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Effect of Nd:YAG LASER on human teeth

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Influence of Low Temperature on Lymph Formation and Lymph Flow Velocity in Mice

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SUMMARY

The influence of low temperature on lymph formation and its flow velocity in mice was studied. Experimental animals were exposed to low temperature of -60°C in a cryogenic chamber for 1 minute a day. After a single exposure, immediately after the end of a cycle of 10 exposures and on 21st day after the end of this cycle lymph formation and lymph flow velocity were estimated. A 1% water solution of Trypan Blue was injected intravenously. After the injection the time points at which the dye reached the mesenteric lymphatic vessels and the mesenteric lymph nodes were recorded. Based on measurements of time between dye administration and its appearance in the lymphatic vessels and lymph nodes, the lymph formation and its flow velocity were established both in experimental and control mice. It was concluded that low temperature does not influence the lymph formation in mice, but accelerates the lymph flow. This effect is long-lasting, but it appears only at the end of the exposure cycle.

Key-words: low temperature, cryotherapy, lymph formation, lymph flow velocity, mice

DER EINFLUSS NIEDRIGER TEMPERATUREN AUF DIE PRODUKTION UND FLIESSGESCHWINDIGKEIT DER LYMPHE BEI MÄUSEN

Der Einfluss niedriger Temperaturen auf die Produktion und Fließgeschwindigkeit der Lymphe wurde bei Mäusen untersucht. Die experimentellen Tiere wurden in einer Kältekammer bei -60° C täglich 1 Minute lang exponiert. Die Lymphproduktion und die Fließgeschwindigkeit der Lymphe wurden nach einer einzigen Exposition, am Ende von 10 aufeinander folgenden Anwendungen und 21 Tage nach Ende einer Anwendungsserie beurteilt. Eine 1% wässrihge Lösung von Trypan-Blau wutde intrvenös injeziert. Die Zeit, in der Farbstoff nach der Injektion die mesenterialen Lymphfäße und die mesenterialen Lymphknoten erreichte hatte, wurde vermerkt. Die Zeit, die zwischen der Injektion des Farbstoffes und seinem Erscheinen in Lymphgefäßen und Lymphknoten verstrichen, diente bei behandelten und Kontroll-Tieren als Grundlage der Schätzung der Produktion und Fließgeschwindigkeit der Lymphe. Als Schluss-folgerung der Untersuchung scheinen bei Mäusen niedrige Temperaturen zwar nicht die Lymphproduktion, jedoch den Lymph fluss zu beschleunigen. Dieser Effekt ist lang anhaltend, stellt sich aber erst am Ende einer Behandlungsserie ein.

Schlüsselwörter:niedrige Temperatur, Kryotherapie, Lymphbildung, Fließgeschwindigkeit der Lymphe, Mäuse

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Introduction

The lymphatic system plays a crucial role in the integration of body functions, besides the nervous and endocrine systems. These three systems form the socalled neuro-endocrine-lymphatic network [1,2].

It is nowadays accepted that the lymphatic system comprises the perivascular-interstitial spaces, all types of lymphatic vessels, lymph nodes, other agglomerates of organised lymphatic tissue and all lymphocytes [3,4,5].

The functions performed by the lymphatic system can be classified into two groups: 1) participation in immunologic processes and 2) transport of macromolecular substances (especially proteins) from the perivascular space to the blood [6]. The lymphatic system is also involved in the transport of fluids but only to a small degree, as shown by the difference between the daily volume of blood circulating through the heart and the amount of lymph reaching the venous blood [7].

The lymph vessels transfer immunological and non-immunological information contained in the lymph, which has an influence on the lymph node morphology [8,9,10]. It seems that cellular immune response depends on the delivery of lymphocytes from the lymph node and their immobilisation in small calibre vessels during their passage through the inflammatory microcirculation [11]. On the other hand by removing proteins from the perivascular space, the lymphatic vessels also influence the local tissue conditions – the osmotic and hydrostatic pressure as well as the tissue volume [12,13,14].

For these reasons the lymphatic vessels play an important role in all inflammatory processes [15]. Uncontrolled oedema – a natural part of the inflammatory process can increase pain, prolong immobilization, reduce range of joint motion and inhibit ligament healing, and all of which may extend the recovery in patients suffering from inflammatory diseases or injury of to locmotor system.

Cryotherapy is one of methods of physical medicine using extremely low temperatures below -100°C to stimulate physiological reactions of organisms. This method is thought to prevent acute oedema formation probably by decreasing blood flow, metabolic activity and permeability of post-capillary venules [16,17], but the mechanisms of beneficial effects of low temperature on the course of inflammatory processes remain still unclear. Many authors suggest that the lymphatic system may play an important role in these mechanisms, but no relevant data are available so far.

The present study was undertaken to determine the influence of low temperature on lymph formation and its flow velocity in laboratory animals.

Material and Methods

The experiments were performed in the Cryotherapy Center, Ruda Œl¹ska, Poland. The experimental material consisted of 40 adult male BALB/c mice weighing 50g each. All animals were kept in an air-conditioned room (12/12 hours light/dark cycle) in plastic cages, four animals per cage. They were fed with a standard diet and water *ad libitum*.The local Bioethic Committee of Medical University of Silesia for Animals, approved the experiment. All animal testing was conducted according to NIH regulations on animal care, as described in „Guide for the Care and Use of Laboratory Animals" [National Academy of Sciences, 1996].

The animals were allocated to three experimental groups consisting of 10 mice each exposed in cryogenic chamber to low temperature of (-60)°C for 1 minute daily and a control group in which no exposure was made.

In experimental group 1, a single exposure was made with subsequent measurements of lymph formation and lymph flow velocity.

In experimental group 2, 10 daily exposures were made with subsequent measurements of lymph formation and lymph flow velocity made immediately after the last exposure.

In experimental group 3: 10 daily exposures were made with subsequent measurements of lymph formation and lymph flow velocity performed on 21 day after the last exposure.

The assessment of lymph formation and its flow velocity was made according to a previously described method [14]. The mesentery and the mesenteric lymph nodes were prepared under general anaesthesia (40 mg/kg Pentobarbital intraperitoneally) and 1% water solution of Trypan Blue (Reanal, Hungary) was injected during 30 seconds into the inferior vena cava. After the injection the time points at which the dye reached the mesenteric lymphatic vessels (near the mesenteric border of the jejunum) and the mesenteric lymph nodes were recorded. The animals were anaesthetized with an overdose of Pentobarbital (200 mg/kg) and Chloral-hydrate (400 mg/kg).

All measurements were made at the same time (5-6 p.m.). Lymph formation and its flow velocity were established on the basis of the differences between the times of dye administration and its appearance in the lymphatic vessels and the lymph nodes. The differences between all groups were analysed statistically with STATISTICA 6,0 PL using Student's t-test.

Results

The results are presented in tables 1 and 2. A single exposure (Group 1) caused a slight, statistically insignificant enhancement of lymph formation and its flow velocity as compared to the control values. An assessment made immediately after the end of a cycle of 10 exposures (Group 2) showed a slight and insignificant delay in lymph formation ($p>0.05$) and a statistically significant delay in its flow time ($p<0.05$). In the group 3 studied on 21 day after the end of a cycle of 10 exposures a slight, statistically

Table 1
Comparison of mean times of dye appearance in mesenteric lymphatic vessels between experimental groups exposed to low temperature (group 1 – a single exposure, group 2 – 10 daily exposures and group 3 – 10 daily exposures with subsequent measurements on 21st day after the end of exposures) and control group with statistical evaluation.

Group	Time of dye appearance [s] Mean value ± SD	Statistical significance - control vs. experimental group
Control	44.75 ± 9.26	-
Group 1	40.67 ± 10.86	p>0.05 Insignificant
Group 2	48.67 ± 13.36	p>0.05 Insignificant
Group 3	43.50 ± 14.74	p>0.05 Insignificant

Table 2
Comparison of mean times of dye appearance in mesenteric lymph nodes between experimental groups exposed to low temperature (group 1 – a single exposure, group 2 – 10 daily exposures and group 3 – 10 daily exposures with subsequent measurements on 21st day after the end of exposures) and control group with statistical evaluation

Group	Time of dye appearance in mesenteric lymph nodes [s] Mean value ± SD	Statistical significance -control vs. experimental group
Control	124.42 ± 18.47	-
Group 1	120.00 ± 14.19	p>0.05 Insignificant
Group 2	138.33 ± 24.55	p<0.05 Significant
Group 3	96.50 ± 11.24	p<0.001 Significant

insignificant enhancement of lymph formation and a highly statisti cally significant acceleration of lymph flow ($p<0.001$) was observed.

Discussion

The dye (Trypan Blue) injected intravenously binds to the blood proteins, leaves the circulatory bed and is absorbed into lymph capillaries. Then it flows in the small, collecting and greater lymphatic vessels to the thoracic duct which empties into the left venous angle.

The lymph formation depends on the differences between osmotic and hydrostatic pressures in blood capillaries and perivascular spaces. It also depends on the molecular size, physical and chemical properties of transported substances and also on the morphology of blood and lymph capillaries [12,19]. The method used in this experiment enables easy assessment of lymph formation and its flow velocity.

The main mechanism responsible for the lymph flow are contractions of lymphangions (i.e. segments of lymphatic vessels containing smooth muscles). The valves between lymphangions enable an unidirectional flow of the lymph [8].

In our experiment, low temperature (-60)° did not have a marked influence on the time of appearance of the dye in lymphatic vessels in any of studied groups of mice. This suggests that low temperature does not influence lymph formation. Measurements made immediately after a single exposure showed only a slight, insignificant increase in lymph flow velocity as compared to the controls. Immediately after the end of exposure cycle a significant decrease in lymph flow was observed. The mechanism of slowing down of the dye flow time after the tenth exposure is not quite clear. It is possible that repeated exposure to low temperature initially causes a decrease in the reactivity of smooth muscle cells, that later is followed by a transient in- crease in the contraction rate. The measurements made three weeks after the end of a cycle of 10 exposures showed a significant increase in lymph flow velocity, which was manifested by reduction of time in which the dye reached the mesenteric lymph nodes compared to the controls. It seems that the final effect of repeated exposures to low, cryogenic temperatures results in a long-lasting increase in the frequency of lymphangion contractions with subsequent increase in lymph flow in exposed tissues, which appears several days after the end of exposure cycle.

The data obtained in this experiment could explain the favourable therapeutic results of cryotherapy in man, related to reduction of oedema in the course of inflammatory diseases or injuries of the locomotor system, which appears as a late, prolonged effect after a cycle of repeated exposures.

The anti-inflammatory effect of cryotherapy was confirmed in numerous clinical papers and in experimental studies [20,21] in which animals with intended inflammation induced by injection of chemicals into a paw, presented with a significantly faster reduction of paw swelling than controls. In one study [22] that has assessed the effects of cooling on blood flow and intramuscular water content in human skeletal muscles after exercise using magnetic resonance imaging, the authors confirmed that cooling attenuates increased perfusion and prevents oedema formation in skeletal muscle immediately after exercise. Other authors showed high therapeutic efficacy of cryotherapy in reduction of oedema and pain intensity, and also improvement of range of motion iof pathological joints during treatment of patients suffering from rheumatoid arthritis and deforming osteoarthrosis [23,24,25,26]. In most of these patients a significant decrease in concentration of markers of the inflammatory process were observed and also a reduction of granulocytes both in serum and intra-articular fluid [26,27,28].

Conclusions

1. Low temperature does not influence the lymph formation time in mice, but accelerates the lymph flow.

2. The lymph flow acceleration is long lasting, but it appears not before some time after the end of exposure cycle.

References

1.Besedovsky HO, del Rey A, Sorkin E. Immunoneuroendocrine interactions. J Immunol 1985; 135: 750-4.

2.Dabrowski MP, Dabrowska-Bernstein BK. Immunoregulatory Role of Thymus. Boca Raton, Florida: CRC Press Inc;1990.

3.Foldi M. The lymphatic system. A review. Zeitschr Lymphol 1997; 1: 1-56.

4.Olszewski WL. What is lymphology – prospects in human studies. Lymphology 1982; 15: 80-7.

5.Olszewski WL. Lymphatics, lymph and immune cells: an integrated immune system. Eur Surg Res 1986; 48: 264-70.

6.Van Rooijen N. The "in situ" immune response in lymph nodes: a review. Anat Rec 1987; 218: 359-64.

7.Földi M. Physiologie und Pathophysiologie des Lymphgefäss-systems. In: Meessen H, editor. Lymphgefass-System. Berlin, Heidelberg, New York: Springer Verlag; 1972, p. 239-310.

8.Reddy NP. Lymph circulation: physiology, pharmacology, and biomechanics. CRC Crit Rev Biomed Eng 1986; 14: 45-91.

9.Sainte-Marie G, Peng FS, Belisle C. Overall architecture and pattern of lymph flow in the rat lymph node. Am J Anat 1982; 164: 275-309.

10. Sainte-Marie G, Peng FS. Diffusion of a lymph-carried antigen in the fiber network of the lymph node of the rat. Cell Tissue Res 1986; 245: 481-6.

11.Su M, West CA, Young AJ, He C, Konerding MA, Mentzer SJ. Dynamic deformation of migratory efferent lymph-derived cells "trapped" in the inflammatory microcirculation. J Cell Physiol 2003; 194: 54-62.

12.Casley-Smith JR. The fine structure and functioning of the tissue channels and lymphatics. Lymphology 1980; 13: 177-83.

13.Hawley AE, Illum L, Davis SS. The effect of lymphatic edema on the uptake of colloids to the lymph nodes. Drug Dispos 1998; 19: 193-7.

14.Olszewski WL. Putting the immune system back in the body. Lymphology 1988; 21: 83-5.

15.Karkkainen MJ, Jussila L, Ferrell RE, Finegold DN, Alitalo K. Molecular regulation of lymphangiogenesis and targets for tissue oedema. Trends Mol Med 2001; 7: 18-22.

16.Ho SS, Coel MN, Kagawa R, Richardson AB. The effects of ice on blood flow and bone metabolism in knees. Am J Sports Med 1994; 22: 537-540.

17.Knight KL. Cryotherapy in sports injury. Champign Human Kinetics; 1995.

18.Dreszer H, Slusarczyk K, Stoklosa E. Zachowanie siê uk³adu ch³onnego jelita cienkiego szczura pod wp³ywem wibracji. Med Pracy 1979; 30: 331-6.

19.Casley-Smith JR. The structure and functioning of the blood vessels, interstitial tissues, and lymphatics. In: Foldi M, Casley-Smith JR, editors. Lymphangiology. Stuttgart, New York: F. K. Schattauer Verlag; 1983. p. 27-164.

20.Kenjo T, Kikuchi S, Konno S. Cooling dicrease fos-immunoreactivity in the rat after formalin injection. Clin Ortho 2002; 394: 212-277.

21.Wojtecka-Lukasik E, Ksiezopolska–Orlowska K, Burakowski T, Marton A, Maslinska D, Ciurzynska G. et al. Wplyw krioterapii na przebieg odczynu zapalnego. Badania doswiadczalne. Reumatologia 2002; 40: 28-35.

22.Yanagisawa O, Kudo H, Takahashi N, Yoshioka H. Magnetic resonance imaging evaluation of cooling on blood flow and oedema in skeletal muscles after exercise. Eur J Appl Physiol 2004; 91: 737-740.

23.Gachewicz S. Skrzek A. Przybylski J. Skutecznosc krioterapii miejscowej w leczeniu choroby zwyrodnieniowej stawu kolanowego. Acta Bio-Optica Inform Med 1999; 5: 125-130.

