most modern systems operate at video rate – 50 frames per second or higher [1]. Modern thermal imaging systems can give temperature resolution up to 0.01°C, with spatial resolution resolving 1mm spot target at 0.5 meter.

Most investigators use similar techniques and agree on the need for standardization and equilibration of the patient prior to a thermal provocation test. After a baseline thermal image, thermal challenge usually involves immersing the hands (and feet in some cases) in water at a fixed temperature for a fixed time period. A mild challenge, water at 20°C for 1 minute is favoured by a number of centres in Rheumatology, especially with connective tissue diseases. The recovery is monitored in a reasonably short time (10-20 minutes).

In Vibration White Finger, a thermal stress is part of an accepted protocol where immersion of the hands for 5 minutes in water at 15°C has been shown to lower digital systolic pressure by 40% [2]. In the author's experience, it has been possible to show a reduction in thermal recovery in affected fingers after a mild stress at 20°C in a few cases. However, exposing the fingertips to a vibrating surface has yielded more dramatic effects, which can be monitored by infrared thermal imaging. More work is required to examine the range of frequencies and duration of experimental exposure before the systematic establishment of a normal range of responses, which could be used as part of a screening or test procedure for clinical studies.

References

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PRIMARY, SECONDARY RAYNAUD´S PHENOMENON AND VIBRATION INDUCED WHITE FINGERS: ARE THEY ALL THE SAME ?

K.Ammer

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The diagnosis of Raynaud´s phenomenon is based on episodic triphasic changes of skin colour, mostly provoked by coldness. Decreased temperature of the fingers and the poor ability to cope with a cold environment have become a surrogate sign for vaso-spastic disease. However, subjects showing skin changes and those with low finger temperatures may be two different entities, with a large overlap of symptoms. This becomes obvious from the fact that sufferers from primary Raynaud´s disease often present with a normal reaction to a mild cold water challenge.

The hand-arm vibration syndrome is an accepted disorder in industrial and occupational medicine. Such a diagnosis entitles the sufferer to claim compensation in most European countries and in the USA. Work exposure to vibrating tools may affect the peripheral nerves and the vascular tone. In contrast to the typical sequence of colour changes from white, through blue, to red in Raynaud´s phenomenon, only blanching of the fingers is required to establish vibration induced vasospastic disease. Symptoms of nervous involvement such as tingling or numbness may appear together or precede the vascular signs of the disease. The interaction between nerve damage and vasospasm is still under debate.

Thermal images of typical cases classified as primary, secondary Raynaud´s phenomenon and of vibration induced white fingers will be presented. The coincidence of changes of skin colour and the occurrence of diagnostic thermal gradients of the fingers will be discussed.

THE 'DISTAL-DORSAL DIFFERENCE': A THERMOGRAPHIC PARAMETER BY WHICH TO DIFFERENTIATE BETWEEN PRIMARY AND SECONDARY RAYNAUD'S PHENOMENON

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1 University of Manchester Rheumatic Diseases Centre, Hope Hospital, Salford, M6 8HD, and

2 Arthritis Research Campaign Epidemiology Unit, University of Manchester Medical School, Manchester, Ml3 9PT.

*Aim*To evaluate a) all parameters measured during thermographic testing of patients with Raynaud's phenomenon, and b) the hypothesis (suggested from a pilot study from our group), that a temperature difference of >1°C (fingers cooler than dorsum) between fingertips and dorsum of the same hand (distal-dorsal difference or DDD) at 30°C room temperature suggests underlying structural vascular disease. The latter may help to differentiate between primary RP (PRP) and RP secondary to systemic sclerosis (SSc).

Patients and Methods:We carried out a retrospective analysis of case notes and thermography results of patients who had attended our vascular laboratory for standard thermographic testing of the hands (imaging at 23°C and 30°C room temperatures, plus cold challenge).

Results

	SSc	PRP	Total
DDD>1^0C at 30^0C (1 or more digits)	31	8	39
DDD£ 1^0C at 30^0C (all digits)	14	48	62
Total	45	56	101

A DDD>1°C at 30°C has 86% specificity and 69% sensitivity in identifying the patient with RP secondary to SSc. On logistic regression (age /sex/ smoking adjusted), individual DDD (at 23 and 30°C) and rewarming curve parameters were significantly different for the PRP and SSc groups. Combined logistic regression of all DDD and rewarming curve variables plus age yielded
a) older age,
b) DDD>1°C at 30°C and
c) smaller maximum rewarming curve gradient.

Conclusions: A DDD>1°C°at 30°C is reasonably specific for underlying structural vascular disease and, in combination with older age of patient, may complement other investigations in alerting the clinician to an increased likelihood of underlying connective tissue disease.

ASSESSMENT OF RAYNAUD'S PHENOMENON WITH A HAND HELD INFRA-RED SCANNER

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Raynaud's phenomenon is an intermittent abnormal spasm of the peripheral arterioles of the limbs after exposure to cold or emotional stimuli, resulting in painful or cold digits and clumsiness. Will et al demonstrated in 1992 that average finger to wrist temperature indices of minus 4 or greater acquired from an infra-red radiometric camera are indicative of Raynaud's phenomenon. Infra-red cameras and their inherent hardware and software can be expensive and inconvenient for use in the Outpatient Clinic or General Practitioner setting.

The aim of this study was to compare the temperature index obtained with a thermal imaging camera with that obtained using a hand held infra-red temperature scanner.

20 patients with suspected Raynaud's phenomenon undergoing thermological examination in a specialist clinic using an infra-red camera (Agema Thermovision 782) were also assessed using a hand held infra-red temperature scanner (Exergen Dermatemp). A temperature index was calculated for each hand using measurements before and 10 minutes after a cold challenge (immersion of gloved hands in water at 20 degrees C for 1 minute), using the average temperature of the fingers minus the wrists for the thermal image and the average of 12 finger minus 8 wrist temperature measurements taken with the infra-red scanner.

12 out of the 20 patients assessed by the infra-red camera and by the hand held infra-red temperature scanner demonstrated index values of minus 4 or greater indicating Raynaud's phenomenon. The hand held infra-red scanner gave a comparable result to the 'Gold Standard' of assessment with the infra-red camera. This could allow the use of hand held infra-red temperature scanners in Outpatient Clinic or General Practitioner settings, providing appropriate staff training is given, and a suitable environment is available for thermal assessment.

THE USE OF PORTABLE RADIOMETRY TO ASSESS RAYNAUD'S PHENOMENON: A PRACTICAL ALTERNATIVE TO THERMAL IMAGING.

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*Department of Rheumatology, Royal Free Hospital, Pond Street, London NW3 2QG UK

Obectives: To compare the performance of a portable radiometer with thermal imaging and to assess the potential for radiometry to provide a practical alternative for assessing vascular responsiveness in Raynaud's Phenomenon.

Methods: Subjects comprised 18 patients with diagnosed Raynaud's Phenomenon (RP) and 19 non-RP subjects. A thermal imager (Starsight) and a portable radiometer (Cyclops) measured digital temperature at baseline and the subsequent drop and rise in temperature following a cold challenge test.

Results: The intra-class correlations between the two instruments for all three measures exceeded 80%. The overall performance of each instrument was almost the same, with the Starsight thermal imager correctly classifying 84% of subjects as RP or non-RP and the Cyclops portable radiometer correctly classifying 86% of subjects. The sensitivity of the thermal imager was 83%, compared with 89% sensitivity for the portable radiometer, with the specificity of both instruments 84%. The positive and negative predictive values of the thermal imager were 83% and 84% respectively; the comparative values for the portable radiometer being 84% and 89%.

