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Abstracts

THERMOGRAPHY AND COLOUR DUPLEX ULTRASOUND ASSESSMENTS OF ARTERIO-VENOUS FISTULA FUNCTION IN RENAL PATIENTS

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Vascular and clinical assessments of arterio-venous 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 measurements. For example, these modalities can help study problems relating to either fistula failure or to excessive fistula flow which can result in vascular steal (finger blood flow impairment resulting in skin temperature reduction). The aims of this study were to investigate the relationship between fistula region skin temperature and fistula blood flow using manual and automatic image temperature extraction techniques.

Patients underwent objective vascular measurements which comprised thermal imaging of the fistula region followed by fistula blood flow estimation using colour duplex ultrasound at the brachial artery. Temperature measurements were collected using a FLIR SC300 infrared thermal imaging system (spectral range 7.5 to 13.0 μm) fitted with its standard 24 viewing lens. Skin emissivity was assumed to be 0.97. Differences (fistula - non-fistula side) in fistula region temperatures were determined using a) manually extracted measurements and b) measurements calculated using an automated image processing procedure based on global thresholding and region growing. Temperature readings from the regions of interest were then compared with fistula blood flow and the correlation coefficients calculated. Differences between manual and automatic techniques were tested using Student's t-test.

Fifteen patients were studied (mean age 60 years). Estimated fistula flows ranged from 30 to 1950 ml/min (mean [standard deviation] of 920 [680] ml/min) and were significantly correlated with bilateral differences in maximum fistula region skin temperature for manual and automatic techniques (Manual $R=+0.71$, $p<0.01$; Automatic $R=+0.73$, $p<0.01$), each demonstrating an association between fistula region skin temperature and estimated fistula blood flow. There were no significant differences between the manual and automatic temperature extraction techniques, with mean (standard deviation) differences (manual – automatic) of +0.02 (0.28) C ($p=0.8$). Further work is now needed to explore the clinical utility of these findings, and also to examine the detailed characteristics of the fistula thermal profiles.

EFFECT OF A SHORT PERIOD OF ABSTINENCE FROM SMOKING IN YOUNG AND OLD HABITUAL SMOKERS ON SKIN RE-WARMING PATTERNS OF THE HANDS FOLLOWING LOCAL COOLING.

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Circulatory complications associated with cigarette smoking are well known. Nicotine is known to be a powerful inhibitor of peripheral vasodilation. In addition to the nicotine-dependent stimulation of the sympathetic system and the inactivation of vagal cardiovascular control, smoking also decreases the availability of endothelium-derived nitric oxide in arteries. Thermal imaging is an excellent means to measure and demonstrate the strong and immediate influences of smoking on the blood supply and heat regulation of the extremities. In smokers one can

easily use infrared thermography to demonstrate a 'temporary thermal amputation' of their fingertips due to vasoconstriction, even after smoking a single cigarette. In this project we have examined the effect on skin circulation following a short period of abstinence from smoking in both young and elderly habitual smokers (10-20 cigarettes per day for at least 5 years). For comparison experiments were also made in young and elderly non-smokers. The subjects used were young male non-smokers (n=15) and smokers (n=13), and elderly non-smokers (n=15) and smokers (n=16). Participants were asked to abstain from alcohol, caffeine, physical activity, and cold exposure in the 12 h preceding the study. To prevent potential acute effects of smoking, the smokers were also asked to refrain from smoking for 12 h before the study. A follow up study in which the period of abstinence from smoking was reduced to 2 hours was made in 7 of the elderly smoking subjects. During the experiments, the lightly clothed subjects were seated in a draught free environment in a temperature-controlled room (27.5°C). To indirectly compare changes in peripheral circulation in the hands of the healthy, non-smoking and the habitual smoking young and elderly subjects we examined the speed of recovery following hand cooling. The cooling consisted of immersing the right hand in water at 10°C for a period of 2 minutes. The hand was covered with a thin plastic bag during the immersion period to prevent the skin from becoming wet. Skin surface temperature of the dorsal surface of both hands were measured before, during and after immersing the hands in the cold water by high precision IR thermography. Palmar surface temperatures at selected sites were measured with thermocouples. To compare the responses to local cooling, calculations were made from the temperature data of the time taken for the skin temperature in the "cooled" hand to regain 63.2% of the cold induced drop in temperature, which is referred to as the recovery time. The results showed that the skin temperature prior to cooling was significantly warmer in the elderly smoking subjects (34.5 ± 0.1 °C) compared to elderly non-smoking subjects (33.8 ± 0.2 °C). After 63.2% re-warming there was a significantly difference in average skin temperature of the dorsal hand between elderly smokers (32.1 ± 0.2 °C) and elderly non-smokers (31.3 ± 0.1 °C). A follow-up study of elderly smokers, who had smoked as usual until 2 hours before the experiment, resulted in recovery responses in-between the non-smokers and the smokers who had had the longer period of abstinence from smoking. Since the vasculature of habitual smokers is subjected to nearly continuous vasoconstrictor effects of nicotine, we suggest that the resting skin vasodilation following the short period of abstinence from smoking is due to a vascular adaptation to nicotine, as an effect of smoking-induced up-regulation of vasodilating substances driven by the vasoconstrictor effect of nicotine.