24.Kalmus P, Wlodarczyk K, Pinkowska I, Piotrkowska E, Szulicka A. Wyniki leczenia reumatoidalnego zapalenia stawow zabiegami krioterapeutycznymi i peloidowymi. Baln Pol 1999; 41: 83-91.

25.Misztela A, Kulinski W, Rybak T. Ocena krioterapii miejscowej w reumatoidalnym zapaleniu stawow. Baln Pol 1995; 37: 38-41.

26.Moon AH, Gragnani JA. Cold water immersion for the oedematosus hand in stroke patients. Clin Rehab, 1989; 3: 97-101.

27.Gajewski M, Ksiezopolska-Pietrzak K, Jozwicka M, Smigielski R, Slynarski K, Sygitowicz G et al. Chemiluminescence of neutrophils isolated from patients with rheumatoid arthritis before and after cryotherapy. Reumatologia 1998; 36: 337-345.

28.Jonderko G, Kosmus-Kuczia I, Galaszek Z, Szkliniarz J. Wplyw krioterapii na wybrane odczyny ostrej fazy u chorych na reumatoidalne zapalenie stawow. Reumatologia 1988; 26: 111-116.

29.Romanowski W. Wplyw krioterapii miejscowej na liczbe komorek oraz odsetek granulocytow w plynie stawowym u chorych na reumatoidalne zapalenie stawow. Reumatologia 1993; 31: 61-63.

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Infrared thermographic analysis of temperature distribution on the surface of human tooth during Nd:YAG laser irradiation - in vitro study

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SUMMARY

AIM: This study was designed to use thermal imaging for temperature measurement to analyze the in vitro tooth surface temperature changes during Nd:YAG laser irradiation of human teeth with different energy and repetition rate settings.

METHODOLOGY: Ten extracted lower central incisors were used in this study. After root canal preparation teeth were cut in half along its axis in coronal plane and placed in the sleeve full with wet cotton wool. Experimental investigations have been conducted on two experimental stands, which were designed to ensure thermal condition of the experiment as close as possible to the thermal conditions of the alveolar bone and the tooth socket:

1)with simulation of cooling of the surgical area with water (cotton wool with excess of water)

2)without simulation of cooling (wet cotton wool).

The external surface of incisor was coronally irradiated with the Nd:YAG laser for 30 sec at the power ranged from 1W to 3W. Two different energies of 50mJ and 100mJ were tested at a frequency of 20 – 30 Hz. Temperature changes during laser irradiation were measured for each setting on the internal surface of the tooth by thermovision. The thermal imaging system used was ThermaCAM SC1000 (Inframetrics, USA) and its dedicated software package (Thermal Studio) allowed analysing the stored images.

RESULTS: Our results revealed, that Nd:YAG laser irradiation at a power of 3W applied on the external surface of human teeth elicited the temperature in the pulp above 40 ° C, when measurements were performed on experimental stand without simulation of cooling.

CONCLUSIONS: The Nd:YAG laser irradiation, applied on the external surface of human teeth may result in excessive rise in temperature in the pulp chamber. Infrared thermography is a useful device for mapping patterns of temperature change over a large area.

Key words: thermographic imaging, laser curettage, heat transfer, temperature rise

INFRAROT-THERMOGRAPHISCHE ANALYSE DER TEMPERATURVERTEILUNG AN DER OBERFLÄCHE MENSCHLICHER ZÄHNE WÄHREND DER BESTRAHLUNG MIT EINEM ND:YAG LASER - EINE IN VITRO STUDIE

ZIEL: An Wärmebildern wurden Temperaturmessungen zum Zweck der Analyse der Oberflächentemperaturen an Zähnens während der in vitro Bestrahlung mit Nd:YAG Laser unterschiedlicher Intensität und Pulsrate durchgeführt.

METHODE: Zehn extrahierte untere Schneidezähne wurden in der Studie verwendet. Nach Präparierung des Wurzelkanals wurden die Zähne in der Koronarachse halbiert und dann in eine Hülle mit feuchter Baumwollwatte gesteckt. Für die Experimente wurden zwei Halterung konstruiert, welche die thermischen Bedingungen des Alveolarknochens und der Zahnverankerung möglichst genau nachbilden sollten:

1)mit Simulation einer Kühlung des Operationsgebiets mittels wasser (Watte mit Überstand and Wasser)

2)ohne Simulation einer Kühlung (feuchte Wattel).

Die Zahnoberfläche der Schneidezähne wurde in der Koronarebene mit einem Nd:YAG Laser 30 Sekunden lang bei einer Leistungsabgabe zwischen 1W und 3W bestrahlt. Zwei Intensitäten, nämlich 50mJ und 100mJ wurden bei einer Pulsfrequenz zwischen 20 und 30 Hz getestet. Die Temperaturänderungen im Zahnkanal wurden während der Laserbestrahlung während jedes Einzelexperiments mittel Thermographie gemessen. Dazu wurde die Wärmebildkamera ThermaCAM SC1000 (Inframetrics, USA) und das dazu gehörige Stoftware-Paket (Thermal Studio)verwendet, mit der die aufgezeichneten Bilder analysiert werden können.

ERGEBNISSE: Unsere Ergebnisse zeigen, dass es bei der Bestrahlung der Zahnoberfläche mit dem Nd:YAG Laser mit einer Leistung von 3W zu einer Temperatur in der Zahnpulpa von 40° C kommen kann, wenn die Messungen ohne Simulation einer Kühlung durchgeführt wurden.

SCHLUSSFOLGERUNG: Die Bestrahlung der Oberfläche menschlicher Zähne mit einem Nd:YAG Laser kann zu einem massiven Temperaturanstieg in der Zahnpulpa führen. Die Infrarot-Thermographie hat sich für die Dar stellung der Temperaturverteilung in großen Gebieten bewährt.

Schlüsselwörter: Thermographie, Laser Curettage, Wärmetransport, Temperaturanstieg

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Introduction

The main problem to be considered when bringing new dental devices and treatment modalities into clinical practice is the safety for patient. Major dental therapy processes, like removal of carious lesions with rotary burs or exposition of the tooth to the polymerisation lamplight are closely related to thermal stimuli propagation in dental structures and surrounding tissues [1, 2]. Temperature increases exceeding the threshold level for tissue survival will cause irreversible damage in the pulp as well as in tissues surrounding tooth. In an effort to prevent the risk of tissue damage, analysis of the heat effects and heat transfer phenomena should be performed.

Among the procedures connected with thermal side effects, which may place patients at risk for damage to dental pulp and subjacent tissues, is subgingival laser cutettage [3, 4]. The intrapocket use of Nd:YAG laser has been recommended as an alternative or adjunctive therapy in the treatment of inflammatory periodontal diseases, although usual treatment plan consist of scaling and root planing, prophylaxis and home care instructions. Subgingival laser-assisted curettage is recommended when gingival pockets are deeper than 5 mm. Using the laser technique for pockets preparation provides the significant improvements in patients comfort compared with conventional curettage due to reduction of bleeding and shorter operation time. Laser energy delivered through an optical fibre is capable of ablating and vaporising residual bacteria and granulation tissues and permits the removal of the epithelial lining of the pocket [5]. Due to an effect of biostimulation, occurred in the deeper layers of tissues, the use of laser accelerates fibroblast proliferation, collagen synthesis and wound healing [6]. One of the major problems of subgingival laser-assisted curettage is the penetratio of laser energy towards alveolar bone and the dental pulp. Radiant light energy absorbed by blood haemoglobin becomes transformed into heat energy, which produces thermal effects. The specific antomically structures of the tooth and the heat- accumulating capacity of enamel and dentin may produce temperature increases in the pulp, which exceed the adaptation ability of this tissue and produce heat-related damage in the pulp tissue [7].

Experimental measurements of heat transferIn vivo are very difficult to conduct because of many instrumental, methodological and ethical limitations. Even slightly invasive procedures can not be accepted by a patient due to the average duration of an experiment. The range of parameters, investigated under in vivo conditions is limited and many high-power experiments are excluded from in vivo studies because safety is the most important element in clinical investigations. For those reasons most of research is performed under in vitro conditions, using thermocouples or/and a thermal imaging camera [4, 8, 9]. The main problem is to create experimental stand, ensured thermal conditions of measurements as close as possible to the thermal conditions of the oral cavity, imitating the blood circulation-related effects and thermal properties of gingival tissues and the dental pulp.

The purpose of the present study was to analyse the effect of Nd:YAG laser on temperature increases in the pulp chamber.

Materials And Methods

Study Samples

The study sample consisted of 10 lower central incisors extracted because of poor prognosis. The teeth were periodontally affected and showed no signs of caries upon visual examination. Prior to their respective treatments, all extracted teeth were cleaned to remove gingival and periodontal ligament soft tissues. Standard canal preparation was performed. Each root canal was shaped with at least a # 35 K-file. Then teeth were cut along long axis in coronal plane to expose root canal dentin

Selection of the Nd:YAG Laser Parameters

The parameters of laser for this in vitro study were selected on the basis of previous clinical investigations. The patient provided written consent to participate in the study [4]. This clinical research was part of the project "Thermal effects connected with dental devices in course of different treatment modalities" supported by the State Committee for Scientific Research of Poland. The ethical committee approved the protocol. This study evaluated the effect of Nd:YAG laser on temperature increases on the surface of marginal gingiva during laser subgingival curettage. The pocket of periodontally affected upper incisor was irradiated with laser (Fig. 1C). No simultaneous cooling of the operation site was applied. Temperature changes of the marginal gingiva were measured using a thermocouple and thermal imaging system (Fig. 1A, B). Periodontal pocket was irradiated at low laser energy of 50mJ and pulse repetition rate from 20 to 28 Hz to prevent overheating and destruction of tissues. On the basis of results obtained from measurements the in vitro study was performed.

To ensure conditions similar to those, occurring in the patient's mouth during a real dental procedure, the thermographically investigated tooth was fixed in a special experimental stand imitating thermal properties of alveolar bone and marginal gingiva.

General description of the experimental stand

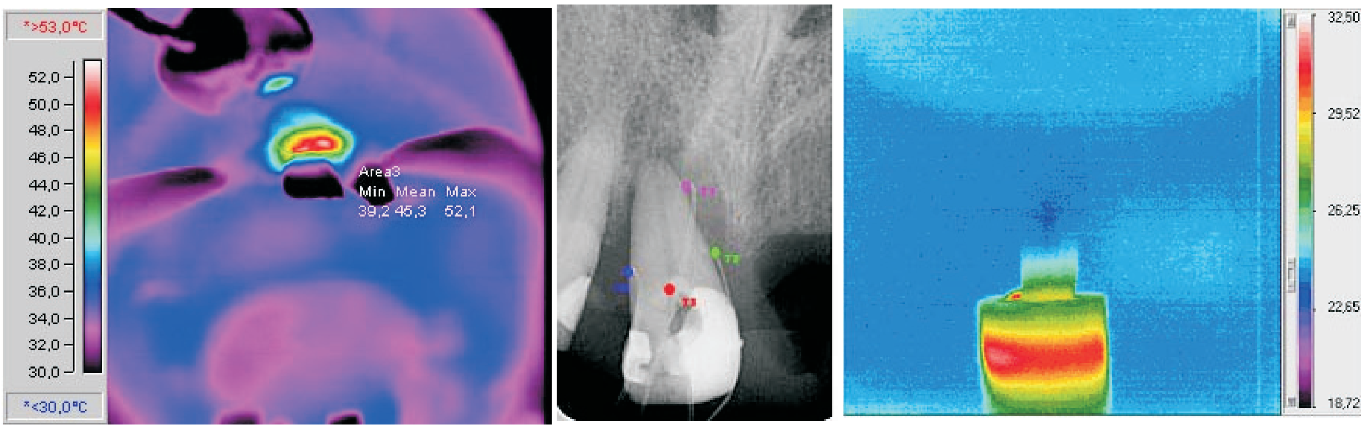
Measurements were conducted on two experimental stands:

1)The tooth sample was fixed in the sleeve full with moisturized cotton wool (without excess of water) (Fig. 2A, B). The evaporated water was supplemented after each measurement cycle to maintain aconstant level of humidity during the whole experiment - **experimental stand without simulation of external cooling.**

2)The tooth sample was fixed in the sleeve as described above, but the cotton wool was more moisturized with water (with excess of water – the content of water reached 1 mm above cotton wool) - **experimental stand with simulation of external cooling.**

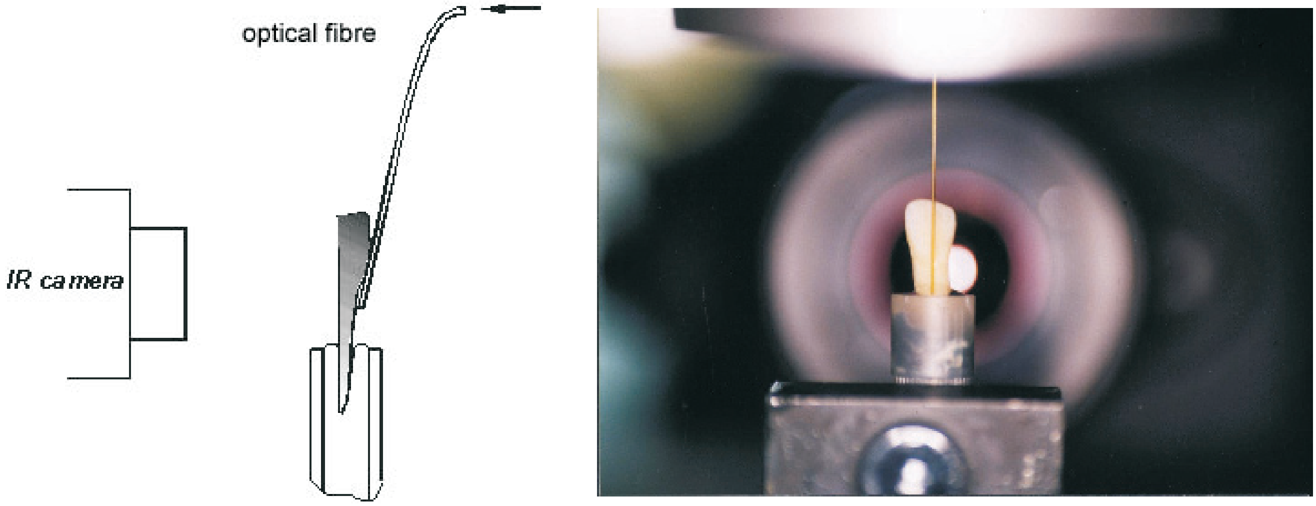
Laser radiation and sample irradiation

A Nd:YAG laser system (model 1503 CTL) that emitted pulsed infrared radiation at a wavelength of 1064nm was used. The single pulse width was 150ms. A 320-mikrons



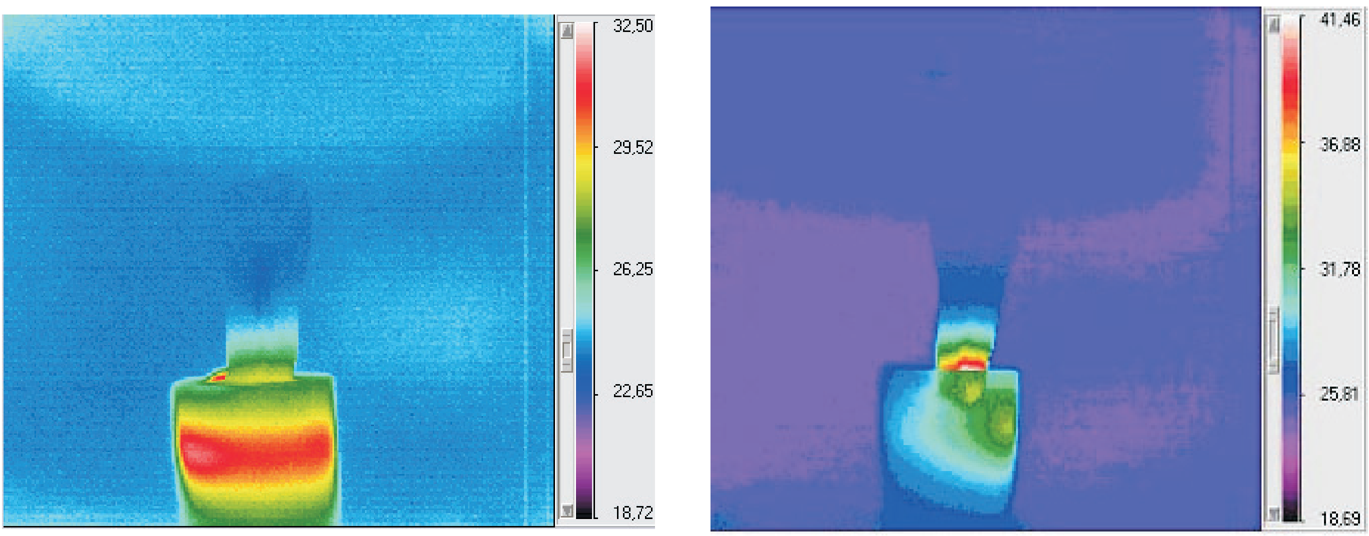
1 A 1 B 1 C

Figure1.
Nd:YAG laser subgingival curettage: A) Thermal image obtained immediately after laser irradiation. B) Schematic diagram of the tooth equipped with thermocouples C) Operation site after laser curettage.