Conclusions: Both instruments performed equally well and the differences between them in their absolute measurements did not influence their ability to detect RP. Portable radiometry provides a practical, cheap, accurate and reliable alternative to thermal imaging and has the potential to be applied to a range of clinical and epidemiological settings.

THE USE OF THERMOGRAPHIC CRITERIA TO IDENTIFY RAYNAUD'S PHENOMENON IN A POPULATION SETTING

L Cherkas, L Carter, T Spector, KJ Howell*, CM Black*, AJ MacGregor

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Obective: To assess the value of thermographic measurements of digital skin temperature after cold challenge in classifying subjects with Raynaud's Phenomenon (RP) in subjects ascertained from a population setting.

Methods: 175 subjects with RP (reporting a history of two or more colour changes including white on exposure to cold) and 404 normal subjects were subjected to a 60-second cold challenge test, with water at 15°C. Digital temperature measurements were taken at baseline, immediately post-immersion and 10 minutes after immersion using a portable radiometer.

Results: The average temperature of the fingers of RP subjects at baseline was significantly lower than that of normal subjects (28.30 ± 0.26°C v 29.97 ± 0.15°C, $p<.01$: t-test). Baseline skin temperature was a significant predictor of RP; however, the fall in temperature on immersion and the subsequent rewarming rate provided no additional information. Only 4% of normal subjects had baseline digital temperatures below 24°C. The majority of subjects reporting symptoms of RP did not have particularly cold hands.

Conclusion: Baseline skin temperature can predict the occurrence of RP in subjects drawn from the general population. The cold challenge test itself is of limited additional value for classification. Although objective temperature measurements show little power overall to discriminate between RP and non-RP subjects, detecting low baseline digital temperature may be a useful adjunct to clinical history in classifying the disease

IMAGE ANALYSIS OF NAILFOLD CAPILLARY PATTERNS FROM VIDEO SEQUENCES

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Video capillary microscopy is a valuable tool in the assessment of Raynaud's phenomenon (RP) and systemic sclerosis (SSc). Previous work relied on storage of the output from a video microscope onto VHS videotape and digitizing a single video frame for analysis. The major drawback to this approach is that the capillary walls are transparent with only red blood cells visible; therefore, plasma filled gaps can render the capillaries incomplete at any one instant. A method of integrating information from a number of sequential video frames was developed, based on linear feature detection to register adjacent overlapping nail fold images and build up a composite mosaic image of the capillary network. Capillary dimensions were measured made using electronic calipers.

The new technique provides improved images for qualitative analysis and allows measurement of dimensions in a given individual over time. We are currently assessing the sensitivity and reproducibility of our technique. Results from intra and inter observer variability studies will be presented.

PHOTOPLETHYSMOGRAPHY AS A TOOL FOR ASSESSING THE MICROCIRCULATION

John Allen, Alan Murray

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The optical technique of photoplethysmography (PPG) has been used for many decades to assess a variety of cardiovascular parameters including tissue oxygenation, heart rate, vasomotor function, regional pulsatility and vessel compliance. PPG has several strengths and allows the simple, non-invasive, and low cost measurement of changes in microvascular blood volume with each heart beat. The technique still tends to be employed as a research tool partly because the waveforms obtained can be difficult to describe, and that the interaction processes of near-infrared radiation with tissue are not fully understood. However, the potential information content of the waveforms, the recent improvements in opto-electronic technology, and advancements in computer analysis techniques currently make PPG an accepted tool in the vascular measurement environment. The PPG technique can be used to study waveforms from single or multiple measurement sites simultaneously. For example, good quality pulse waveforms can be obtained from the ear lobes, and the tissue pulps of the fingers and toes. The catchment volume of PPG probes can provide information relating to both the 'nutritional' and 'thermoregulatory' components of the microcirculation. The characteristics of PPG waveforms have been shown by the authors to be body site specific. In healthy subjects the features of bilateral (right and left) similarity and segmental differences (head to foot) are the usual presentation. These features are evident for short term beat-to-beat changes in pulse and also over much longer periods of many minutes - the low frequency 'vasomotor' information contained in the latter is of particular interest in the study of the microcirculation. The authors will also describe the application of the PPG technique both for single site and multi-site assessments. Examples will be given of the measurement

and analysis of PPG pulses for the study of spontaneous and deep inspiratory gasp-induced vaso- constrictor waves, determining the relationships between skin temperature and PPG pulse following a *mild* cold challenge, quantifying bilateral changes in pulse during reactive hyperaemia, and studying multi-site pulse changes with age and in patients with vascular diseases. These examples will consider the methodology of data collection and subsequent PPG pulse analysis. The need for well-considered microvascular measurement protocols will also be highlighted.

IONTOPHORESIS AND FACTORS AFFECTING RESPONSES MEASURED BY LASER DOPPLER

Rodney Gush

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Iontophoresis is a low voltage, non-invasive technique to overcome the epidermal barrier to get drugs into the skin quickly. The dose of drug iontophoresed depends on the drug, the electric current and the duration. It provides relatively high local concentrations of drug without systemic effect: e.g. 50 microAmps for 20 seconds delivers less than 2 micrograms of acetylcholine (ACh).

Laser Doppler (LD) monitoring or imaging is used to assess the microvascular responses of skin to drugs iontophoresed, often measured through the solution. Many LD/iontophoresis protocols have been described: multi-period protocols enable cumulative dose response curves to be observed over a range of currents and durations (standard protocols have yet to be defined). Routine uses include assessment of endothelial function with ACh and smooth muscle function with sodium nitroprusside. The technique avoids vasodilation due to local trauma, as caused by injection, but the rate of iontophoresis should be limited to avoid the 'galvanic' effect: a non-specific response, recently shown to be related to applied voltage.

Reproducibility of LD measurements during iontophoresis depends on the equipment used and the protocol followed: COV between 6% (MoorLDI) and 40% (2-fibre probe) have been reported.

In addition to direct measurement (at the site of drug delivery) measurements can be made at adjacent sites to assess axon reflex flare: e.g. to assess peripheral autonomic neuropathy.

Examples of recent applications of LD/iontophoresis will be reviewed.

LASER DOPPLER FLOWMETRY IN THE ASSESSMENT OF RAYNAUD'S PHENOMENON

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A widely used technique for measuring skin microvascular blood flow non-invasively is laser Doppler flowmetry (LDF). The aim of this presentation will be to review the applications of LDF in Raynaud's phenomenon.

The use of single-point LDF to examine skin microvascular function in patients with Raynaud's phenomenon has been used largely for research purposes. Experimental protocols and patient groups have differed in the various studies but nevertheless, the general findings have shown reduced skin perfusion in patients compared with control subjects. The use of scanning laser Doppler imaging has confirmed abnormalities of the skin microvasculature in patients with primary Raynaud's disease and secondary Raynaud's syndrome. However, it has not been possible to distinguish between patients with primary Raynaud's disease and secondary Raynaud's syndrome using either of these techniques because of the large overlap in measurements between groups. Other studies using laser Doppler imaging have shown that rheological factors might be implicated in abnormal cold reactivity.