IN-VIVO TEMPERATURE MEASUREMENT OF THE KIDNEY DURING LAPAROSCOPIC PARTIAL NEPHRECTOMY

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The development of laparoscopic partial nephrectomy has demonstrated the need for a device that will provide localised hypothermia of the renal tissue. We have developed such a device and a method for evaluating its performance by monitoring and recording temperatures throughout the kidney.

During a partial nephrectomy, the blood supply to the renal tissue is disrupted. Without the inducement of hypothermia, the tissue can only survive an ischemic period of 30 minutes, before loss of kidney functionality occurs. Hypothermia extends this period, allowing the surgeon a longer operating time. Research into the hypothermic effects on renal tissue have shown that temperatures between 5°C and 20°C provide greatest preservation of function, with 15°C being considered as the optimum temperature. In practice, this demands continuous temperature monitoring of the kidney during each stage of the procedure.

We have developed a temperature monitoring system for use with the cooling device consisting of type K thermocouples linked to an 8-channel thermocouple datalogger, connected to a PC via RS-232 communication running PicoLog data acquisition software. The data acquisition software allowed real-time monitoring of temperature measurements as well as the recording of data, allowing the exact point at which the optimum temperature is reached to be detected. At this point the surgical procedure can begin. Continuing to monitor the temperature of the tissue provides an indication of when the blood supply needs to be reconnected to prevent damage to the tissue and loss of functionality. Our cooling device consists of a cooling bag and cooling circuit. The bag is inserted into the abdomen to provide the direct cooling to the kidney. It is constructed from a double layer tube where coolant (water) is circulated via three catheters between the layers. The circuit maintains the coolant at a low temperature and circulates it through the bag and heat exchanger.

In laboratory assessment of the cooling device, the temperature measurement system was used to monitor the temperature inside a representative model of a kidney as well as at other points to determine the device's effectiveness and efficiency to cool.

Animal trials will be used to assess the performance of the device in-vivo by the monitoring of renal temperature. Specially designed thermocouples have been built in-house for these experiments that go a set distance into the tissue. A depth of 10mm locates the thermocouple into the renal parenchyma, which is the tissue at greatest risk during the ischemic period.

In the laboratory assessment, the temperature measurement system clearly represented the real-time data to allow the determination of when cooling should end. The recorded data also provided the means to assess the overall effectiveness of the device and to hypothesise which factors within the system may affect the cooling and warming rates of the kidney. Measurements show that the device decreased the temperature of the kidney from 37°C to 15°C in 32 minutes (± 1 minute). After cooling was halted, a temperature between 11.5°C and 15°C was maintained for 58 minutes (± 7 minutes).

Currently the animal trials have not been undertaken, but a study using eight pigs has had approval and is due to start shortly.

The laboratory assessment has shown that the temperature measurement system provides effective monitoring of temperature at multiple points through the kidney and cooling system, indicating that it should be easily applied in the animal trials.

STILL A VEXING MATTER; THE ROLE OF INFRARED IMAGING IN BREAST HEALTH MONITORING AND EARLY DETECTION OF BREAST CANCER PARTICULARLY IN YOUNGER WOMEN IN AUSTRALIA

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In Australia the role of infrared imaging is still being actively discouraged, both in practice and research. However, the figures of breast cancer incidence indicate that more younger women outside the free breast screening program are getting breast cancer. Younger women tend to have dense breasts, which is the major reason why mammography is contraindicated, not to mention the accumulative risks of mammography over time. Radiologists have even suggested that there should be alternative ways of examining the breast in between scans to reduce interval cancers. As infrared imaging is a totally non-invasive method it makes it an ideal tool for monitoring over time the behaviour within the

breast. The methodology we use which includes an autonomic cold challenge test will be discussed, illustrated and its importance in detecting small changes in independent metabolic activity that may indicate early signals of breast cancer. A proposal for a longitudinal study in the detection of early signals of breast cancer in women aged 35-44, incorporating other physiological technologies will also be presented for discussion.