2 A 2 B

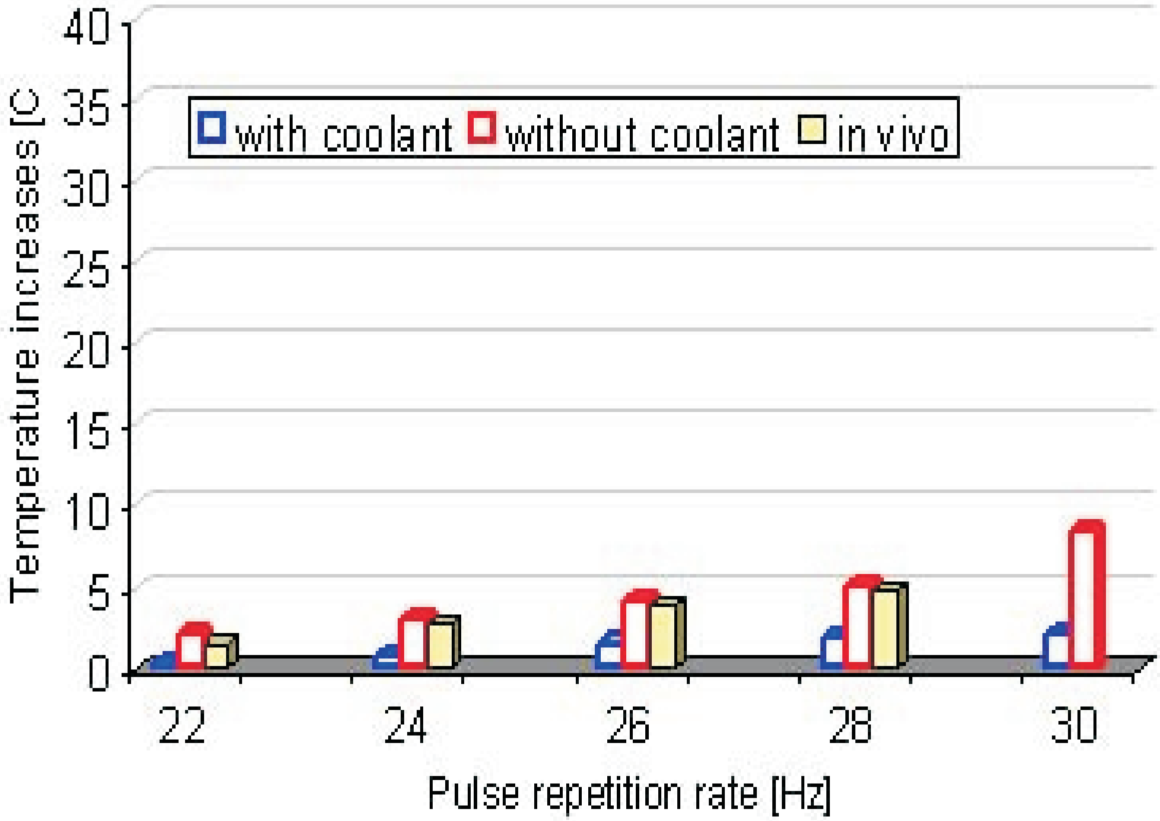
Figure 2
The experimental stand: A) schematic diagram B) front view



3 A 4 B

Figure 3
Thermal image of the surface of sample in 30th sec of laser irradiation at the energy of 100mJ and a pulse repetition rate of 20pps: A) without simulation of external cooling B) with simulation of external cooling

4A



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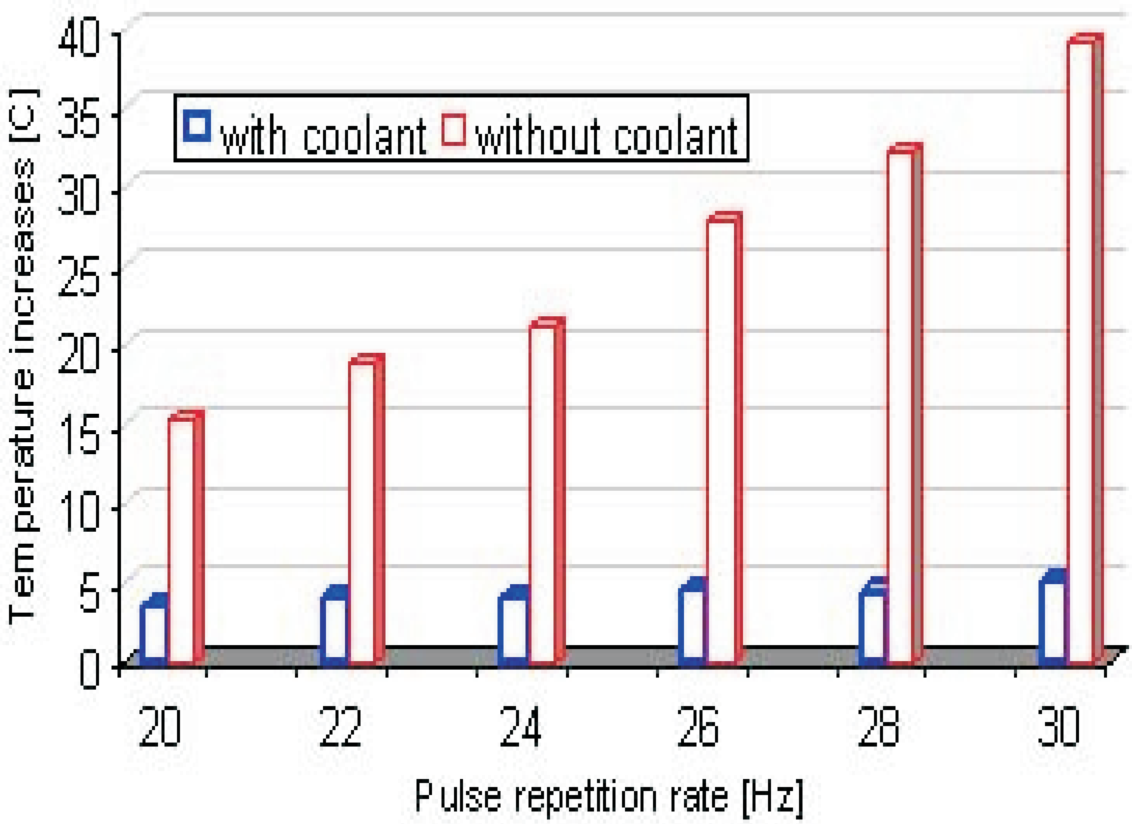

Figure 4.
The rise in temperature on the internal surface of the tooth depending on laser frequency and condition of experimental stand: A) laser energy of 50mJ B) laser energy of 100mJ

Table 1.
Parameters of the Nd:YAG laser used in experimental study taking the real output laser energy into consideration.

Energy [mJ]	50	50	50	50	50	50	100	100	100	100	100	100
Output energy [mJ]	22,9	23,2	23,3	23,9	24,3	24,5	40,5	42,1	41,9	41,8	41,9	42,1
Frequency [Hz]	20	22	24	26	28	30	20	22	24	26	28	30
Power [W]	1.0	1.1	1.2	1.3	1.4	1.5	2.0	2.2	2.4	2.6	2.8	3.0

optical fiber was fixed in the handle and positioned in the cervical region parallel to the tooth surface (Fig. 2.). Laser irradiation of all samples was performed in the contact mode for 30 sec. The radiation energy of 50mJ and 100mJ and pulse repetition rate of 20, 22, 24, 26, 28 and 30 Hz (power levels 1 – 3W) were tested on each experimental stand. To increase accuracy of measurements, each cycle for each combination of laser parameters was repeated three times. Prior to the irradiation of each sample, the real radiation energy was determined using a joulemeter. The laser parameters and results of measurements with joulemeter are listed in table 1.

Temperature measurement

Temperature changes on the internal surface of the tooth at the time of laser irradiation were measured by means of thermal imaging camera ThermaCAM SC1000 (Inframetrics, USA) with its dedicated software package Thermal Studio, allowed continuous registration as well as analysing the stored images. For each laser power settings thermal images were taken, at a rate of 10 frame/sec, over a period of 30 sec. Example thermal images, registered during measurements are presented in figure 3. Data obtained from all measurement cycles are shown in the form of graphs (Fig. 4.).

Results

Prior to the irradiation the mean background temperature was determined. This value was then subtracted from all the data in each thermal sequence, enabling the increase in temperature, from room temperature, to be observed.

The mean rises in maximal temperature, recorded on the internal surface of tooth ranged from a minimum 0.2°C to a maximum of 1.3°C, if measurements were conducted on experimental stand with simulation of external cooling and low laser energy (50mJ) was used (Fig 4A). On the stand without simulation of external cooling the mean rises in temperature ranged from 2°C to 8.4°C. Under in vivo conditions the maximal temperature observed did not exceed 4.7°C (Fig. 4A). Data obtained at higher laser power (100mJ) showed that an increase in power setting generally corresponded to an increase in detected temperature (Fig. 4B). The rises in temperature at an energy of 100mJ were 4.5°C-5,1°C (with simulation of cooling) and 15.3°C – 39.2°C (without simulation of cooling). Lower levels of maximum temperatures were obtained from the experimental stand with simulation of external cooling.

A rise in temperature with increased repetition rates was observed for all power settings.

Discussion

The results suggest, that irradiation of the tooth surface with Nd:YAG laser can cause under particular circumstances an increase of temperature in the dental pulp chamber. The depth of energy penetration in dentin is dependent on the thickness of dentin and on the power and energy densities of laser. At a low energy density the depth of laser beam penetration is smaller, than the thickness of dental hard tissues [10]. Small range of penetration in dentine does not preclude the risk of undesirable collateral heat effects in the dental pulp [11]. Published studies using extracted human teeth have shown that Nd:YAG laser radiation at an energy density of 700J/cm^2 and a power of 5W can induce temperature increases up to 9-22°C [12]. Rises in temperature above 8°C have also been reported by other authors [7, 13].

When the temperature value in the dental pulp exceed the critical value of 5.5°C, irreparable changes may occur [14]. This suggests that the temperature increases encountered in this study may pose a potentially serious threat to pulp vitality. One should keep in mind that most investigations upon thermal effects were conducted on extracted human teeth, without external cooling. Irradiating the root surface under in vivo conditions might improve the diffusion of heat due to the perfusion with blood. The cooling of a tissue by water during laser irradiation results from the heat capacity of water, thermal gradients, thermal diffusion and cooling by convection [15].Avoiding external cooling on the experimental stand results in greater temperature rises, as was confirmed in this study. The temperature increase of 39.2°C at the internal surface of the tooth occurred when laser power of 100mJ at repetition rate of 30Hz was used without simulation of external cooling. For the experimental stand with simulation of cooling, the overall temperature increase of the tooth surface was less than 5°C with the identical laser parameters Published research and the data obtained in this in vitro study show that an increase in laser power setting leads to an increase in heat generation. Furthermore, cooling of the surgical field seems to be an essential condition for subgingival laser curettage without health hazard.

The depth of energy penetration resulting from laser irradiation is dependent on variables such as laser wavelength, optical and thermal properties of the target, power and energy densities and duration of exposure [15]. The most critical features in determining the extent of tissue damage appear to be those over which the clinician has control, e.g., power, energy, rate and duration of exposure and use of surface coolant [16]. The selection of proper laser parameters is one of the main problems connected with the use of Nd:YAG laser in periodontology. Various authors recommend a power ranged from 1,25W to 3W [6]. Such a power seemed to be save with respect to the adjacent tissues and the dental pulp [17, 18].

The results of this study show, that the temperature rise at the internal surface of the tooth at high laser power of 3W (100mJ, 30Hz) was lower, than the critical value for a dental pulp injury, providing that simulation of cooling was used. It should be emphasized, that in this study the Nd:YAG laser exposures were made with an optical fiber, held immobile for 30 sec in contact with experimental samples. Although in clinical conditions curettage is lasting for 60 sec or even longer, the laser energy is divided on larger area since the optical fiber is not in a fixed position, but is moved horizontally and vertically over the surface of the tooth and prevents in that way spot heating. Furthermore, in clinical conditions external cooling of the operation area is always applied. Blood flow through the pulp chamber and the diffusion of heat into surrounding tissue may also reduce a rise of pulp temperature [19].

Conclusions

1.To prevent undesirable thermal side effects and dental pulp injury due to excessive heating laser assisted sub-gingival curettage should be performed using power setting ranged from 1,5W to 3W with simultaneous water cooling at the site of instrumentation.

2.Thermal imaging system provides means for monitoring temperature rise on the external surface of the tooth during laser instrumentation under in vitro conditions and in preclinical studies.

References

1.Loney RW, Price RB. Temperature transmission of high-output light-curing units through dentin. Oper Dent. 2001; 26(5): 516-20.

2.Srimaneepong V, Palamara JE, Wilson PR. Pulpal space pressure and temperature changes from Nd:YAG laser irradiation of dentin. J Dent. 2002; 30(7-8): 291-6.

3.Dederich DN. Laser curettage: an overview. Compend Contin Educ Dent. 2002; 23(11A): 1097-103.

4.Zmuda S, Ignatowicz E, Dabrowski M, Dulski R. Thermographic assessment of the thermal effects of laser during sterilization of pathological periodontal pocket. Thermography and Lasers in Medicine, Lódz (6th December 2003)

5.Ben Hatit Y, Blum R at all. The effects of a pulsed Nd:YAG laser on subgingival bacterial flora and on cementum: an in-vitro study. J Clin Laser Med Surg 1996; 14(3): 137-43.

6.Simunovic Z (red). Lasers in Surgery and Dentistry. Eurotrade Print, Murska Sobota, Slovenia 2001.

7.Turkmen C, Gunday M, Karacorlu M, Basaran B. Effect of CO, Nd:YAG, and ArF excimer lasers on dentin morphology and pulp chamber temperature: an in vitro study. J Endod 2000; 26(11): 644-8.

8.Mc Cullagh JJ, Setchell DJ, Gulabivala K, Hussey DL, Biagioni P, Lamey PJ, Bailey G. A comparison of thermocouple and infrared thermografic analysis of temperature rise on the root surface during the continuous wave of condensation technique. Int Endod J. 2000; 33(4): 326-32.