With respect to endothelial dysfunction and nitric oxide activity, abnormal vascular responses have been reported to both acetylcholine (endothelium-dependent vasodilator) and sodium nitroprusside (endothelium-independent vasodilator) in the digits of patients with Raynaud's phenomenon. One proposed mechanisms for these abnormal responses is increased oxidative stress, which has been known to attenuate nitric oxide activity. Abnormalities in endothelial function and nitric oxide activity have not, however, been a consistent finding, which might reflect the site (e.g. finger v forearm) at which assessment are made in different studies.

While LDF is a very useful instrument for investigating the underlying mechanisms of Raynaud's phenomenon, it still needs to be established whether it has real utility for clinical evaluation.

COMPARISON OF MICROVASCULAR BLOOD FLOW CHANGES IN THE FINGERTIPS OF RAYNAUD'S PHENOMENON PATIENTS AND NORMAL SUBJECTS FOLLOWING COLD CHALLENGE.

MD Aldridge, KJ Howell[1], RE Smith, E Bowers[2], A Jehangir

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[1] Department of Rheumatology, Royal Free Hospital, London
[2]Regional Medical Physics Department, Freeman Hospital , Newcastle upon Tyne

This study establishes the normal laser-Doppler (LDF) response to cold challenge of the hands, and compares it to that of Raynaud's phenomenon patients.

25 Raynaud's phenomenon patients and 25 sex-matched control subjects have so far been analysed.

After a period of acclimatisation, laser Doppler probes were attached to the pulp of the middle finger of each hand, and each subject was monitored

for five minutes to establish a baseline flux. The subject then immersed both hands in a waterbath at a temperature of 15±1°C for one minute, keeping the laser-Doppler probes in place. The flux was then measured for ten minutes post cold challenge.

To date, analysis has been undertaken on LDF measurements recorded at baseline, one minute and 5 minutes post cold challenge. There was found to be no significant difference in baseline flux between Raynaud's patients and normal subjects. Significant differences in flux were found between Raynaud's and normal subjects at one minute ($P<0.01$) and five minutes ($P<0.05$) post cold challenge. Although differences in erythrocyte speed were not observed at any of these time points, significant differences in cell concentration ($P<0.01$ at all 3 time points) were found.

Flux is the product of red cell concentration and speed. This preliminary analysis suggests that differences in flux levels observed between Raynaud's patients and control subjects arise predominantly from differences between the two groups in red cell concentration. Laser-Doppler concentration may therefore be a more effective measure for discriminating Raynaud's subjects from normals than either the flux or speed signals.

A LASER DOPPLER IMAGING PROTOCOL FOR PATIENTS WITH CONNECTIVE TISSUE DISEASE

Nigel Harris, David Elvins, Neil McHugh

Royal National Hospital for Rheumatic Diseases and Department of Medical Sciences, University of Bath, Bath BA1 1RL

Primary Raynaud's phenomenon (PRP) is a condition characterised by reversible episodes of ischaemia, but normal maximum (hyperaemic) blood flow. In contrast, Raynaud's phenomenon secondary to systemic sclerosis (SSc) is associated with irreversible structural changes within the vasculature, abnormal vascular regulatory responses and reduced maximum blood flow. Early detection of vascular changes is an essential element of the diagnosis of these patients and Laser Doppler flowmetry, combined with cold challenge or vasoactive agents, has proved to be a particularly sensitive tool for studies of the vascular dynamics.
We have carried out a review of papers on Medline from 1990, using the terms 'systemic sclerosis and blood flow'. There are more than 20 studies, but there is no consensus as to whether it is possible to discriminate between PRP and SSc using laser Doppler measurements. This is due to differences in the test protocols, small numbers of patients and variations in the type of disease and duration. If we are to make progress with the diagnosis and management of these conditions, there is a clear need for agreed test protocols so that multicentre studies can be carried out. We have developed 4 simple tests based on; cold challenge, vasodilator response to acetylcholine iontophoresis, maximum hyperaemic response and contralateral vasoconstrictor response. The protocol, together with some preliminary results will be presented.

VARIABLE WAVELENGTH LASER DOPPLER IMAGING (LDI) IN RAYNAUD'S PHENOMENON (RP) – A NEW TECHNIQUE BY WHICH TO STUDY MICROVASCULAR PATHOPHYSIOLOGY

ME Anderson[1], TL Moore[1], T King[2], AL Herrick[1]

University of Manchester: [1]Rheumatic Diseases Centre, Hope Hospital, Salford, M6 8HD. UK,
[2] Department of Laser Physics and Astronomy.

Background Different wavelengths of laser potentially allow study of different levels of the microvasculature. Our aim was to use this newly developed research tool to study primary and secondary RP.

Methods We scanned the right hand (dorsum) of 15 control subjects, 15 primary RP (PRP), 10 undifferentiated connective tissue disease (UCTD) and 21 systemic sclerosis (SSc) patients, with standard red (633nm) and specially developed green (532nm) LDI, at baseline (after acclimatisation at 23°C) and after local heating.

Results On both green and red LDI, in comparison to controls, greater flux increases in response to heating were found in UCTD (green $p=0.041$, red $p=0.004$) and SSc (green $p=0.002$, red $p=0.007$) groups, whilst the UCTD group also had lower flux at baseline (green $p=0.048$, red $p=0.001$). On green LDI, greater flux response of the dorsum of the hand in response to heating was found in PRP patients compared to controls ($p=0.015$). [Mann Whitney U]

Conclusions Abnormalities of microvascular flow exist at different levels of the skin in both UCTD and SSc, as greater flux increase in response to heating with both red and green LDI implies relative resting peripheral vasoconstriction of the dermal microcirculation. Green LDI suggests minor abnormalities in resting vascular tone cause decreased flow in the superficial dermal capillaries in patients with PRP. Variable wavelength LDI is an exciting tool for study of microvascular pathophysiology and warrants further investigation.

TOPICAL APPLICATION OF A NOVEL NITRIC OXIDE GENERATING SYSTEM IN PATIENTS WITH SEVERE RAYNAUD'S SYNDROME

A Tucker [1,2], Pearson R [2], Benjamin N[2]

The Ernest D. Cooke Clinical Microvascular Unit [1], St. Bartholomew's Hospital, Department of Clinical Pharmacology [2], William Harvey Research Institute, Bart's & The Royal London School of Medicine and Dentistry.

Aims. The aim of this study was to determine the effect of a topical nitric oxide (NO) generating system on the skin microcirculatory blood flow of the

forearm and fingers of patients with severe primary Raynaud's Syndrome (RS).

Methods. The effect of topical application of NO-generating gel was measured in 20 RS patients and 10 healthy subjects. The NO-generating system was prepared by mixing two solutions. The first KY jelly™ and sodium nitrite (5% w/w) and the second KY jelly ™and ascorbic acid (5% w/w). 0.5 ml of each solution was applied and mixed on the skin of the forearms and the finger pulps. The changes in skin microcirculatory volume were measured simultaneously by infra-red photoplethysmography and microcirculatory velocity by laser Doppler fluxmetry against placebo treatment.

Results. Forearm skin blood flow increased markedly following topical application of a NO-generating gel in both healthy volunteers ($p<0.01$) and RS patients ($p<0.001$). Application of NO-generating gel resulted in an increase in the finger pulp microcirculatory velocity in RS patients ($p<0.01$) and the healthy subjects ($p<0.01$), which was sustained after gel removal in the RS patients ($p<0.05$).

Conclusion. This study suggests that although micro-cir culatory function is impaired in primary Raynaud's syndrome, topical application of a NO-generating system is able to restore blood flow to that seen in healthy subjects at rest.

SATURDAY 18TH MAY 2002.
MEDICAL INFRARED THERMOGRAPHY

9.00-9.25 Registration and Coffee, Sheila Sherlock Centre Common Room

9.25 WELCOME
from KJ Howell, meeting organiser

9.30 KEY NOTE ADDRESS

The historical development of infra red thermal imaging in medicine
EFJ Ring

SESSION 1: INSTRUMENTATION AND CALIBRATION

Chair: G Machin

10.00 **Temperature traceability issues in medical thermography**
B Chu

SESSION 2: THERMAL IMAGING OF THE BREAST

Chair: KJ Howell

10.20 **Breast tumour detection using functional parametric thermographic imaging**
DK Harrison

10.40-11.00 Coffee and exhibitors: Common room

11.00 KEY NOTE ADDRESS

Thermography in surgery
Professor Sir Alfred Cuschieri

SESSION 3: THERMOGRAPHY IN RHEUMATOLOGY

Chair: EFJ Ring, JM Engel

11.30 **The relaxation thermogram after cold challenge test - graphical representation of relaxation velocities**
JM Engel

11.50 **The role of thermography in the diagnosis of reflex sympathetic dystrophy in clinical & forensic rheumatology**
AG White

SESSION 4: THERMOGRAPHY IN NEUROLOGY

Chair: PA Campbell

12.10 **Thermography in nerve root diseases**
P Dub

12.30– 1.30 Buffet lunch and exhibitors: Common room

1.30 KEY NOTE ADDRESS

The detection of human deception using thermal imaging.
JA Levine

SESSION 5: THERMAL PHYSIOLOGY

Chair: K Ammer, JR Harding

2.00 **A database of normal thermal images of healthy subjects**
K Ammer

2.20 **The effect of somatotype on thermograhic imaging of the back and whole body**
AI Heusch

2.40 **IRT - a valuable tool for evaluation of infrared radiation therapy (water filtered IR-A, broad band IR and low dose IR)**
JM Engel

3.00 – 3.20 Tea and exhibitors: Common room

SESSION 6: THERMOGRAPHY IN VASCULAR DISEASE

Chair: DK Harrison, KJ Howell

3.20 **Thermal imaging in the investigation of deep vein thrombosis**
JR Harding

3.40 **Thermographic imaging and skin oxygen saturation measurements applied to routine clinical prediction of amputation level viability**
DK Harrison

4.00 **Thermal imaging in diabetic foot ulceration**
JR Harding

SESSION 7: THERMOGRAPHY IN DERMATOLOGY

Chair: EFJ Ring

4.20 **The cold provocation test and Epidermolysis Bullosa Simplex**
AI Heusch

4.40 CLOSING ADDRESS

Future prospects for medical infrared thermography
KJ Howell

4.50 – 5.00 Update and discussion forum for UKTA Medical Section members

THE HISTORICAL DEVELOPMENT OF INFRA RED THERMAL IMAGING IN MEDICINE

EFJ Ring

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The observation of human body temperature and its relation to disease is as old as medicine itself. However, thermometry did not develop much before the 16th Century, and remained imprecise for over a hundred years. The first major progress to be made in the systematic study of body temperature was made by Carl Wunderlich in Leipzig. His treatise documented the basis of the clinical use of temperature recordings, and many hundreds of case studies were reported which were supported by charts of temperature changes from the patients studied, during onset, and progression of disease. Wunderlich also proposed the well-known clinical thermometer, which was designed to operate around 37°C with a constriction to act as a maximum thermometer.

Electrical sensors, thermocouples, thermistors and thermopiles were developed later. Many early physiological studies in the late 19th and early 20th century were made with multiple thermo-electric devices and multi-channel pen recorders to make a record.

Non-contact measurement became possible through the discovery and development of infrared radiation. In 1800 the heating part of the spectrum was identified, and in 1840 the first thermogram recorded using solar radiation. In the late 1950s indium antimonide detectors for remote sensing became available to industry and medicine. The Smith's Pyroscan was the first British camera to be manufactured for medical applications in 1960. Later developments brought faster scan times, and oscilloscope displays. Other infrared detectors including cadmium mercury telluride were introduced. More recently, uncooled and cooled focal plane array systems have been introduced which offer high speed and high-resolution imaging. Computer image processing has transformed the practical use of thermal imaging, with reliable facilities for temperature measurement.

Improved infra red optics and advanced processing for image manipulation have brought this technology to a high standard in under 50 years, and more improvements and miniaturization can be expected.

TEMPERATURE TRACEABILITY ISSUES IN MEDICAL THERMOGRAPHY

Brian Chu, Graham Machin.

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Manufacturers generally supply thermal imaging cameras in a calibrated state. Their performance is usually checked by the users either with their own in-house reference sources or by returning the imager to the manufacturer for re-calibration. This approach can have several drawbacks (a) If regular re-calibration isn't performed it is not possible to have confidence in the measurements performed by the imagers. (b) In-house calibration sources are not always traceable to the International Temperature Scale of 1990 (ITS-90), leading to a multiplicity of temperatures scales based upon the per- formance of the local standard. (c) Returning the imager to the manufacturer is no guarantee that rigorous traceability to ITS-90 has been achieved unless manufacturers calibration services are ISO 17025* accredited. In response to this issue, the UK Department of Trade and Industry (DTI) has funded a project to develop a blackbody reference source whose specifications are optimised for the calibration and traceability requirements of the medical thermography user community.

This paper consists of three parts. First an outline of the project is given. The second part contains the results of a survey, which was sent out to various

medical thermography users both within and outside of the UK. The purpose of this survey was to identify current and future requirements for a reference source. Finally a proposed design for a suitable reference source is given. Once the source is constructed it will be circulated to two user groups within the UK who will test and evaluate the source to ensure it meets the functional and traceability requirements of the majority of the medical thermography user community.

* ISO 17025 is the recognised International Standard for demonstrating that a laboratory has the requisite competence and equipment to undertake traceable calibrations.

BREAST TUMOUR DETECTION USING FUNCTIONAL PARAMETRIC THERMOGRAPHIC IMAGING

DK Harrison, AIM Cook†

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Statistics show that 150,000 women die of breast cancer worldwide each year. According to the American Cancer Society, mammography misses 10 to 15% of breast cancers, but about 50% of diagnostic surgical open biopsies find non-malignant tumours. This combination of false positive and negative results, together with the desire to detect very small tumours (less than 1cm if possible) means that there is a need for improved non-invasive methods for breast cancer detection.

Medical infrared thermographic imaging has been applied in the past to the detection of breast tumours but the technique resulted in an unacceptable number of false positive results and failed to gain wide acceptance.

In the present study, thermographic images were recorded dynamically during the reheating of skin following cooling to 25°C. Pixel-by-pixel component analysis of the images was carried out offline in order to construct the functional parametric images. Normal volunteers were investigated using dynamic thermographic imaging of the left volar forearm skin under different experimental conditions. In a further pilot study 6 patients with known tumours were studied in order to investigate whether the lesions could be characterised by abnormalities in the parametric images.