9.Lipski M. Wzrost temperatury na powierzchni korzeni zêbów w nastêpstwie wypelniania kanalów technika iniekcyjna Ultrafil. Badania in vitro. Czas Stomat 2003; LVI (10): 639-644.

10.Ling PL, Karim AC. A surgical technique for administering laser irradiation to rat incisor dentin. Anat Rec 2000; 260(4): 359-65.

11.Gow AM, McDonald AV, Pearson GJ, Setchell DJ. An in vitro investigation of the temperature rises produced in dentine by Nd:YAG laser light with and without water cooling. Eur J Prosthodont Restor Dent 1999; 7(2): 71-7.

12.Wilder – Smith P, Arrastia AA, Schell MJ at all. Effect of Nd:YAG Laser irradiation and root planing on the root surface: structural and thermal effects. J Periodontol 1995; 66: 1032-1039

13.Mehl A, Kremers L, Salzmann K, Hickel R. 3D volume-ablation and thermal side effects with the Er:YAG and Nd:YAG laser. Dent Mater 1997; 13(4): 246-51.

14.Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg 1965; 19: 515-530.

15.Dederich DN. Laser/Tissue interaction. Alpha Omegan 1991; 8: 33-36.

16.Israel M, Cobb CM, Rossmann JA, Spencer P. The effects of CO, Nd:YAG and Er:YAG lasers with and without surface coolant on tooth root surfaces. An in vitro study. J Clin Periodontol 1997; 24: 595-602.

17.Myers TD, Murphy DG, White JM, Gold SI. Conservative soft tissue management with the low-powered pulsed Nd:YAG dental laser. Pract Periodontics Aesthet Dent 1992; 4(6): 6-12.

18.Ignatowicz E. Oddzialywanie termiczne promienia lasera Nd:YAG na tkanki przyzêbia i miazgê zêbów szczura w trakcie opracowywania szczeliny dziaslowej. Rozprawa na stopieñ doktora nauk medycznych. Warszawa 2003.

19.Walmsley AD, Williams AR. Acoustic absorption within human teeth during ultrasonic descaling. Journal of Dentistry 1986; 14: 2-6.

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A thermographic investigation of skin temperature changes in response to a thermal washout of the knee in healthy young adults

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SUMMARY

This paper presents the results of a normative study of a thermal washout test of the knee. Significant and prolonged changes in the temperature of the knee were recorded after a 3 minute application of a Cryo/Cuff to the knee of young healthy adults. Gender differences with males recording significantly lower temperatures than females were also found. This study has implications for the therapeutic use of ice in the management of acute soft tissue injuries. These normative data will provide a very useful comparison for ongoing research into patellofemoral joint problems.

Key Words: Thermal washout, Knee, Patellofemoral, Cold, Rehabilitation

EINE THERMOGRAPHISCHE ERFASSUNG DER HAUTTEMPERATUR NACH WÄRMENTZUG AM KNIE BEI JUNGEN, GESUNDEN ERWACHSENENEN

Diese Arbeit stellt die Ergebnisse einer normativen Studie über den Wärmeentzug am Kniegelenk dar. Signifikante und anhaltende Veränderungen der Temperatur des Kniegelenks wurden nach einer 3 Minuten dauernden Anwendung einer Kühlmanschette bei jungen Erwachsenen beobachtet. Geschlechtspezifische Unterschied zeigten sich insofern, dass männliche Probanden signifikant geringere Temperaturen als Frauen boten. Die Studie hat Bedeutung für die therapeutische Anwendung von Eis in der Behandlung akuter Weichteilverletzungen. Diese Normalwerte können als nützliche Vergleichsdaten für die laufende Forschung über femuropatellare Probleme gesehen werden.

Schlüsselwörter: Wärmentzug, Knie, patellofemoral, Kälte, Rehabilitation

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Introduction

The purpose of this study is to provide normative thermographic data for a thermal washout test of the knee that will later be used on a group of patients with patellofemoral problems referred to physiotherapy. It is hypothesised that patients who have compromised circulation will respond differently to this test compared with the normal subjects reported here. Previous studies report that the patella is, thermographically, a very cold area [1,2] . This is interesting and is something of a paradox as the knee has a well-developed vascular anastomosis the rete patellae, which encircles the patella. The proximal part of the rete patellae, is very superficial [3]. As the proximal part of the rete patellae is superficial and the patella is thermographically a cold area a thermal washout, may show interesting results when comparing how normal subject's temperature recovers compared with patellofemoral patients.

Arnoldi [3] with Sanchis-Alfonso and Rosello-Sastre [4] provide evidence that points toward there being circulatory disruption in some patients with patellofemoral pain secondary to malalignment. These authors argue that malalignment produces abnormal stresses on the vascular supply leading to vascular torsion or bending which in turn leads to intermittent tissue hypoxia.

Clinical evidence supports that this may be the case [5]. This study investigated the natural history of anterior knee pain in a sample of 54 adolescent females, mean age 15 years, they followed their progress for a mean period of 4 years and 4 months; they reported that 16.7% (n=9) of the sample had pain that was aggravated by cold weather. There is further clinical evidence that some patients with patello- femoral pain have circulatory problems [6]. At initial assessment 18% (n=14) of patients were classed as cold sufferers. These patients initially recorded worse scores on 4 outcome measures and at 3 month review following discharge from an exercise based physiotherapy approach these patients had not significantly improved, however the non-cold sufferers had shown some significant improvements in their condition. The conclusions were; firstly patients with patello- femoral pain syndrome classed as cold sufferers reported greater pain levels and tolerated less physical activity than non-cold sufferers at initial assessment. Secondly, cold sufferers, showed less response to an exercise based treatment programme than non-cold sufferers.

The thermal washout test that has been specifically developed for this study uses a Cryo/Cuff (Aircast, New Jersey, USA) to cool the knee and a ThermaCAM PM 595 (Flir Systems AB, Danderyd, Sweden) infrared camera to measure how quickly the temperature of the knee recovers to baseline following removal of the cold stimulus.

Methodology

Thirty nine young healthy subjects were recruited from Satakunta Polytechnic. The study was designed in accordance with the World Medical Organisation declaration of Helsinki (1964) [7] and all participants gave written consent to participate.

The following eligibility criteria were used

Inclusion criteria

Participants had to be healthy adults with no history of neuromusculoskeltal or vascular injury to the lower limb or lumbar spine.

Exclusion criteria [8,9]:

- Cold Hypersensitivity
- Cardiac Disease
- Hypertension
- Sensory Deficit
- Raynaud's or Buerger's disease
- Cryoglobinaemia or Cold Urticaria

Following the confirmation of eligibility partici pants filled in a general health screening questionnaire. Participants were requested not to drink alcohol and to shave the measurement area of the knee the night before testing. In the two hours preceding the test participants were requested not to smoke, eat, and take part in strenuous exercise or to have drinks containing caffeine [10,11].

Skin fold measurements were taken, to estimate body composition using four points on the dominant side of the body, these were; biceps brachii, triceps brachii, lower angle of scapula and just proximal to the anterior superior iliac spine [12,13]. In addition the skin fold over the centre of the patella was also measured [14].

Prior to the baseline temperature measurement of the knee being taken subjects were asked to undress and put on shorts. The exposed lower limbs were allowed to equilibrate to the room temperature of a mean 22.7C (20.2- 23.3C) away from localised sources of heat, sunlight or draughts, for 15 minutes [2,15,16]. The baseline temperature measurement of the knee was then taken with the ThermaCAM PM 595. Immediately, following the baseline temperature reading the Cryo/Cuff was applied to the knee.

The Cryo/Cuff is comprised of two components.: 1. A sleeve that was placed on the subjects over the knee. 2. A flask that acts as the reservoir for a cold water and Ice mix.The flask was raised to a height 40 cm above the knee sleeve. This allows the cold water contained in the flask to flow into the the knee sleeve and provide the cooling effect. It is re_ ported that an elevated flask at a height of 40cm produces 30mm Hg of compression [17]. Thermographic measure- ments were taken with subjects in a stable relaxed sitting position. The knee angle was standardised to 45 degrees using a goniometer. The thermal camera was focused on the centre of the patella and aligned parallel with the skin overlying the patella. Once the subject and camera were positioned in the correct experi mental setup the first temperature measurement was taken, this was used as the baseline Figure 1. Following removal of the Cryo/ Cuff temperature data were sampled at a rate of 1 image per minute.

Pilot studies

In the first pilot study the Cryo/Cuff was left in place for 5 minutes, this was based on the work of Ho et al [18] who reported that 5 minutes of ice application produced a significant decrease in temperature in all the tissues of the knee. The effect of the cooling was recorded for 20 minutes. This first study showed that the temperature continued to decrease at 20 minutes following removal of the Cryo/Cuff. Based on this result the second pilot study used a cooling time of 3 minutes with a follow up time of 30 minutes. In this study the temperature stopped decreasing between 20 and 25 minutes. The third pilot study con- firmed the findings of the second pilot study.

Statistical analysis

Parametric and non parametric statistics were used for analysis. T-tests were used for comparing skin temperatures, fat percentages and skin fold thickness. Mann Whitney U tests were used for the analyses of differences in smoking, physical activity and alcohol intake between males and females. Kruskal-Wallis tests were used for the analysis of the effect of physical activity levels on measured temperatures. The Pearson correlation was calculated between skin fold thickness, fat percentage and skin temperatures. Confidence Intervals (CI) of 95% are reported where appropriate.

Results

Thirty nine healthy young adults were recruited for this study, demographic data for the subjects are presented in Table 1. As it is well recognised that the incidence of patello-femoral problems is higher in females than in males, the decision to present and analyse the results separately for females and males was made apriori.

Using t-tests significant differences were found between the fat percentage (p= <0 .001, 95% CI 19.6-24.1) and skin fold thickness (p=0.005, 95% CI 10.7-13.3) over the patella between females and males with females displaying higher fat percentages and thicker patella skin fold measure ments. However for the other demographic variables of smoking (p= 0.749), alcohol intake (p= 0.513) and physical activity (p= 0.411) no significant differences were found using Mann Whitney *U*-tests.

Figure 2 shows the temperature measurements following the thermal washout. The mean temperature difference between females and males was 0.5ºC at baseline, this was non significant (t-test p=0.313, 95% CI -0.48-1.45) with females recording the higher temperatures. Immediately after the thermal washout the mean difference between females and males decreased to 0.4ºC (t-test p=0 .289, 95% CI -0.39-1.23).

Following removal of the Cryo/Cuff temperatures continued to decrease in both females and males with males showing a consistently lower temperature than females the difference between females and males progressively increased to 0.8ºC (t-test p= .014, 95% CI .17-1.41) by the end of the measurement period.

In females a low of 26.9ºC was reached at 14 minutes thereafter the temperature remained stable. In males a low of 26.2ºC was reached at 16 minutes thereafter the temperature remained stable.

T-tests were used to compare skin temperatures of males and females after cooling. Males and females differed significantly at 7 minutes after cooling (p= .041, 95% CI 0.03-1.42), males having lower skin temperature.

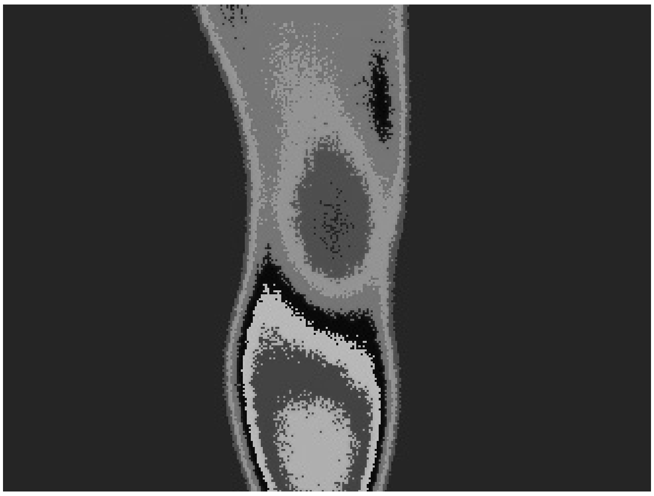
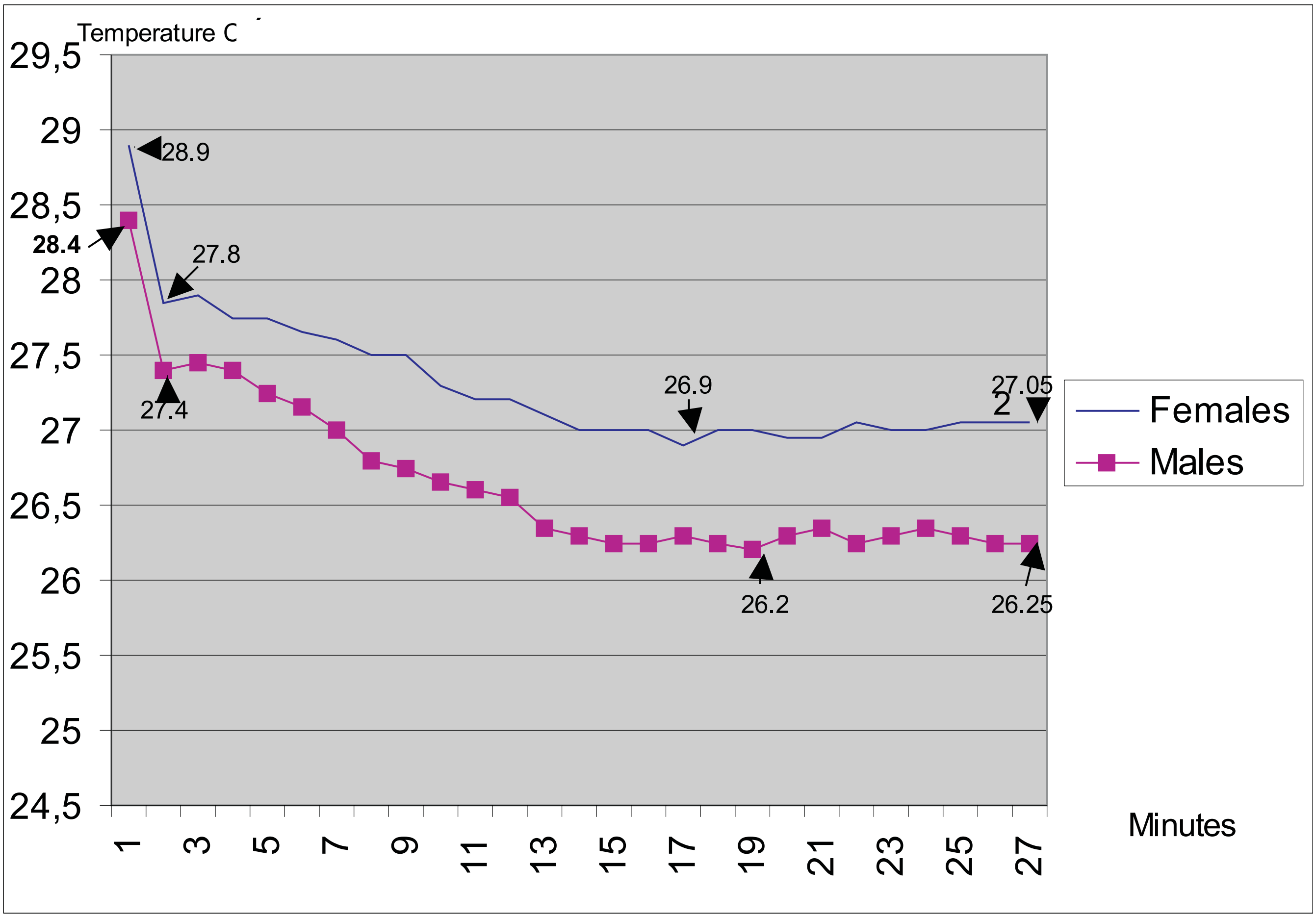


Figure 1.
Baseline thermogram of a female subject showing cool area over patella

Table 1 Demographic data

	Males (n=19)	Females (n=20)	p-values
Age (range) years	25.2 (21,30)	25.6 (21,30)	ns.
Fat % (SD)	16.5 (5.3)	26.9 (3.8)	p < .001
Skin fold over patella (range) mm	10.3 (5,21)	13.7 (9,18)	p = .005
Smoking	4	3	ns.
Alcohol intake **0-10 units per week** **..> 10 units per week**	 12 7	 18 2	ns.