The resultant parametric images display information on the heterogeneity of skin blood flow in the areas examined. The heterogeneities observed are very much greater than those obtained with static thermographic images and characteristic patterns appear to emerge under the different experimental conditions. In particular, the early parametric images of breast tumours indicate clear characteristic patterns.

DYNAMIC THERMOGRAPHY AS AN ADJUNCT TO ENERGISED SURGERY

Sir Alfred Cuschieri, PA Campbell

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We have used dynamic infrared thermography in two distinct surgical contexts, (i) the laboratory based optimisation of energised instrument/device performance, and (ii) the real time in-vivo observation of energised [electro- and ultrasonic based] surgical instrumentation. The goal of both studies was to ensure that collateral damage induced by prolonged tissue heating is minimised, and therefore that the incidence of any subsequent complications is reduced.

The focus of the first study relates to our use of shape memory alloy (SMA) staples as an alternative to conventional suture line for minimally invasive [keyhole] procedures. This application is attractive as suturing in a keyhole environment is a particularly laborious and time consuming procedure. We will illustrate the principle of operation via infrared movies of the activation process, and highlight the method whereby quantitative dynamic thermography can aid instrument design and optimisation for in-vivo procedures. Computational finite element based analyses will also be illustrated

In the second part of the presentation, we will show the results of two large scale in-vivo case studies where thermography was used to monitor, in real time, the extent of thermal spread during activation of energised surgical devices. Subsequent histological analysis is compared with the recorded thermograms in order to correlate the thermal exposure with actual damage. We found that ultrasonic based devices can produce thermal collateral damage over wide areas of several centimeters or greater. However, with bipolar electrosurgical devices incorporating an intelligent feedback system, thermal spread can be as low as 0.65mm on certain vessels, and not greater than 1.8mm on vessels with diameters of up to 5mm.

We will illustrate the vessel dependent performance of one particular device (Ligasure), together with a thermographic based guide to best handling for optimum results.

THE ROLE OF THERMOGRAPHY IN THE DIAGNOSIS OF REFLEX SYMPATHETIC DYSTROPHY IN CLINICAL & FORENSIC RHEUMATOLOGY

AG White & KJ Howell

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Reflex Sympathetic Dystrophy (RSD), otherwise termed algodystrophy or complex regional pain syndrome I, is highly variable in both its presentation and severity. It involves most commonly upper or lower limb extremities and may follow trivial in-

jury or major trauma, presents to many different specialties and is frequently diagnosed late, due to lack of sufficiently characteristic clinical signs.

In severe cases a careful history and meticulous examination will secure the diagnosis. When few physical signs are present yet pain is severe, investigations may fail to confirm the diagnosis as abnormalities present on radio-isotope scintiscan may have other causes. However the combination of the demonstration of increased deep blood flow in such a scan with evidence of reduced skin blood flow in an adjacent area of the same limb, provides much more convincing support for the diagnosis. Examples of this will be presented.

Owing to the freedom from ionizing radiation, thermography is attractive for follow-up investigation of RSD as the presentation will show, and offers an underused method of evaluating treatment modalities over which there is much dispute at present.

In recent years thermography has found wider applications in strengthening the evidence in support of the diagnosis of RSD in medico-legal medicine, with significant benefits to successful claimants.

THERMOGRAPHY IN NERVE ROOT DISEASES

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We performed an initial study, which should prove the usefulness of thermography in nerve root diseases. Unlike Xray-CT and MRI, thermography does not show anatomical changes of vertebrae or discs, but it may show the result—the involved nerve root can be seen as a colder area at the corresponding dermatome. The precise mechanism of this effect is still unknown, but our experience with 22 patients (and 17 students as a control group) shows that this effect is present.

At the beginning of our research we have concentrated on the problems related to herniated discs at the lower part of the back (mostly L4/L5 and L5/S1). Since corresponding dermatomes are situated on the patient's legs, we have used our ThermaCAM PM575 digital infrared camera to measure temperature changes in this area. The selection of legs is intentional, because corresponding dermatomes are larger than in other parts of the human body. Nineteen of the patients underwent surgical treatment of their disease and we made another measurement one week after the operation. Fourteen of them also underwent a control examination five weeks later. Our first results show that the area of decreased temperature is topologically correlated with dermatomes and therefore could replace EMG in diagnosis. This can be useful especially with patients who have AIDS, hepatitis or other infectious diseases.

We have made also a single long-term study. This 59-year-old male had nerve root disease, which could be seen by neither Xray-CT nor MRI, but was diagnosed by EMG. This patient was treated clinically. We have already made 58 measurements of this patient and the results show that the temperature difference of over 1°C has dropped to 0.4°C during the ten-month-long study. The temperature difference can be evaluated from any area in the given dermatome—it is independent of size of the area and position inside the dermatome, but the bigger the area is, the more precise (statistically) result we obtain. The overall changes of thermal pattern are in correlation with the patient's subjective feelings.

THE DETECTION OF HUMAN DECEPTION USING THERMAL IMAGING

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An instrument for automated, rapid mass screening for deceitfulness has obvious applications, but such an instrument does not exist. We explored high definition thermal imaging of the face by detecting deceptiveness because we had demonstrated in previous studies a specific, quantifiable, "thermal signature" in the face that accompanied fright. Were the same thermal signature to accompany lying, it might represent an opportunity to perform automated, instantaneous lie detection without physical contact and even without the subjects' awareness.

To examine whether thermal imaging of the face could be used to detect lying, we had volunteers commit a mock crime and then assert innocence under experimental conditions at the Department of Defense Polygraph Institute, US Army. Twenty volunteers were randomly assigned to commit a mock crime, whereby they stabbed a mannequin, stole $20 from it and then asserted innocence. Control, "innocent" subjects, had no knowledge of the crime or crime scene. The thermal imaging system correctly categorized 83% of these subjects; 6 of 8 guilty subjects were correctly identified as guilty and 11 of 12 innocent individuals were correctly characterized as innocent. Traditional polygraphs were performed by experts on the same subjects. The polygraphs correctly characterized 70% of the subjects; 6 of 8 subjects were correctly identified as guilty and 8 of 12 were correctly identified as innocent.

In this experiment, high definition thermal imaging of the face exhibited compatible precision to the traditional polygraph and warrants further investigation for detecting deceitfulness and lying.

Support:
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A DATABASE OF NORMAL THERMAL IMAGES OF HEALTHY SUBJECTS

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The literature does not provide enough information on reference values of temperature distribution on the human body surface. Standardized positions of the body for image capturing and definition of reproducible placement of regions of interest (ROI) for temperature measurements can reduce systematic errors. Images captured and analyzed in a clearly defined protocol will show mainly the individual variations of temperature distribution, and deviations from these standard images would be suggestive for a physical dysfunction.

We established a protocol for capturing a series of images that covered the whole body of a healthy subject. The protocol defined a healthy subject as someone who had no problems with mobility, no difficulty in caring for himself, no restrictions in performing normal activities, experienced no pain or discomfort and was not suffering from anxiety or depression. A total of 24 views of the body were specified and within these views, a total of 87 regions of interest (ROI) were defined. The repeatability of some standard views by different investigators and the inter- and intrarater reliability of temperature readings from selected regions of interest was investigated.

The repeatability of standard views varies by the body regions investigated. However, standard views can be reproduced within a narrow range by different investigators. Interrater reliability coefficient alpha and intraclass correlation coefficient of the ROI "Lower Arm", and the hourglass shaped ROI at the anterior knee confirmed excellent repeatability of ROI placement. Reference values for the surface temperature of body regions based on images captured according to our protocol will reflect mainly the individual temperature variation.

THE EFFECT OF SOMATOTYPE ON THERMOGRAMHIC IMAGING OF THE BACK AND WHOLE BODY

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The recent improvements in infrared camera technology and computer software have improved its reliability. We are currently involved in compiling a reference bank of standard thermal images of 'normal' people. We therefore decided to investigate the influence of Body Mass Index and somatotype upon the thermal image within 'normal' people.

Ethical approval was obtained from the University's ethics committee. The subjects were asked to refrain from exercise for twelve hours prior to imaging and the following modalities: Manipulation, electrotherapy, ultrasound, heat treatment, cryo-t herapy, massage, acupuncture and hydrotherapy. They were also asked not to shower, bathe, sauna, shave, drink alcohol, or eat a large meal within four hours of their scheduled thermogram.

Thirty-four male volunteers (age range 19 - 45 years old) were imaged. The subject disrobed and equilibrated for twenty minutes within a stable environment (23.0 ± 0.5°C), without folding their arms or leaning against a surface. The whole body was imaged (ventral, dorsal and laterally) and the average mean temperature calculated. Also the standard image of the dorsal surface of the lower torso was taken and the average temperature for the paraspinal lumbar region calculated.

There was a significant relationship between Body Mass Index and lumbar paraspinal temperature (Kruskal-Wallis $p<0.03$). Therefore, consideration of body size is important in interpreting standard images.

THERMAL IMAGING IN THE INVESTIGATION OF DEEP VEIN THROMBOSIS

JR Harding

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Thermal imaging can have a useful role to play in the investigation of clinically suspected deep venous thrombosis (DVT).

When a patient presents with DVT, in addition to having a painful swollen lower limb, the patient is at significant risk of the serious, and frequently fatal, complication of pulmonary embolism (PE).

Effective treatment by anticoagulation dramatically reduces the risk of PE, but the treatment has risks of its own and is expensive and time consuming. Treatment, therefore, should not be undertaken without a confirmed diagnosis, particularly as there are a number of conditions which are clinically indistinguishable from DVT. Indeed, clinical diagnosis of DVT is notoriously unreliable, hence the need for accurate clinical tests to confirm or exclude DVT.

The most commonly utilised conventional imaging investigations for DVT, venography and Doppler ultrasound have disadvantages of their own.

Venography is invasive and exposes the patient to ionising radiation and risks of contrast allergy, dislodging of an embolus, cardiac failure, and development of DVT if not already present.

Doppler ultrasound avoids the risks of venography, but is operator dependent and can be very time consuming. This is where thermal imaging with its very high sensitivity for detection of DVT (approaching 100%) can have a place, by avoiding the need for conventional investigation in over one third of cases.

A negative thermogram effectively excludes DVT and no further investigation is needed. In addition to the clinical benefits to the patient, this can result in substantial savings in time and revenue.

THERMOGRAPHIC IMAGING AND SKIN OXYGEN SATURATION MEASUREMENTS APPLIED TO ROUTINE CLINICAL PREDICTION OF AMPUTATION LEVEL VIABILITY

DK Harrison, JM Hanson, IE Hawthorn

Regional Medical Physics Department and
†Surgical Directorate, University Hospital of North Durham, Durham DH1 5TW, UK.

About 5% of British males over 50 years of age contract peripheral arterial occlusive disease. Of these about 2% ultimately require lower limb amputation. In 1995 we proposed a new technique using lightguide spectrophotometry to measure the oxygen saturation level of haemoglobin (SO_2) in the skin as a method for predicting tissue viability. This technique, in combination with thermographic imaging, was compared with skin blood flow measurements using the (I_{125}) 4-Iodoantipyrine (IAP) clearance technique. The techniques gave a sensitivity and selectivity of 1.0 for the prediction of successful outcome of a below knee amputation compared with a specificity of 93% using the "traditional" IAP technique at a below knee to above knee amputation ratio (BKA:AKA) of 75%.

The present study assesses the routine clinical application of these two techniques. The study is ongoing, but the data to date comprises 22 patients. 4 patients were recommended for above knee amputation (AKA) and 18 patients for below knee amputation on the basis of thermographic and tissue SO_2 measurements. All but one of the predicted BKA amputations healed. The study to date produces evidence of 94% healing rate (specificity) for a BKA: AKA ratio of 82%. This compares favourably with the previous figures given above.

THERMAL IMAGING IN DIABETIC FOOT ULCERATION

JR Harding[1]. DF Wertheim[2], RJ Williams[2], JM Melhuish[3], KG Harding [3]

1X-Ray Department of Clinical Radiology, Royal Gwent & St Woolos Hospitals, Newport, Gwent.
2 School Of Electronics, University of Glamorgan, Pontypridd, Mid Glamorgan.
3 Wound Healing Research Unit, University of Wales College Of Medicine, Cardiff, South Glamorgan.

Diabetic foot ulcers present a difficult problem in clinical management, promotion of healing not being easy because of increased risk of soft-tissue infection in diabetes plus impaired local blood supply due to diabetic vascular disease.

Infection of diabetic foot ulcers have particular risk of involvement of the adjacent bone resulting in the serious complication of osteomyelitis. This needs early aggressive antibiotic therapy to avoid even more serious secondary long term complications, but unfortunately clinical diagnosis and 'marker' blood tests such as ESR and C-reactive protein may be negative in early osteomyelitis, when antibiotic therapy is most likely to be effective.

The large number of patients plus the chronic and recurrent nature of diabetic foot ulceration precludes routine investigation for early osteomyelitis by x-ray, isotope bone scanning, or MRI in cases in the absence of positive markers, for logistic radiation protection and cost reasons. There is significantly increased temperature on infra-red imaging not only around the ulcer, but in the entire sole of the foot in patients subsequently confirmed radiologically as having early osteomyelitis.

Quantitative infra-red imaging in diabetic foot ulceration defines objectively whether or not early osteomyelitis is likely to be present, reducing morbidity and mortality by selecting those patients who will benefit from appropriate aggressive antibiotic therapy.

THE COLD PROVOCATION TEST AND EPIDERMOLYSIS BULLOSA SIMPLEX

PWMcCarthy, B.Bath, AI Heusch

Welsh Institute of Chiropractice, University of Glamorgan, Treforest, Pontypridd, CF37 1DL

Epidermolysis Bullosa Simplex (EBS) is a skin disorder, where mechanical trauma can lead to blister formation. The blister occurs in the basal epidermal layer because of an autosomal mutation of epithelial keratins (K5 & K14). Diagnosis involves a biopsy of the blister. We therefore undertook a pilot study to investigate the potential use of thermography protocols in diagnosis.

Ethical approval was obtained from the University's ethics committee. Volunteers with confirmed EBS and age-matched controls (age range 23 - 76 years old) were imaged. On entering the stable environment of the thermography laboratory (22.0 ± 0.5ºC), the subjects sat and removed their shoes and socks. Their feet and lower limbs equilibrated for twenty minutes before imaging was commenced. Standard images of the plantar surface were taken. The feet were placed individually in plastic bags before immersing them in 'cold' water (20°C) for sixty seconds. The feet were then removed from the water and plastic bags before plantar surface images were taken every minute for fifteen minutes.