Figure 2 Temperature measurements.



Comparison of skin temperatures of the whole study population (N=39) showed that the mean skin temperature decreased significantly during the 3-minute cooling from 28.65° (SD 1,50) to 27.62° (SD 1.25) ($p<0.001$, 95% CI –1,28 - -0.79). When comparing the temperature immediately after cooling to temperatures taken during the recovery period a significant decrease was seen at 4-minutes from 27.62° (SD 1.25) to 27.29° (SD 1.08) ($p=0.004$, 95% CI 0.39-3.05). The mean temperature stayed significantly lower during the whole follow-up period thereafter.

Skin fold thickness over patella had no significant effect on the skin temperature before the cooling (p= 0.055), after cooling (p=0.275), and after 25-minute follow-up period (p= .343). There was a high correlation between skin fold thickness and fat percentage ($r=0.74$, $p<0.001$). There was no correlation between skin fold thickness and skin temperature, there was a low correlation between fat percentage and skin temperature at the last follow-up measurement point ($r=0.39$, $p= 0.014$).

A previous study [13] investigated temperature change in response to exercise. It was decided to follow up this work by investigating the response to the thermal washout in subjects classed as high exercisers n=20 (>3 times per week) compared the subjects classed as low exercisers n=19 (0-3 times per week). Based on a Kruskal Wallis Test the level of physical activity did not have any significant effect on measured temperatures e.g. before cooling (p=0.126), after cooling (p= 0.614), at the 1st minute follow-up point (p= 0.472), at the 7th minute follow-up point (p=0 .431) and at the 25th minute follow-up point (p= 0.242).

Discussion

This study gives relevant new information on the effects of cooling using the Cryo/Cuff-method. It confirms the findings of the pilot studies that thermal changes over the patella area continued for a prolonged period after a short 3-minute cooling period and that recovery to baseline temperature did not occur even after 25 minutes. The results of this study support the work of Ho et al [18] who also reported a prolonged cooling effect (20 minutes) after a brief (5 minutes) application of ice to the knee.

However it can be assumed that the room temperature, subject's state of undress and static subject positioning are confounding variables when considering the length of the follow up period. It is also interesting to note that during follow up period we did not observe any reflective increase in circulation (Hunting response), however this may be due to the very brief period (3 minutes) that the cold application was in place.

The results of this study suggest that the length of application of cold therapy should be reconsidered. Physiotherapists commonly treat acute soft tissue injuries using cold, apart from the Cryo/Cuff method a variety ice packs which can be made from reusable gels or from chipped ice wrapped in wet towels applied directly to the skin are available. It is important to note that different methods of cooling are considered non-aggressive (reusable gel packs) and aggressive (ice chips) as at the same temperature ice has a higher specific heat and because ice absorbs a large amount of energy as it melts and converts from solid to liquid [9]. It is also important to note that a typical therapeutic treatment session using cold would last for 10-15 minutes [9]. It is interesting to speculate what level of temperature decrease and over what time period this occurs for following a typical treatment session in light of our findings following a very brief non- aggressive cold application.

As predicted there were significant differences in temperature between males and females, these were probably due to the differences recorded in fat percentage. Females tended to have higher fat percentages and were therefore more insulated and were affected less than males by the thermal washout. It is interesting to reflect on the clinical relevance of this finding with respect to patients with patellofemoral pain. As stated previously patello- femoral pain is more common in females however if circulatory factors were important in the condition then based on these results males should be more affected. Further studies investigating this are ongoing.

Relevance to future study

This study design is easy to copy and apply to many patient groups in a clinical environment to study the effects of cold therapy. It would also be very interesting to compare the effects of different cold therapy modalities.

References

1. Lovisatti L, Mora L, Pistolesi GF. Thermographic patterns of lower limb arterial disease. Thermography proceedings 1 European Congress Amsterdam. Bibliotheca Radiologica 1975; 6: 107-114.

2. Mayr H. Thermographic evaluation after knee surgery. The Thermal Image in Medicine and Biology. Uhlen-Verlag, Wien. 1994.

3. Arnoldi CC.. The Patellar Pain Syndrome. Acta Orthop Scand. 1991; 62: (Suppl. 244), 1-29.

4. Sanchis-Alfonso V, Rosello-Sastre,E. Imunohistochemical analysis for neural markers of the lateral retinaculum in patients with isolated symptomatic patellofemoral malalignment. The American Journal of Sports Medicine. 2000; 28: 725-731.

5. Sandow MJ, Goodfellow JW. The natural history of anterior knee pain in adolescents. J Bone Joint Surg [Br]. 1985; 67: 36-38.

6. Selfe J, Harper L, Pedersen I, Breen-Turner J, Waring J, Stevens D. Cold legs: a potential indicator of negative outcome in the rehabilitation of patients with patellofemoral pain syndrome. The Knee. 2003; 10: 139-143.

7. World Medical Association., 1964. Declaration of Helsinki. . Accessed 5/11/03.

8. Low J, Reed A. Electrotherapy explained: Principles and practice. Butterworth-Heinemann, Oxford. 1994.

9. Cameron MH. Physical agents in rehabilitation. W.B. Saunders Company, Philadelphia. 1999.

10. Scudds RJ, Helewa A, Scudds RJ. The effects of transcutaneous electrical nerve stimulation on skin temperature in asymptomatic subjects. Physical Therapy. 1995; 75: 7, 621-628.

11. Landry MD, Scudds RA.. The cooling effect of electroaccupuncture on the skin temperature of the hand. Journal of Hand Therapy. 1996; 9: 359-366.

12. Fogelholm M. Antropometria. In Kuntotestauksen perusteet. Liikuntalääketieteen ja testaustoiminnan edistämisyhdistys Liite ry. 1999

13. Karki A, Lahdeniemi M. The effects of peripheral dynamic movements on the lower limb circulation assessed by thermography: three-one group studies. Proceedings of SPIE, Thermosense 24, Orlando, 2002; 4710: 384-389.

14. Oosterveld FGJ, Rasker JJ, Jacobs JWW, Overmars HJA. The effect of local heat and cold therapy on the intraarticular and skin surface temperature of the knee. Arthritis & Rheumatism. 1992; 35: 2, 146-151.

15. Sherman RA, Karstetter KW, Damiano, M, Evans CB. Stability of temperature asymmetries in reflex sympathetic dystrophy over time and changes in pain. The Clinical Journal of Pain. 1994; 10: 71-77.

16. Ring EFJ. Cold stress test for the hands. The Thermal Image in Medicine and Biology. Uhlen-Verlag, Wien. 1994.

17. Webb JM, Williams D, Ivory JP, Day S, Williamson DM. Orthopedics. 1998; 21: 1, 59-61.

18. Ho SSW, Coel MN, Kagawa R, Richardson AB.. The Effects of Ice on Blood Flow and Bone Metabolism in Knees. The American Journal of Sports Medicine. 1995; 22: 537-540.

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1. Costello JT., McInerney CD, Bleakley CM, Selfe J, Donnelly AE. The use of thermal imaging in assessing skin temperature following cryotherapy**:** A review Journal of Thermal Biology2012, 37(2). 103-110
2. Selfe J, Sutton C., Hardaker NJ, Greenhalgh S, Karki A, Dey P. Anterior knee pain and cold knees: A possible association in women**.** Knee 201017 (5) 319-323
3. Selfe J, Hardaker N, Whitaker J, Hayes C. Thermal imaging of an ice burn over the patella following clinically relevant cryotherapy application during a clinical research study**.** Physical Therapy in Sport 2007, 8 (3) 153-158
4. Selfe, J., Hardaker, N., Thewlis, D., Karki, A. An Accurate and Reliable Method of Thermal Data Analysis in Thermal Imaging of the Anterior Knee for Use in Cryotherapy Research**. A**rchives of Physical Medicine and Rehabilitation 2006, 87 (12) 1630-1635
5. Ammer, K Thermology 2004 - A computer-assisted literature survey. Thermology International 2005, 15 (1). 5-37

Normative data of thermal washout of the knee - point of view

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Karki et al present a paper in this issue with a claim to provide normative data for thermal washout of the knee in healthy young adults. Normal data could be useful for the evaluation of cold treatment particularly after acute injuries.

Unfortunately, there are a number of questions raised in this publication. The references are not comprehensive and number of previous and recent papers, where skin temperatures have been measured after a variety of cooling modalities such as cold packs (1,2,3) or cold air (4,5,6) are missing. This introduces major bias into the background information.

The most surprising finding of Karki et al is a continuous decrease of knee temperature after removal of the cryo-cuff. These results are in contradiction to all other published findings. All authors have reported a rapid recovery of local skin temperatures (1-6)

Enwemeka et al. described a rapid increase of skin temperature and tissue temperature 1 cm below the skin after removal of a cold pack, but ongoing decrease of tissue in 2 and 3 cm depth (3). The deeper tissues lost heat simultaneously as the superficial tissues rewarmed; to the extent that 40 min after treatment, the deeper levels were cooler than the cutaneous and 1.0 cm levels.

Karki has referred to a paper from Ho et al. (7), to support their finding of continuous skin cooling. However, this paper used a bone scan for the investigation of blood flow and bone metabolism. Although they found a prolonged decrease in blood flow and technetium uptake in bone, this was not related to age, sex, knee circumference, or skin temperature after cooling.

The mechanism of prolonged skin cooling after removal of the cooling device remains unclear. Such phenomena are known in patients with Raynaud´s phenomenon, when a mild cold stimulus shuts down the peripheral circulation for 40 to 120 minutes. But healthy subjects react with hyperaemia due to such cold challenge. This is understandable, because the fingers have a major involvement in temperature regulation, whereas the knee is not normally an area of major thermoregulation. It is therefore unclear, why healthy young adults should present with constricted skin vessels in the knee region after application of compressive intensity of 30mm Hg and a cold stimulus of 0°C degrees, although the contact temperature of the cryo-cuff was not stated by the authors.

References

1.Schmidt KL, Mäurer R, Rusch D: Zur Wirkung örtlicher Wärme und Kälteanwendungen auf die Hauttemperatur am Kniegelenk. Z.Rheumatol 1979; 38; 213-219

2.Ring EFJ. Thermography and Rheumatic Diseases. Thermography,Proc. 1 Europ. Congr. Amsterdam 1974 Karger Basel 1975, p. 97-106

3.Enwemeka CS; Allen C; Avila P; Bina J; Konrade J; Munns S. Soft tissue thermodynamics before, during, and after cold pack therapy. Medicine and Science in Sports and Exercise 2002; 34:45-50

4.Dachs E, Schartelmüller T, Ammer K. Temperatur von Kaltluft zur Kryotherapie und Veränderungen der Hauttemperatur am Kniegelenk nach Kaltluftbehandlung. Thermol Österr. 1991; 1(1): 9-14

5.Mayr H, Ammer K. Reproduzierbarkeit der Kaltlufttherapie. Thermol Österr. 1992; 2(1):25-29

6.Kim Y-H, Back S-S, Choi K-S, Lee S-G, Park S-B. The Effekt of Cold Air Application on Intra-Articular and Skin temperatures in the Knee. Yonsei Medical Journal 2002; 43, 621-626

7.Ho SS, Coel MN, Kagawa R, Richardson AB. The effects of ice on blood flow and bone metabolism in knees. The American Journal of Sports Medicine 1994; 22 (4): 537-540.

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2004 UK Symposium on Medical Infrared Thermography, 3rd November, Bushy House, NPL, Teddington, Middlesex, UK.

UK Thermography Association, National Physical Laboratory (NPL)

10.00 Registration, coffee and welcome

Session 1 Clinical applications of thermography

10.30 Cooling curves: is time important? *A Heusch*

10.50 Combined thermal imaging and colour duplex ultrasound assessments in renal fistula patients. *J Allen*

11.10 Thermography, photography, laser Doppler flowmetry and 20 MHz B-scan ultrasound for the assessment of morphoea activity: a pilot protocol. *K Howell*

11.30 Infrared thermal imaging and autologus breast reconstruction surgery. *J Mercer*

Session 2 Quality assurance and calibration

11.50 Reliability of quantitative measurements in medical thermography. *P Plassmann*

12.10 Quality assurance in medical thermography: is it necessary? *F Ring*

12.30 Medical infrared radiation thermometry – traceability and calibration. *R Simpson*

12.50 Lunch and tour of NPL radiation thermometry facilities

Session 3 Techniques, technology and resources

14.30 Trends in infrared detector and camera systems. *R Thomas*

14.50 Microwave radiometry technique for medical and industrial thermometry. *D Land*

15.10 Publications on medical infrared imaging from European countries. *K Ammer*

Session 4 Infrared image processing and computing

15.30 Compressing thermal medical images. *G Schaefer*

15.50 Registration of clinical photography and infrared thermograms. *C Jones*

16.10 Thermal medical image retrieval by moment functions. *S Y Zhu*

16.30 Open forum discussion / close

COOLING CURVES: IS TIME IMPORTANT?

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The time required for the body to equilibrate with its surrounding temperature is an accepted factor in the production of a standardised thermogram. If the environment is at a different temperature to that of the body, the body will try to compensate. This means that there will either be no change, an increase or a decrease in radiated heat from the body. At present, neither the time required nor the factors which might affect this have been scientifically determined, however, it is often stated that one should wait at least 15 minutes before imaging.

Sixteen volunteers gave their written consent before participating in this ethically approved project (School of Applied Sciences Ethics Committee). The subjects disrobed to the required level and thermal images were taken every five minutes for an hour (laboratory temperature 22.1°±1.2°C, outside temperature 9° ±2°C). A standard protocol was used to minimise non-biological variance.

The neck was found to increase in temperature over the time of assessment, yet the difference (comparing right side to the left) for the majority of the subjects was 0±0.3°C, irrespective of the cooling time allowed. The thoracic region showed a slight cooling effect, whereas the lumbar was variable. Between 15 and 30 minutes appears to be relatively stable period.

We conclude that the 3 gross anatomical regions of the back appear to vary in their reaction to being disrobed in a controlled environment. Although this data suggests that separate regions of the body might require different standardisation protocols, as yet there is not enough data for use to propose a region specific cooling time.

COMBINED THERMAL IMAGING AND COLOUR DUPLEX ULTRASOUND ASSESSMENTS OF RENAL FISTULA PATIENTS

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Vascular and clinical assessments of fistula function are important in patients undergoing or preparing to undergo renal dialysis. Objective assessments at Freeman Hospital now include combined colour duplex ultrasound and medical thermography. For example, these modalities can help study problems relating to high fistula flow and vascular steal, where digital blood flow (and hence skin temperature) can be impaired. The aims of this pilot study were a) to determine if fistula region skin temperature was related to fistula region blood flow and b) to compare simple differences in mean hand temperature against the clinical steal grading.