The average temperature for the balls and toes together (BT) and heels were calculated. The final temperatures for analysis were derived from deducting H from BT (BT-H) for pre and post- provocation test (5, 10 and 15 minutes). Subjects were then thermographically classified according to their feet's average temperature difference (post 5 - pre). Class 1 non-EBS, non heat stressed; class 2 EBS,

non heat stressed and class 3 heat stressed feet. There was a significant difference between the classes (Kruskal-Wallis p = 0.007).

DEVELOPING MEDICAL INFRARED THERMOGRAPHY IN THE UK, EUROPE AND THE WORLD

KJ Howell

Department of Rheumatology, Royal Free Hospital, Pond Street, London. NW3 2QG

Today's varied meeting programme has demonstrated that thermography is now an established imaging technique in medicine. The availability in recent years of high-resolution infrared imagers at competitive prices has encouraged a wider adoption of medical thermography.

To accommodate this growing interest, an infrastructure exists for the dissemination of thermographic research. The International College of Thermology stages regular meetings, which are hosted in rotation by the American, Asian, and European associations. Intra-continental meetings are held more frequently, and a number of national associations also run regional meetings.

The international journal of medical infrared imaging, "Thermology International," is now an Embase-listed journal. An extensive archive of papers published in earlier journals (all now out of print) is available on CD-ROM.

Researchers in the UK have played a leading role in the development of medical thermography throughout its 40-year history. The Medical Section of the UK Thermography Association is affiliated to the European Association of Thermology. It exists to promote medical thermography in the UK, and currently has about 15 members. This does not reflect the current number of active medical thermographers in the UK, and we would hope to increase membership in the coming months.

Opportunities now exist in both the UK and continental Europe for formal training in medical thermography, so whilst the quantity of medical thermographers increases, the quality of their knowledge also improves.

Today's meeting has showcased the development of medical thermography worldwide, and highlighted a potentially bright future for the discipline in the UK.

News in Thermology

9th European Congress of Thermology

Prof.Dr.Anna Jung is preparing the organisation of the 9th European Congress of Thermology, which will take place in Krakow May 30 to June 1, 2003. The conference will be combined with 6th National Congress of the Polish Association of Thermology. Thermal physiology, thermoregulation, clinical applications of thermal imaging, advances in thermal imaging technology, thermal image processing and telemedicine are the main topics of this important meeting.

Deadline for abstracts is February 1st 2003, please use the form on page 85 of this issue. Registration fees are 350 US$ before February 1st, 2003 or 450 US$ after February1st, 2003. All payment has to be made to
10201156-202693-270-1,
Polskie Towarzystwo Diagnostyki Termograficznej W Medycynie.

The venue of the congress is the Cultural Institute, located in the centre of the old university city of Kraków in Zyblikiewicza 1 Str. Kraków has an International airport, with a number of direct flights from the major European cities. A regular service is provided from Warsaw International airport.

A convenient hotel, Campanile, is located 100 meters from the conference hall in Sw. Tomasza 34 Str. Prizes are for a single room: 75 USD (breakfast included) and 85 USD (breakfast included) for a double room. Deadline for hotel reservation is April 15th 2003. Please use the form printed in this issue (page 83). Reservations can also be made by e-mail:
ajung@cskwam.mil.pl

3rd Asian-Pacific Federation of Thermology Meeting

Yong-Eun CHO, M.D., Ph.D, is the Secretary General, of the 3rd Congress of APF, which will be held at the Olympic Parktel, Seoul in September 2002

This meeting will be perfect opportunity to meet people interested in thermology from Asian-Pacific countries including China, Japan, Korea etc. and to share knowledge and experience in infrared imaging. International experts in the field of thermology will be invited to attend the meeting and will present their views about the future of thermology in the new millennium

Thermology Society in China

In November 2001 the 1st official Medical Infrared Imaging Committee in the People Republic of China was founded, supported by the Chinese Medical Association. Prof. Zi Bin Yang and Prof Guo-Zhong Yu, who both attended the 5th International Congress of Thermology in Vienna last year, are the key members of this new society. Arcon Science Technology Ltd acts as the secretary and the main sponsor of the Chinese Thermology Society.

A number of instructional and training courses were organized since the National Conference of Clinical Application of Infrared Thermography, held in Beijing in November 2000. Infrared imaging was also accepted by the Chinese Association of Preventive Medicine as non- invasive clinical examination technique.

AAT Meeting in Orlando

Dr. Hoshmand and Dr. J.Goldberg will organize this years´ meeting of the American Academy of Thermology in early November in Orlando. The venue is the Marriott Seaworld Residence Hotel, which is only 11 miles from the international airport. An interesting scientific programme together with the first class sporting facilities in this pleasant hotel and the sunny Florida weather promises to make this a special conference.

Veranstaltungen (MEETINGS)

May 23-25, 2002

ESHO 2002 in Bergen; Norway

20th Annual Meeting of the European Society for Hyperthermic Oncology Joint with the 13thEuropean BSD Users Conference

Venue: Raddisson SAS Royal Hotel Bergen

Registration fee: Member NOK 3200.-(400)
Non-Member NOK 3600.- (450)

Scientific Secretary:
Olav Dahl, MD. Ph,D, Professor

Dept. of Oncology, Institue of Medicine
Haukeland Hospital, University of Bergen,
Bergen, Norway

Phone:+47 5597 2018
Fax: +47 5597 2046
email: olav.dahl@haukeland.no

Organising Agent:
PLUS Converntion Norway AS

Att:Aina Vonheim
Strandgaten 59, N-5004 Bergen

Phone: +47 55544044
Fax: +47 55544040
email: akv@plus-convention.no

September 24-27, 2002

6th International Conference on Quantitative Infrared Thermography, QIRT´2002, in Dubrovnik, Croatia

Organized by: University of Zagreb (Croatia), Faculty of Mechanical Engineering and Naval Architecture

QIRT´2002 Deadlines

Jan. 15, 2002 Deadline for abstracts

March 15, 2002 Information about the acceptance of the paper-final instructions for authors

April 15, 2002 mailing of final announcement, detailed proghramme and registration form

Sept 1, 2002 camera-ready paper

Information:

Please reply by email on the site

http://www.fsb.ht/Qirt2002

Or return a letter to ther conference secretary

QIRT´2002

Igor Sindov, Faculty of Mechanical Engineering and Naval Architecture

O-Lucica 5, 10000 Zagreb,Croatia

Phone: +385 1 616 8174 Fax: +385 1 616 5940

September 6-7, 2002

3rd Asian-Pacific Congress of Thermology in Seoul, Korea

Venue: Olympic Parktel, Seoul,

*Information:*Yong-Eun CHO, M.D., Ph.D.
Secretary General,
The 3rd Congress of APFT
Tel : (82-2) 3497-3393, FAX: (82-2) 3461-9229
E-mail: ydnscho@yumc.yonsei.ac.kr

September 28-29,2002

5thConference of the Polish Society of Thermology

Venue: Zakopane

Information: Prof Dr.Anna Jung
Department of Paeditarics and Nephrology
Central Clinical Hospital MMU,
Szerow str 128, 00-909 Warsaw, Poland

Phone/Fax +48 22 681 67 63
email: ajung@cskwam.mil.pl

November 7-10, 2002

Annual Meeting of the American Academy of Thermology in Orlando

Venue: Marriott Residence Inn.
Seaworld International Center,
11000 Westwood Boulevard,

Orlando, Florida 32821.

Phone: 407-313-3600, Fax; 407-313-3611.
www.residenceinnseaworld.com

Information:

Dr.Hooshmand at hoosh@prodigy.net
or Dr.Goldberg at JerryGol@aol.com

December 4-8, 2002

EMBEC´02 , 2nd European Medical & Biological Engineering Conference in Vienna, Austria

Special Session:
Developments in Infrared Thermal Imaging, organised by Prof EFJ Ring & Prof.K.Ammer

Information about EMBEC:
Prof. Dr. Helmut Hutten
Institute for Biomedical Engineering
University of Technology
A-8010 Graz (Austria), Inffeldgasse 18
tel: ++43-316-873-7390 fax: ++43-316-46 53 48
email: hutten@ibmt.tu-graz.ac.at

Information about the infrared session:

Prof. Francis Ring, email:efring@glam.ac.uk

Prof.Kurt Ammer. email:kammer1950@aol.com

2003

May 30th – June 1st, 2003

9th European Congress of Medical Thermology in Krakow, Poland

Topics: thermal physiology, thermoregulation, clinical applications of thermal imaging, advances in thermal imaging technology, thermal image processing, telemedicine

Venue: Cultural Institute, Kraków,
Zyblikiewicza 1 Str

Abstract deadline: February 1st 2003

Registration fee

Before February 1st, 2003 350 USD

After February 1st, 2003 450 USD

The payment has to be made to

10201156-202693-270-1

POLSKIE TOWARZYSTWO DIAGNOSTYKI

TERMOGRAFICZNEJ W MEDYCYNIE

Hotel accommodation

A convenient hotel, Campanile, is located 100 meters from the conference hall in Sw. Tomasza 34 Str.

Single room: 75 USD (breakfast included)

Double room: 85 USD (breakfast included)

Deadline for hotel reservation April 15th2003

Reservation e-mail: ajung@cskwam.mil.pl

June 18.-20, 203

13th International Conference on Thermal Engineering and Thermogrammetry (THERMO)

in the OSSKI Center (Törley Palace). Budapest, XXII. (Budafok), Anna u. 5.

SCIENTIFIC COMMITTEE:

Chairman: Dr. I. Benkõ BME, DoE, Hungary (EAT, HST, President of TE & TGM)

Secretary: I. Kovacsics, MSc.EGI-Contracting/Engineering Co. Ltd., Budapest, Hungary (HST, TE & TGM)

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-LBF für Phys. Diag., Wien, Austria (EAT)

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Middle East Techn. Univ., Ankara, Turkey (ICHMT)

Dr. T. Ayhan
Univ. of Bahrein, Dept of Mech. Eng., State of Bahrein

Dr. W. Bauer
University of Duisburg, Duisburg, Germany

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University of Trakya, Edirne, Turkey

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King Fahd Univ. of Petroleum & Minerals,Dhahran, Saudi Arabia

Dr. E.F.J. Ring
School of Computing, University of Glamorgan, Pontypridd, U.K. (EAT)

Dr. S. Kakaç
University of Miami, Coral Gables, USA

Dr. L.I. Kiss
University of Québec in Chicoutimi, Canada

Dr. G. J. Köteles
OSSKI, Director, Budapest, Hungary (HST)

Dr. M. Groll
IKE- University of Stuttgart, Stuttgart, Germany

Dr.T.-M. Liou
National Tsing Hua Univ., Hsinchu, Taiwan, Rep. of China

Dr. X. Maldague
University Laval, Quebec city, Canada (QIRT)

Dr. S. Mochizuki
Tokyo Univ. of Agriculture and Techn., Tokyo, Japan

Dr. T. Kapros
TÜKI Rt., Miskolc, Hungary

Dr. L. Rádonyi
BME, Head of the DoE, Budapest, Hungary

Dr. Müller-Steinhagen
University of Stuttgart, Stuttgart, Germany

Dr. M. Osztheimer
VEIKI Rt., Budapest, Hungary

Dr. E. Hahne
University of Stuttgart, Stuttgart, Germany

Dr. S. Švaic
FSB, University of Zagreb, Zagreb, Croatia (QIRT)

Dr. W. -J. Yang
University of Michigan, Ann Arbor, USA

Dr. B. Wiecek
Technical University of Lodz, Lodz, Poland (QIRT)

Venue

The conference is hosted by the OSSKI Center (Törley Palace, Budapest, XXII. (Budafok), Anna u. 5.) located in the vicinity of the famous Budafok wine cellars. More information about the conference place and hotel accommodation will be sent after the arrival of the Registration Form.

CALL FOR ABSTRACTS

The photocopy-ready abstracts of six A4 format pages to be presented on the conference are to be submitted before 15 October, 2002. To assist the work of the Scientific Committee the authors are kindly requested to point out the aim, method and results of their work.

Notification of the acceptance will be forwarded to the authors until 28 February, 2003. The abstract of all accepted papers will be included the Proceedings to be presented to the participants at the Conference.

INFORMATION

Application Forms and abstracts should be sent to:

Dr.Imre BENKÕ,
MATE Secretariat, House of Technology, III.318.,

H-1372 Budapest, POB. 451., Hungary.

Fax: +361-353-1406 Phone: +361-332-9571.

E-mail: mate@mtesz.hu

For any further information please contact the following address:

Dr.Imre BENKÕ,
Budapest University of Technology and Economics (BME), Department of Energy (DoE), H-1111 Budapest, Mûegyetem rkp. 7. D.208., Hungary.

Office phone: +361-463-2183.

DoE Phone/fax: +361-463-3273 or -310-0999.

BME Fax: +361-463-1110

E-mail: benko@eta.enrg.bme.hu

9th European Congress of Medical Thermology

6thNational Congress of the Polish Association of Thermology

Kraków / Poland – May 30th – June 1st, 2003

REGISTRATION AND HOTEL ACCOMMODATION FORM

PARTICIPANT

First Name .....

Family Name .....

Address .....

ZIP Code .....

City .....

Country .....

Phone .....

Fax ..... E – mail .....

REGISTRATION FEE

Paid until	February1st, 2003	350 USD
Paid after	February1st, 2003	450 USD

HOTEL ACCOMODATION

I would like to make the following reservation in Campanile Hotel:

.....	Single room	75 USD
.....	Double room	85 USD

Deadline for hotel reservation – April 15th, 2003

Date of arrival ..... Date of departure ..... no. .....of nights

PAYMENT

The payment has been made to: 10201156-202693-270-1

POLSKIE TOWARZYSTWO DIAGNOSTYKI

TERMOGRAFICZNEJ W MEDYCYNIE

Signature ..... Date.....

Return to:
Organising Comittee:
Pediatric and Nephrology Clinic MSM
Szaserów str 128 00 909 Warsaw 60, POLAND
Tel/fax (48 – 22) 6816763 E – mail ajung@cskwam.mil.pl

9th European Congress of Medical Thermology

6thNational Congress of the Polish Association of Thermology

Kraków / Poland – May 30th – June 1st, 2003

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

Institution .....
Street .....

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

Phone..... Fax .....E – mail.....

Title

Autors

Abstract

Return this form not later than February 1st, 2003 to: Prof. Anna Jung
Pediatric and Nephrology Clinic MSM
Szaserów str 128 00 909 Warsaw 60, POLAND
Tel/fax (48 – 22) 6816763 E – mail ajung@cskwam.mil.pl