Renal patients were clinically assessed for vascular steal by the transplant surgeon (either steal or no steal). Patients also underwent objective vascular measurements which comprised thermal imaging of the hands and fistula region followed by fistula blood flow estimation using colour duplex ultrasound at the brachial artery. Differences in hand temperature and mean fistula region temperature were determined using dedicated image processing software (FLIR SC300 thermal imaging system with ThermaCam Researcher image processing software, skin emissivity 0.97). These temperatures were then compared with fistula flow and steal grading.

Twelve patients were studied (mean age 59 years), with five classed as having some degree of steal. Ultrasound measurements also identified the presence of stenosis in three patients. Estimated fistula flows ranged from 30 - 1950 ml min (mean [standard deviation] of 1100 [640] ml min) and were correlated with mean fistula region skin temperature ($R = +0.6$, $p<0.05$). Thermography usually clearly highlighted the warmer superficial blood vessels in the region of the fistula (33.7 [1] °C). Hand (non-fistula – fistula side) temperature differences with a cut-off of +1 °C were found to separate steal from non-steal patients with an accuracy of 92% (specificity 100%, sensitivity 80%). In this study the maximum difference between mean hand temperatures for a patient with steal was close to 5 °C.

We have demonstrated an association between fistula region skin temperature and estimated fistula blood flow. We have also shown that a bilateral hand temperature difference cut-off of +1 °C separates steal from non-steal patients with an accuracy of greater than 90%. Further work is now needed to explore the clinical utility of these findings, to identify which patients subsequently needed surgery, and also to examine the detailed characteristics of the fistula thermal profiles.

THERMOGRAPHY, PHOTOGRAPHY, LASER DOPPLER FLOWMETRY AND 20 MHZ B-SCAN ULTRASOUND FOR THE ASSESSMENT OF LOCALISED SCLERODERMA ACTIVITY: A PILOT PROTOCOL

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Background Localised scleroderma (LS) is a rare skin disorder characterised by an initial phase of inflammation, followed by progressive fibrosis (which can affect both the skin and underlying tissues), and ultimately atrophy. Infrared thermography (IRT) has been shown to be of value in the detection of active LS lesions in children. Plaques with a temperature >0.5°C warmer than adjacent or contralateral uninvolved skin can be considered "thermography +ve." On this basis, a positive thermogram detects clinically active LS lesions with a sensitivity of 92% and a specificity of 68% (*Martini et al, 2002). Skin surface temperature is influenced not just by dermal blood flow, but also by the morphological skin changes that can occur in LS. Increased heat transfer through the skin in older, clinically quiescent lesions associated with fat and muscle atrophy has been thought to be the reason for "false-positive" thermograms.

Method We have evaluated a new protocol for the assessment of LS in children. This combines IRT with laser Doppler flowmetry (LDF, a measure of microvascular skin erythrocyte flow), 20 MHz B-scan ultrasound (US, a technique for imaging skin structure), and digital photography (to record the extent of the clinically visible lesion). The digital images are superimposed on the infrared thermograms to assist the physician in relating the anatomy to the extent of skin involvement.

We re-assessed 15 clinically quiescent LS patients who were found to have "false-positive" thermograms on previous assessment by IRT (11F, 4M,). Up to 3 involved skin sites from each patient were selected for assessment by IRT, LDF and US. Equivalent measurements were also made from contralateral or adjacent uninvolved skin. Each involved site was re-assessed by two experienced clinicians to confirm that the area had remained clinically quiescent. Only data from such quiescent sites was included in our analysis. We calculated temperature data from the infrared thermograms at each skin site, and also LDF flux data from each site. All involved LS sites were then grouped into those that remained "thermography +ve" and those that were reclassified "thermography -ve."

Results The difference in LDF red cell flux between involved LS skin and contralateral/adjacent uninvolved skin was expressed as a percentage of the flux in the uninvolved skin. The mean (± standard deviation) flow difference for the "thermography +ve" group was 131 ± 153% versus 11 ± 51% for the "thermography -ve" group (p<0.004, t-test)

Conclusions Microvascular skin blood flow is increased in thermographically warm LS plaques that are considered to be clinically quiescent. This may suggest residual disease activity and could have implications for the length of medical treatment. Our protocol shows promise for the assessment of skin structural changes and blood flow in LS. Overlay of clinical photography onto thermograms improves the utility of thermography for monitoring LS plaque extension. Further work is in progress to refine our imaging techniques in order to define whether the increase in blood flow observed is related to inflammation or to structural changes.

*Martini et al, Rheumatology 2002;41:1178-1182

INFRARED THERMAL IMAGING AND AUTOLOGUS BREAST RECONSTRUCTION SURGERY

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Background and purpose

Autologus breast reconstruction has become an integrated part in the overall treatment for breast cancer patients who have had a mastectomy. Many studies have demonstrated the psychological, cosmetic, and sexual benefits of post-mastectomy breast reconstruction. One of the standard methods is to reconstruct a new breast using tissue removed from the patient's own abdominal wall (skin and underlying fat). Two different procedures may be used with regards to the preparation of the abdominal skin flap: (a) a free transverse rectus abdominis musculocutaneous (TRAM) or (b) a deep inferior epigastric perforator (DIEP) flap. In both cases patients are specifically pleased with the natural shape, soft consistency and permanency of the end result. However, there is a recognised incidence of partial flap necrosis in both the TRAM flap and the DIEP flap: this is more likely in smokers and the obese. A critical period during the operative procedure occurs during the re-connection (anastomosing) of the harvested flap. Blood circulation to the newly reconstructed breast is dependent on the viability of the microvascular anastomosis. Having an efficient non-invasive technique to monitor the blood flow status of the flaps used in autologus breast re-construction would provide invaluable information during such a procedure and may well help to reduce the incidence of post-operative complications. We wished to find out whether Infared (IR) thermal imaging (IR-thermography) could provide this possibility.

Method

Infra-red thermal images of selected skin areas in patients undergoing autologus breast reconstruction surgery using the DIEP flap method were taken prior to, during (to check circulation in the stomach flap when the blood supply is reconnected to the mammary artery) and in the days, weeks and months following surgery (to monitor blood flow status in the newly constructed breast). All IR-images were taken using a Nikon Laird S270 (Tokyo, Japan) IR-camera. This camera is a so-called 2 generation IR-camera that is capable of producing high-definition digital infrared thermal images. The images were stored electronically. For processing of the IR digital images we used image analysis software PicWin-IRIS (EBS system technik GmbH, München, Germany), which could produce measurements of skin surface temperatures to an accuracy of 0.1ºC. IR-images were taken under both steady state conditions as well as following a mild cold challenge. This latter procedure called dynamic IR-thermography, basically consists of activating the sympathetic nervous system by challenging the body with a cold stimulus (e.g. short period of fan cooling) and taking a series of images during the spontaneous recovery (re-warming) period. This technique allows one, for example, to more easily identify so-called perforatoring vessels of the medial and lateral branches of the deep inferior epigastric artery, one or more of which will be selected for re-connection to the internal mammary artery (the usual recipient vessel) during surgery. IR-thermography during surgery was used to indirectly monitor the blood flow status of the DIEP flap following re-connection of its blood supply to the internal mammary artery and associated veins. Dynamic IR-thermography was also performed during the post-operative period to monitor blood flow status in the newly constructed breast.

Results

In the pre-operative situation the use of IR-thermography to identify perforating vessels in the abdominal tissue was found to be helpful to the surgeons. The number and distribution of the perforating vessels varied greatly from patient to patient. During the operation the dissected flap cools down during the period it is not receiving a blood supply (ca. 50 min.) The rate and pattern of the re-warming in the flap after anastomoses to the recipient vessels gives a very clear indication as to how good blood circulation is in the DIEP flap. With a successful and adequate outcome of the anastomosis process the re-warming response was found to be rapid and well distributed. A poor re-warming response often resulted in anastomosing an extra vein to improve venous drainage (the most common problem). In the days following surgery IR-thermography of the new breast was found to be a quick and easy way to monitor its blood flow status, especially in the peripheral areas of the implanted flap, where reduced blood circulation often occurs. The easily understandable visualization of blood flow in the newly constructed breast using IR-thermography was also found to be comforting for the patients during the post-operative period.

Conclusions

During surgery IR-thermography was found to be particularly useful for monitoring blood flow status of the DIEP flap immediately after re-connection of its blood supply to its recipient vessels. The use of IR-thermography as a non-invasive indirect method of monitoring blood flow status in autologus breast reconstruction surgery is clearly beneficial, both to the surgeon as well as to the patients

RELIABILITY OF QUANTITATIVE MEASUREMENTS IN MEDICAL THERMOGRAPHY

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This paper describes two experiments designed to establish the measurement accuracy (bias, offset) of 4 thermal imagers after switching on and over a temperature range between 22 ºC and 42 ºC. A highly accurate Thermal Imaging Black Body (TIBB) reference source developed at NPL was used to test the imagers. Results demonstrate that imagers may drift considerably during the first 2 hours after switching on (up to 5 ºC). Results also show that over the normal human range of temperatures the offset error of the 4 systems under test is not necessarily constant or even linear. This means that absolute inter-image or multi centre measurements can not be made reliably. It also demonstrates that precise intra-image measurements can also be unreliable in spite of the fact that the imagers under test were within their respective manufacturer's specification.

The authors therefore recommend the use of external calibration sources in order to achieve repeatable results where high accuracy is required. A simple 3-point source based on the triple point of chemical compounds is suggested.

QUALITY ASSURANCE FOR MEDICAL THERMOGRAPHY, IS IT NECESSARY?

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Imaging systems for infra red thermography are able to provide two dimensional temperature maps. In medicine, it is possible to simultaneously record a large number of temperature measurements and their distribution over the human body surface. Most clinical thermographers are aware of the complexities of imaging curved surfaces, and of the need to examine the patient in a stabilised thermal environment.

Infra red imaging systems have advanced to a remarkable degree in the last decade. Focal plane array detectors are able to produce high resolution images at high speed. However, the size of the detector array and the stability of the camera system vary according to manufacturer and cost. Furthermore, not all systems are designed to provide radiometric measurements, even though the visual image may appear to be of good quality.

An early study performed in 1977 with a heated spatial resolution chart showed how the earlier scanning systems were dependent on distance from the object. Small fields of view 20x20cms often resolved a 2 mm bar on the target, while increasing the distance to image a 30x30 target area of the same area resulted in a marked loss of spatial resolution, which may be biased vertically, horizontally or both. Linearity of field was also tested by the same system.

More recently Ring and Dicks (1999) demonstrated the variability in spatial resolution using a smaller heated target. The focal plane array cameras were compared with an older scanning single element detector camera.

A current study with this thermal target has been used to identify a developing fault in a focal plane array camera, and to compare performance with a low cost low resolution camera using external calibration sources.

These results highlight the need for external monitoring of thermal imagers, which may drift in performance over time, and are undetected until a major fault is evident.

For collaborative studies, such as the Anglo Polish normals atlas project, it is clearly essential to carry out regular calibration to a single traceable temperature reference, and to monitor stability of the system before thermograms captured at different centres can be amalgamated for processing.

References.

1. Quantitative thermography, Fact or Fantasy? Ring EFJ IERE Conference Proceedings 22. " Infra red techniques" 437-439 1977

2.Spatial Resolution of New Thermal Imaging Systems Ring EFJ Dicks JM. Thermology international 9 1, 7-14 1999

MEDICAL INFRARED RADIATION THERMOMETRY – TRACEABILITY AND CALIBRATION

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Infrared radiation (IR) thermometry offers a rapid and non-contact means of measuring patient temperature. In the clinical environment IR ear thermometer devices help to reduce time-scales and cross contamination and provide good diagnostic information; for example, an ear thermometer measurement takes ~ 5 seconds and uses disposable caps, whereas a mercury-in-glass thermometer needs a measurement time of ~ 5-10 minutes and requires sterilisation. In addition thermal imagers are increasingly being used to help diagnose a number of physiological conditions (for example, Raynaud's syndrome) following advances in technology and reductions in imager cost. With the devices being used in critical monitoring and measurement applications good measurement practice is very important.

The accredited calibration of IR thermometers and thermal imagers used within the clinical environment is key to ensuring that a traceable, accurate temperature is provided. With this in mind the NPL has produced three blackbody sources to provide calibration facilities for medical IR thermometry. The first is a novel fixed-point blackbody source operating at 36.3 °C, designed for rapid in-field ear thermometer validation. This source is backed up by a variable temperature blackbody source meeting the CEN requirements for the calibration of ear thermometers and having a range of 15 to 45 °C with an uncertainty of 0.04 °C (k =2). The third source is a variable temperature blackbody for the assessment and calibration of thermal imaging cameras, with a temperature range of 0 to 80 °C and an uncertainty of 0.03 °C (k = 2).

MICROWAVE RADIOMETRY TECHNIQUE FOR MEDICAL AND INDUSTRIAL THERMOMETRY

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Microwave radiometry provides a non-invasive, non-destructive and inherently safe method of temperature measurement for a range of medical and industrial applications. The radiometric temperature of a volume of material is measured by coupling to its microwave thermal radiation field using antenna or cavity type structures, and measuring the equivalent temperature of the coupled signal with a microwave radiometer receiver. At frequencies below about 6 GHz body tissues and many natural materials are partially transparent to electromagnetic radiation. The dielectric properties of these materials at the lower microwave frequencies are such that generation and transmission of microwave thermal radiation occurs over distances of about the radiation wavelength in the material allowing tight coupling to temperature patterns over depths of up to several centimetres in human tissues. This strong coupling of measuring radiometer to source material distinguishes microwave radiometric measurements from surface radiant or contact thermometric techniques.

For microwave radiometric temperatures to be compared between different measurement systems or compared with other thermometry measurements it is essential that the matched-impedance maximum power transfer temperature is measured. The electromagnetic impedance of the source material region usually differs significantly from that of the coupling antenna or cavity structure and may vary during the measurement process. The radiometer must be capable of measuring a true matched-impedance signal temperature in the presence of a significant and variable source impedance mis-match. Since the receiver measures a thermal radiation signal there must always be a natural fluctuation of the measured temperature value. This imposes the natural Gabor limit on the temperature resolution that can be achieved and for efficient measurement the receiver must be designed to operate close to this limit.

The radiometric temperature of a source volume is determined by a convolution of the material temperature pattern with a coupling spatial response or weighting function within the material. The form of this weighting function depends on both the radiation coupling structure and on the geometry and dielectric properties of the coupled material. Through the reciprocity principle the weighting function is identical to the normalised power dissipation distribution in the material when the coupling structure is actively excited. The weighting function can thus be found by analytical or computational modeling or by measurement. When known it can be applied at one or several frequencies or combined with thermal modeling to interpret measured radiometric temperatures in terms of estimated material temperature patterns.

PUBLICATIONS ON MEDICAL INFRARED IMAGING FROM EUROPEAN COUNTRIES

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A literature search was performed in the section" 1996 to 2004 week 28" of the database Embase using the key words "thermography" or "thermal imaging" or "infrared imaging". 589 publications were found betweeen 1999 and week 28 of 2004. The resulting list of publications was matched with the field "institution" showing one of the following European countries (hits in brackets): Austria (22), Belarus (0), Belgium (11), Bulgaria (1), Croatia (2), Cyprus (0), Czech Republic (4) Denmark (5), Estonia (0), Finland (5), France (19), Germany (52), Greece (14), Hungary (3), Ireland (0), Italy (21), Latvia (0), Lithuania(0), Malta (0), Netherlands (9), Norway (4), Poland (24), Romania (0), Russia (0), Slovenia (0), Slovak Republik (0), Spain (13), Sweden (2), Turkey (7), Ukraine (0) and United Kingdom (47). In addition, all issues of the journal Thermology international from 1999 on were searched for full length articles written by European authors.

265 of 589 publication found in Embase were of European origin and 55 of 66 articles in Thermology International were submitted by authors from Europe. The main applications of thermal imaging in clinical medicine were angiology, locomotor diseases, paediatrics and surgery. Physiology, infrared equipment and other methods than infrared were the topics of the remaining publications. In the reviewed period of 5 years, Thermology International did not attract authors from France, Spain or the Netherlands, but was well accepted by thermographers from Poland, United Kingdom and Austria. A total of 39 papers were published from these three countries. The main topics were similar to the papers found in Embase.

COMPRESSING THERMAL MEDICAL IMAGES

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In recent years, there has been a resurgence of interest in the application of infrared thermal imaging in medicine due to improvements in camera technology and the promise of reduced costs. Due to this increased use factors concerning the storing of thermal medical images have become an issue with one of the most prominent of these factors being the storage space used by the images. Hence, in order to reduce the demands on hardware resources compression of the data seems necessary. For images there are two categories of compression algorithms: lossless techniques which preserve all information and lossy algorithms which sacrifice some of the visual quality to gain in terms of compression rate. For medical images typically lossless techniques are employed so as to make sure no image features are remove or distorted. However, lossless image compression achieves only a compression ratio of about 1:2 which is in stark contrast to lossy techniques which provides compression with ratios up to 1:100.

In this paper we apply the recently released JPEG2000 compression standard to thermal medical images. We utilise the lossy mode of JPEG2000 together with its ability of Region of Interest (ROI) coding which allows certain parts of an image to be coded at a different (higher) quality than the rest. The ROIs are obtained following recent work conducted at the University of Glamorgan which defines a set of standard views for thermal medical imaging together with a series of interest regions within each of the views. Coupling these with JPEG2000 allows high quality coding of thermal images with compression rates far beyond the ability of lossless algorithms.

REGISTRATION OF CLINICAL PHOTOGRAPHY AND INFRARED THERMOGRAMS

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Here we describe an application designed for registration of clinical photography and infrared thermograms. For direct comparison of images, registration is necessary to account for differences in camera positions, lens types and resolution. The infrared image is geometrically transformed so that it can be directly overlaid on the clinical photograph. The transformation is computed from reference points present in both images selected manually by a clinician. Three transformation types (Rigid, Affine and Projective) are compared and the merits of each are discussed along with the limitations.

THERMAL MEDICAL IMAGE RETRIEVAL BY MOMENT FUNCTIONS

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[2]School of Computing and Informatics. Nottingham Trent University, UK.

Past efforts on the automated processing on medical infrared images has typically focused on specialized applications like the detection of breast cancer. We propose the application of content-based image retrieval (CBIR) to medical thermal images. One main advantage of using this concept is that it represents a generic approach to the automatic processing of such images. Rather than employing specialised techniques which will capture only one kind of disease or defect image retrieval when supported by a sufficiently large medical image database of both 'good' and 'bad' examples will provide those cases that are most similar to a given one. CBIR allows the retrieval of similar images based on features directly extracted from the image data. Hence, image retrieval for a thermal image that shows symptoms of a certain disease will provide visually similar cases which will usually also represent similarities in medical terms. The features we propose to store as an index for each thermal image are a set of combinations of moments of an image which are invariant to common factors and operations such as scale, translation, and rotation. Each thermal image is characterized by such a set of moment functions. Image retrieval is performed by finding those images whose moment descriptors are closest to the ones calculated for a given query image.

17th Thermological Symposium of the Austrian Society of Thermology

K. Ammer

Ludwig Boltzmann Research Institute for Physical Diagnostics, Vienna, Austria

This years symposium of the Austrian Society of Thermology jointly organised by the Ludwig Boltzmann Research Institute for Physical Diagnostics discussed the use of thermal imaging as outcome measure in clinical trials.

Is Thermal Imaging a Proper Outcome Measure

K. Ammer defined outcome measure as the systematic collection (usually prior to and following an intervention) and analysis of information that is used to evaluate the efficacy of an intervention. Various types of outcome measures exist such as patient-completed self-report questionnaires, clinician-completed observation scales, task-specific activities -tests e.g. sit to stand, tests to assess body structure and tests to assess body function. Thermal imaging must be understood as a technique that images function, but not body structure e.g. anatomy.

Table 1 lists the features of outcome measures. For each feature examples related to thermal imaging were discussed. The fact, that the technique of the intended outcome measure should be published in a peer-reviewed journal was well supported by recent publications, with a mean impact factor of 2,3 (range 0.42 to4.5). Standardised procedures for thermal imaging have been repeatedly published from as early as 1979 (1). Thermal imaging is an appro- priate outcome measure in all cases where changes of the surface temperature are significant signs of a disease associated with inflammation, nerve blocks, nerve entrapment, muscle spasm or reduced blood flow.

As thermal imaging is regarded as a technique for temperature measurement, all requirements for measurements must be met particularly validity (accuracy) and reliability (accuracy). Factors affecting accuracy and precision of measurements from thermal images were discussed based on available publications (2,3,4). Both, accuracy and precision, have an impact on the sensitivity to change of outcome measures. Validity is needed to define correctly the symptom to be measured. Precision will affect the responsiveness also, because a change of the symptom can only detected if this change is bigger than the variation of repeated measurements. Evaluation of exercise treatment for mild pseudo-neurogenic thoracic outlet syndrome has shown that thermal imaging can detect sufficiently changes in finger temperatures induced by therapy (5).

Table 1
Requirements for outcome measures

Published in a peer-reviewed journal
Standardised procedure
Written scoring procedure
Appropriateness
Reliability
Validity
Responsiveness (sensitivity to change)
Interpretability
Acceptability
Feasibility

Thermal imaging is very well accepted by patients because it is an non-invasive, remote method for temperature measurement that can easily be repeated. The technique is yet not fully accepted by medical science (6). This is mainly caused by poor studies in the past, based on clusions from interpretations of thermal images instead of quantified analysis of temperature readings.

With respect to feasibility, thermal images must be recorded under controlled conditions and therefore this technique is not feasible as a bedside test. Also transient changes of the surface temperature, elicited outside the thermal imaging laboratory, may be missed inside the examination room.

Costs for thermal imaging compared to x-ray examination, magnetic resonance imaging, CT-scans or bone scans are low for both installation and maintenance.

Thermal imaging have been already used as an outcome measure in trials of acupuncture for facial paralysis, physical therapy and drug treatment of Complex Regional Pain Syndrome, physical therapy of tennis elbow, exercise treatment of Thoracic Outlet Syndrome, lymphatic drainage of lymphedema, surgery for osteoarthritis of the knee, exercise treatment of low blood pressure in children and drug treatment of occlusive arterial disease.

Thermal imaging provides all necessary requirements to be used as an outcome measure in clinical trials.

Thermal imaging as an outcome in drug trials

Prof Ring, University of Glamorgan, reported the application of thermal imaging as outcome measure in drug trials. The author has long lasting personal experience in this field (7). He was able show already in the nineteen seventies, that a clear relationship exists between the anti-flammatory power of antirheumatic drugs and their ability to reduce radiant heat from inflamed joints (8,9). This was found in a number of non- steroidals (10,11), steroids (12,13,14) and disease modifying drugs (15).

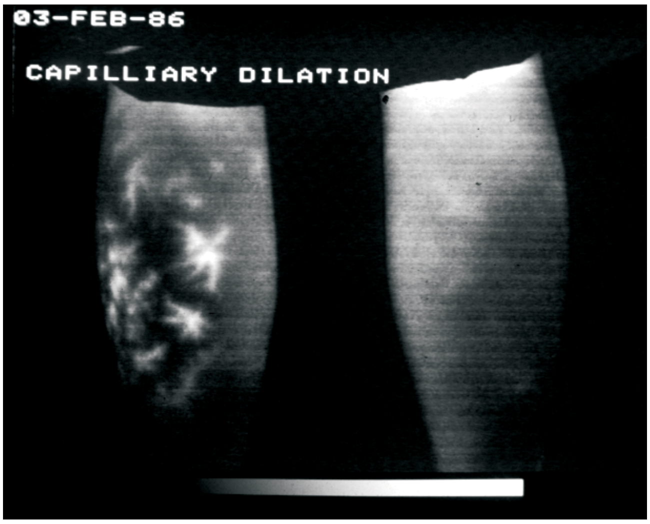

Figure 1
Effect of nicotinic acid on the skin

Treating Paget´s disease of bone with either calcitonin or biphosphanates confirmed the relationship between temperature, pain, activity of alkaline phosphatase. Effects of therapy and flares of the disease could be predicted by infrared thermal images of the affected sites (16,17)..

The effects of vasoactive compounds, given systemically or locally, can be visualized by thermography (18,19,20), major changes follow the local application of nicotinic acid (21, Figure 1).

In conclusion, quantitative thermal imaging performed under a strict protocol in a constant ambient temperature can provide reliable objective evidence of treatment when the disease condition affects temperature.

Temperature Measurements as Outcome Measure in Trials for Raynauds´s Phenomenon

In his second talk, K Ammer presented an overview on temperature related outcome measures in trials for Raynaud´s phenomenon. He started with the fact, that the diagnostic criteria for Raynaud´s phenomenon differ for the primary (22) and the secondary form of the disease. If the diagnosis is based on triphasic colour changes of the fingers, a number of patients with vasospastic disease might be misdiagnosed as only 4 – 65% will present with triphasic colour changes (23). 14 – 40% appear to be biphasic and 10 – 44% will have pallor or cyanosis only.

A cold challange is used to study the skin temperature dynamically. F Ring has suggested immersion of both hands in 20°C water for 1 minute (wearing plastic gloves) after acclimatization for 15 minutes with bare arms to a room temperature 24°C. However, other water temperatures, ranging from 0 to 20° C have been proposed (24), An alternative method is that the participants placed their right hand into a thermostatically controlled cooling chamber with a temperature of 4 , -5(25) or-20°C.. The hand was kept in the chamber either for 10, or 15 min or until the skin temperature reached 18 (26) or 12.5°C. Thereafter, the hand was returned to the 21 or 25°C ambient temperature, and the time course of skin temperature 50 and 100% recovery was recorded at 1 min intervals.

Table 1 lists the variety of techniques for temperature measurements used in published trials for Raynauds disease. Unfortunately the thermal gradient index (27), which summarises s the temperature gradients prior and post cold challenge is not predominantely applied, although this index combines both temperature difference along fingers and temperature recovery. In this index thermal gradient is defined as the mean temperature difference between the fingers and the wrist before and 10 minutes after a cold challenge in waterbath of 20°C for 1 minute. A "+"index indicates (normal) reactive hyperemia, values between + 5 and - 3 normality, -4 to -10 Raynaud´s phenomenon and -10 to -15 secondary Raynaud in suspected connective tissue disease.

The relationship between skin temperature and colour changes is not yet established (28). Cold finger tips prior to a cold challenge predict only in 58.5 percent a prolonged delay in rewarming after cold exposure.Warm finger tips predict in 87% a normal temperature recovery after cold challenge (29).

Table 2
Temperature measurements used in trials

SPOT TEMPERATURES

ONE SINGLE FINGER
at the distal pad,
metacarpophalangeal joint,
metacarpal bone,
wrist joint,
on palmar or dorsal side

MEAN VALUE OF SEVERAL FINGERS
MEASURED BY

Thermocouples
Thermistors
Infrared radiometer
From infrared images

AREA MEASUREMENTS
From total or part of fingers and hands; only possible from thermal images

TEMPERATURE GRADIENT
Difference between spot or area temperatures

TEMPERATURE RECOVERY
(Total or partial) recover of temperature after a defined cold challenge

In a trial, investigating the effect of ceramic-impregnated gloves, skin temperature measurements were done over the fingertips and the finger dorsum (between the nail bed and the distal interphalangeal joint) of the 2nd to 5th digits with an infrared radiometer (30). The distal-dorsal difference was calculated based on previous findings suggesting that a difference > 1°C is specific for Raynaud´s phenomenon. However, the gradient prior to treatment was 0.74°C in the treated group and 0.48 in the placebo treated patients. The active treatment decreased the gradient by 0,25°C and placebo by 0.40°C.

In a trial using triiodothyronin (31), the temperature outcomes were studied, as follows. At least 1 h after arrival at the hospital, the patients' blood pressures and pulse rates were recorded in a room at a temperature of 24°C.

After 30 min temperatures were measured in the left hand using a TP 252 temperature probe (Beckman Industrial, Scotland). For these measurements, the patients were seated semi-erect, with arms placed flat on the arm rests of a chair, hands open and palms upwards with fingers relaxed.

The thermographic index (TI) was defined as the mean temperature over the skin creases of the middle 3 fingers minus 24°C.

The longitudinal thermal gradient (LTG)was defined as the temperature of the palmar crease overlying the metacarpophalangeal (MCP,) joint minus the temperature of the finger crease overlying the distal interphalangeal (DIP,) joint.

Subsequently, skin temperature recovery times (STRT) were measured: both hands were immersed in an ice water mixture (0°C) for 20 s, patted dry and the pulp temperatures of the middle 3 fingers recorded every 5 min until recovery to baseline temperatures or for 45 min.

The acute effect of topical minoxidil (25) was studied as follows: Each subject was studied on 2 separate occasions while in an environmental chamber (25°C, 50% relative humidity).

Subjects were required to refrain from caffeine ingestion, smoking cigarettes, and taking any vasoactive drugs for at least 24 h before the study sessions.

All subjects assumed a supine position with the right arm placed in a neutral position level with the heart. The distal pad of the right first, 2nd, and 3rd fingers (2nd, 3rd, and 4th digits of the hand) were used to measure finger surface skin temperature.

Initial baseline measures of surface skin temperature were made and subsequently measured continuously, with a surface temperature thermistor (Yellow Springs Instruments, Yellow Springs, OH, #408).

Drying the drug solution with hot air, resulted in a localized increase of skin temperature, which complicated the interpretation of temperature effects of the drug.

The experimental procedure in a study applying misoprostol therapy (26), required the subjects to take no caffeine or cigarettes, and to stop any vasoactive drugs for 24 h prior to the study. Subjects were asked to lie in a dimly lit thermostatically controlled laboratory for at least 30 min to obtain stable baseline readings of digital hemodynamics.

The participant then ingested a capsule containing either 400 µg misoprostol or an identical placebo. Thereafter, at 10 min intervals for 1 h, measurements were taken of digital skin temperature, laser Doppler digital skin blood flow, and finger systolic pressure.

Finger skin temperature was recorded with a surface temperature thermistor secured to the distal pad of the right ring finger.

Other studies with low level laser treatment (32) or nitroglcerin tape (33) in patients with systemic sclerosis, used temperature measurements from thermal images and used the re-warming of defined areas in the image.

In conclusion, a variety of temperature measures have been used as outcome in published trials of Raynaud´s phenomenon. The thermal gradient index is the only temperature measure that considers persistent coldness of the distal part of the limbs.

Temperature measurements for the evaluation of therapy with Low Level Laser and Magnetic fields in Raynaud´s patients

M. Al-Awami from the Department of Angiology at the Viennese University Hospital reported the results of trials using low level laser (LLL) and magnetic field treatment in patients suffering from Raynaud´s phenomenon (RP).

The laser study was designed as prospective, randomised, placebo controlled trial in 47 patients with RP (31). 24 subjects (16 f, 8 m, median age 45 years) have allocated to the laser irradiation group and 23 (21 f, 2 m, median age 46 years) to the placebo(sham laser irradiation group).

Continuous temperature recordings were made by means of infrared thermal imaging at the following time intervals: a:. basal finger tip skin temperature after being adapted to room temperature for about 20 minutes,

Figure 2
Setup for low level treatment

b. immediately after 1 minute warm challenge (immersion of gloved hands in water at 39°C) ,

c. immediately after 1 minute cold challenge (immersion of gloved hands in water at 20°C).

d. recovery temperatures were measured 10 and 20 minutes later. The room temperature was 22.0 ± 0.5°C.

Overall a significant reduction of the frequency and the severity of RP in patients with either LLL (frequency $p<0.0001$, severity $p<0.0001$) or placebo treatment (frequency $p<0.0001$, severity $p=0.02$) was found, but patients in the LLL group exhibited statistically a more significant improvement of the frequency $p=0.007$ at 6 weeks and 3 months $p=0.02$ and the severity ($p=0.02$, $p=0.04$) of RP .

A significant improvement in the thermographic response to cold challenge was only seen in patients treated with LLL but not in those treated with placebo.

In conclusion, LLL significantly lowers the frequency and severity of Raynaud's attacks in patients with primary and secondary RP. Since this therapeutic modality is a safe, and non-invasive treatment, it might be considered as an alternative to existing therapeutic regimes.

The treatment of Raynaud's phenomenon with pulsed electromagnetic fields was recently investigated in another randomised, placebo controlled study . The study design was comparable to the LLL-trial. However, treatment was applied as home therapy for 12 weeks in 24 patients (7 male, 17 female) 15 with primary and 9 with secondary RP.

No significant changes of frequency or severity of Raynaud's attacks was observed, and the temperature outcome measures did not show a significant change.

Conclusion

The presentations of the symposium showed clearly that thermal imaging is a useful, but underused outcome measure in trials in which changes of the surface temperature are significant symptoms of the underlying disease. However, this is only true, when quantitative thermal imaging is per formed under a strict protocol in a constant ambient temperature.

References

1. Engel JM. Cosh JA. Ring EFJ. et al. Thermography in Rheumatology - Recommended Procedure. Eur.J. Rheum. Inflammation 1979, 2: 299-306

2. Melnizky P, Schartelmüller T, Ammer K. Prüfung der intra- und interindividuellen Verläßlichkeit der Auswertung von Infrarot-Thermogrammen. European Journal of Thermology 1997, 7: 224-227,

3.Ammer K, Ring EF. Repeatability of the standard view both dorsal hands. Results from a training course on medical infrared imaging. Thermol int. 2004, 14: 100-103

4. Ammer K. Need for Standardisation of Measurements in Thermal Imaging. In: Wiecek B (ed), Thermography and Lasers in Medicine. Akademickie Centrum Graficzno-Marketigowe Lodart S.A, Lodz, 2003, p. 13-18.

5. Schartelmüller T, Melnizky P, Engelbert B. durch Infrarot-Thermographie zur Evaluierung des Erfolgs physikalischer Therapie bei Patienten mit klinischem Verdacht auf Thoracic Outlet Syndrome. Thermology International 1999, 9: 20-24

6. Leclaire R, Esdaile JM, Jequier JC, Hanley JA, Rossignol M, Bourdouxhe M.Diagnostic accuracy of technologies used in low back pain assessment. Thermography, triaxial dynamometry, spinoscopy, and clinical examination. Spine. 1996 21(11): 1325-1331

7. Ring EFJ. Engel JM. Page Thomas DP.Thermologic methods in clinical pharmacology - Skin temperature measurement in drug trials.International Journal of Clinical Pharmacology, Therapy, & Toxicology. 1984, 22(1): 20-24

8. Collins AJ. Ring EF. Cosh JA. Bacon PA. Quantitation of thermography in arthritis using multi-isothermal analysis. I. The thermographic index. Annals of the Rheumatic Diseases. 1974, 33(2):113-5

9. Ring EF. Collins AJ. Bacon PA. Cosh JA. Quantitation of thermography in arthritis using multi-isothermal analysis. II. Effect of nonsteroidal anti-inflammatory therapy on the thermographic index. Annals of the Rheumatic Diseases. 1974, 33(4): 353-6.

10. Dieppe PA. Bacon PA. Ring EFJ. Sathapatayavongs B. Inflammation and anti-inflammatory therapy in osteoarthritis. Annals of the Rheumatic Diseases. 1979, 38(5): 493,

11. Davies J. Dixon St AJ. Ring EFJ.A double blind cross-over comparison of piroxicam and indomethacin in the treatment of rheumatoid arthritis.European Journal of Rheumatology & Inflammation. 1981, 4(3):314-317.

12. Bird HA. Ring EF. Daniel R. Bacon PA.Comparison of intra-articular methotrexate with intra-articular triamcinolone hexacetonide by thermography. Current Medical Research & Opinion. 1977, 5(2):141-6,

13.Bird HA. Ring EF. Bacon PA.A thermographic and clinical comparison of three intra-articular steroid preparations in rheumatoid arthritis.Annals of the Rheumatic Diseases. 1979, 38(1): 36-9,

14. Dieppe PA. Sathapatayavongs B. Jones HE. Bacon PA. Ring EF.Intra-articular steroids in osteoarthritis.Rheumatology & Rehabilitation. 1980, 19(4):212-7,

15. Hall ND. Bird HA. Ring EF. Bacon PA.A combined clinical and immunological assessment of four cyclophosphamide regimes in rheumatoid arthritis.Agents & Actions. 9(1):97-102, 1979

16.Ring EFJ, J.DavieS. Thermal Monitoring of Paget's Disease of Bone, Thermology 1990, 3:167- 172.

17. Elvins DM.EFJ RinG. Objective Measurements of Calcitonin Therapy by Infrared-Thermography. Thermol Österr 6: 21-25. 1996

18. Ring EFJ. Porto LO. Bacon PA. Quantitative thermal imaging to assess inositol nicotinate treatment for Raynaud's syndrome. Journal of International Medical Research. Vol. 9(6) 393-400, 1981

19. Martin MFR. Dowd PM. Ring EFJ. et al.Prostaglandin E1 infusions for vascular insufficiency in progressive systemic sclerosis.Annals of the Rheumatic Diseases. 1981, 40(4)350-354.

20. McHugh NJ. Csuka M. Watson H. Belcher G. Amadi A. Ring EFJ. Black CM. Maddison PJ.Infusion of Iloprost, a prostacyclin analogue, for treatment of Raynaud's phenomenon in systemic sclerosis.Annals of the Rheumatic Diseases. 1988,. 47(1):43-47.

21. Collins AJ, Notarianni LJ, Ring EF, Seed MP. Some observations on the pharmacology of 'deep-heat', a topical rubifacient. Ann Rheum Dis. 1984; 43(3):411-5.

22. Allen EV, Brown GE. Raynaud's disease: a critical review of minimal requisites for diagnosis. Am J Med Sci 1932; 183: 187

23. Coffman J.. Raynaud's Phenomenon. 1989, Oxford University Press, New York

24. Ring EFJ. Cold Stress Test for the Hands. In: Ammer K, Ring EFJ, eds, The Thermal Image in Medicine and Biology, Vienna, Uhlen,1995, p. 237-240

25. Wise RA, Wigley F. Acute effects of misoprostol on digital circulation in patients with Raynaud's phenomenon. J Rheumatol 1994; 21(1):80-3

26. Whitmore SE, Wigley FM, Wise RA.Acute effect of topical minoxidil on digital blood flow in patients with Raynaud's phenomenon. J Rheumatol 1995; 22(1):50-4

27. Ring EFJ. A thermographic index for the assessment of ischemia. Acta thermographica 1980, 5: 35-38

28. Cherkas LF, Carter L, Spector TD, Howell KJ, Black CM, MacGregor AJ. Use of thermographic criteria to identify Raynaud's phenomenon in a population setting. J Rheumatol 2003; 30: 720–2.

29. Ammer K.Thermographic Diagnosis of Raynaud's Phenomenon. Skin Research and Technology 1996, 2: 182-185

30. Ko GD, Berbrayer D. Effect of Ceramic-Impregnated "Thermoflow" Gloves on patients with Raynaud´s Syndrome: Randmized , Placebo-Controlled Study. Alternative Medicine Review 2002, 7(4): 328

31.Dessein PH, Morrison RC, Lamparelli RD, van der Merwe CA. Triiodothyronine treatment for Raynaud's phenomenon: a controlled trial. J Rheumatol 1990; 17(8):1025-8

32. Al-Awami M, Schillinger M, Gschwandtner ME, Maca T, Haumer M, Minar E. Low level laser treatment of primary and secondary Raynaud's phenomenon.Vasa 2001;30(4):281-4

33. Teh LS, Manning J, Moore T, Tully MP, O'Reilly D, Jayson MI. Sustained-release transdermal glyceryl trinitrate patches as a treatment for primary and secondary Raynaud's phenomenon. Br J Rheumatol 1995 Jul;34(7):636-41

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2. Ammer K. Thermology 2004- a computer-assisted literature search. Thermol int 2005, 15(1): 5-37

News in Thermology

8th Congress of the PoIish Association of Thermology

The conference will take place in Zakopane, Poland (2 hours from Krakow International Airport)from March 19-20, 2004. Zakopane is a beautiful ski resort in the Tatra Mountains in South Poland. The hotel HYRNY has been the location for this con- ference for a number of years. The costs are low and this is a good opportunity to meet with European colleagues.

Abstract deadline 20th.]anuary 2005

Registration deadline st March 2005

Congress fee 100.- Euros, paid on arrival includes accommodation (based on double room with Bathroom & TV) from Dinner Friday 19th March to Breakfast Monday 21st March. Attendance at sessions and congress materials, participation in the social programme.

Abstracts to ajung©wim.mil.pl

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Romanian Society of Thermography

The Romanian Society of Thermography (Societatea Romana de Termografie, SRT) was founded on 13 April 2003, by the decision of 87 founding members.The members of the Society are medical doctors and specialists involved in thermographical research. Current president of SRT is the gynaecologist and endocrinologist Dr. Bogdan Cupceancu and treasurer and general secretary is Dr. Calin Tiu-

Postal address of this new thermograpic society is Societatea Romana de Termografie, str. Sergent Major Erou Grigore Nicolae nr.5, Campina, judetul Prahova, Romania, tel/fax 0040244373108, 0040722452576, email office@srt.ro. Further information is available at www.srt.ro

The aims of the SRT are the development of medical expertise in thermography, the harmonisation of concepts for thermography specialists in Romania, alignment of the thermographic activity in Romania to the international standards of thermal imaging. For that purpose contacts with other National Thermography Societies and affiliation to the European Association of Thermology are intended. Regular National Conferences have been organised in the past and will be continued in the future.

The Second National Conference of Thermography was held on10-11 October 2003 in Campina. The town of Campina is located near the well known tourist area, Prahova Valley, 90 km north from Bucharest.

The Third National Conference of Thermography, was organised on 8-9 October in Campina, Romania. Topics included a themed session on multidisciplinary approach to the imaging of breast pathology. .

50th Anniversary of the German Society of Thermography & Regulation Medicine

The longest existing society for medical temperature measurements celebrates its 50th anniversary. Founded by the first president E.Schwamm on 1st February 1954, changes of temperature over time and their predictive value for health conditions became the major focus of interest for this society. Infrared radiometers were the original tools for measurement. A. Rost developed the method further and used fast reacting contact thermo-meters for the recording of temperatures. Under his pre-sidency the society attracted more than 600 members.

The current president R.Berz started in 1985 a journal dedicated to the scope of regulation thermography. Origi-nally named “Thermodiagnostik”, the journal 1988 re-named to ThermoMed and served as the combined publication organ of both German Socities, the German Society of Thermography and the Society of Thermology. The dermatologist R.Stüttgen was the mentor, who put much effort into the liaison of these groups. But the German Society of Thermology left Thermomed in 1998, and since ThermoMed has returned to being the journal of regulation thermography.

However, use of infrared equipment has returned into the practice of regulation thermography and differences in the approach of temperature measurements between the German Society of Thermography and the standards promoted by the European Association of Thermology, to which the German Society of Thermography is affiliated for more than 10 years, are less pronounced than pre-viously.

14thth International Conference on Thermal Engineering and Thermogrammetry (THERMO)

The International Conference on Thermal Engineering and Thermogrammetry (THERMO), which started in 1977 from annual national symposia and became an inter-national conference in 1987 running in a three year circle, is now a series of biennial meetings. The next conference is announced for 22-24th June, 2005 in Budapest, Hungary. This congress is intended to be an event of the interest to all engineers, scientists, physicians and re searchers who are involved in the solution of thermal or energy related problems, and in the applications of thermal imaging.

The conference will cover topics both the field of theory and application including new measurement concepts; transducer technique; thermal mapping; contact, optical and IR imaging; biomedical and biotechnological applications; thermal informatics, automatic methods and systems for industrial energy management and process control; heat loss detection and analysis; heat and mass transfer; utilization of alternative energy; thermophysical properties, common practice of thermal engineering, protection of the human environment, medical and veterinary applications and remote control through infrared sensors.

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

The language of conference and abstracts is English. Oral presentation of papers and also a poster session will be organized.

The preliminary programme (until September 2004) includes more than 50 papers from 29 countries (Algeria, Austria, Bahrein, Belgium, Canada, Croatia, Rep. of China, Czech Republic, France, Germany, Greece, Hungary, India, Iran, Italy, Japan, Jordan, Korea, Poland, Portugal, Romania, Russia, Slovakia, Spain, Tajikistan, Turkey, United Kingdom, Ukraine, USA). . Duration of each presentation will be limited to 15 minutes and additional time for discussion will also be provided. The English translation of lectures not read in English should be submitted at the registration desk on arrival LCD projector and computer with Windows OS for Microsoft Power Point format presentations is available. (Please note, that the use of your own computer is not allowed.)

Those intending to attend the conference are kindly invited to send a registration form (page 156) 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 and personal inquiries please contact the following address:

Dr. Imre BENKÕ,
H-1112 Budapest, Cirmos u. 1, 6/38, Hungary,
Phone/fax: +361-310-0999, E-mail: ibenko@freestart.hu

Veranstaltungen (Meetings)

2005

March 18-20, 2004

8th Congress of the Polish Association of Thermology in Zakopane

Venue: Hotel Hyrny

Congress fee. 100.- Euro

Information: Prof A Jung

Klinika Pediatrii I Nefrologii Dzieciecej
W..I.M. 00909 Warsaw ul.Szaserow 128

Tel +48 22 6817 2316 Fax 48 22 6816 763

Email: ajung@wim.mil.pl

28 March-1 April 2005

Infrared Technology and Applications XXXI (OR34), Part of SPIE's International Defense and Security Symposium

Gaylord Palms Resort and Convention Center, Orlando, FL, USA

Conference Chairs: Bjørn F. Andresen,
ElOp Electrooptics Industries Ltd. (Israel);
Gabor F. Fulop, Maxtech. International, Inc.

Website: http://spie.org/events/dss

June 22-24, 2005

14th International Conference on Thermal Engineering and Thermogrammetry (THERMO) Budapest, Hungary

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Nigde Univ., Fac.of Engineering, Nigde, Turkey

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

APPLICATION FORM

for prospective authors and participants

(If you wish to be put on the mailing list and to receive Conference Announcements, please complete and return the following form as soon as possible, but not later than 15th September, 2004 to MATE Secretariat.)

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- ☐ Please send further information
- ☐ I plan to attend the Conference
- ☐ I intend to submit a paper/poster with the following title:
- ☐ abstract enclosed
- ☐ abstract will be sent until 15 November, 2004.
- ☐ I intend to present (a) film(s), VHS video, etc.
- ☐ I intend to exhibit (a) poster(s) during the workshop-session
- ☐ I intend participate in the exhibition
- ☐ Please send further copies of Second Announcement to the following addresses:

P.S.: The organizers strongly recommend Internet exchange: e-mail: ibenko@freestart.hu

Authors are requested to provide electronic version of their abstract (two pages, A4 format) and camera-ready papers as .doc or .pdf attached file to: mate@mtesz.hu

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