DISTAL-DORSAL TEMPERATURE MEASUREMENTS REVEAL CHARACTERISTIC DIFFERENCES BETWEEN TYPES OF RAYNAUD'S PHENOMENA

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A study carried out by Clark et al [1] used thermographic imaging and a cold provocation test to investigate whether temperature differences between the digits and the dorsum of the hands were different between patients with primary Raynaud's phenomenon and those with underlying systemic sclerosis. Their principal conclusion was that a distal-dorsal temperature difference of > 1°C is specific for underlying connective tissue disorder at ambient 30°C.

In order to investigate the possible clinical usefulness of the distal-dorsal temperature difference (DiD) in our laboratory, thermographic images from patients who had attended for routine Raynaud's assessments were analysed retrospectively. Patients were classified (again retrospectively after obtaining ethical approval) according to clear clinical diagnosis: Primary Raynaud's phenomenon (PR, n=26), Connective Tissue Disorders (CTD, n=8), Hand Arm Vibration Syndrome (VWF, n=16), and non-age-matched Normal volunteers (N, n=7).

Patients were acclimatised in a standard environment (23°C) for a minimum of 15 min. (and up to 60 min.) until all digits had vasodilated sufficiently to carry out a cold challenge (15°C for 1 minute). Thermographic images were recorded using a Starsight system (Insight Vision Systems) prior to the cold challenge (baseline, B) and at 6 min. (6) and 12 min. (12) post cooling. These were evaluated for DiD together with thumb-dorsal (ThD) and digit-thumb (DiTh) temperature differences, including left (L) and right (R) differences in the patient groups. No parameters were normally distributed, so the Mann Whitney test was applied. Differences between median values were considered significant for $p < 0.05$. There were significant differences between all patient groups and the normal subjects (not tabulated for reasons of space). The tables below summarise the within group differences for all subjects and between group differences for the patients. Significant positive and negative temperature differences are designated as + and - respectively; 0 signifies no significant difference.

Within Group Differences	DiD	ThD	DiTh
N (B,6,12)	0+0	0++	000
PR (B,6,12)	0—	000	—-
CTD (B,6,12)	—-	0-0	000
VWF (B,6,12)	0-0	0-0	000

Between Patient Group Differences	DiD	ThD	DiTh	DiTh L	DiTh R
CTD vs PR (B,6,12)	-00	0-0	000	000	000
VWF vs PR (B,6,12)	000	000	000	++0	000
CTD vs VWF (B,6,12)	000	000	-00	-00	000

In summary, as with the Clark et al [1] study, a significant baseline DiD was found between PR and CTD patients (at ambient 23°C in this study). Additional measurements of ThD and DiTh temperature differences at 6 min. and 12 min. post cold provocation revealed further significant differences between PR, CTD and VWF patients. Differentiation between right and left hand temperature differences provided further significant indicators of PR-CTD, PR-VWF and VWF-CTD differences, which appear to be characteristic for each group.

Further analysis is required to establish potentially diagnostic levels of temperature differences between the groups and determine their sensitivities and specificities before these observations can be applied clinically to Raynaud's assessment reporting. Analysis of results according to dominant hand (rather than simply left and right) may improve differentiation between groups (in particular VWF).

References:

[1] S. Clark, S. Hollis, F. Campbell, T. Moore, M. Jayson & A. Herrick, The "distal-dorsal difference as a possible predictor of secondary Raynaud's phenomenon. J. Rheumatol. 26: 1125-1128 (1999).

REFERENCE MEASUREMENTS OF SKIN TEMPERATURE AND LASER DOPPLER FLUX IN CHILDREN ARE SIMILAR TO THOSE OF ADULTS

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Background In 2004 our group published reference measurements for skin temperature and laser Doppler (LD) flux in healthy adults at six body sites*. Here we present further data from 86 healthy skin sites in a cohort of 34 children (23F, 11M, age 11.3 ± 3.9 years (mean ± SD)) who attended our laboratory for the assessment of localised scleroderma (morphoea). All subjects gave informed consent to participate in the study, which was approved by the Ethics Committees of the Great Ormond Street and Royal Free Hospitals.

Method For each subject triangular aluminium foil markers were applied to the skin at up to 3 body sites affected by localised scleroderma, and at up to a further 3 precisely contralateral sites. Only data from the contralateral sites, where the clinician was entirely satisfied that the skin was normal, are presented in this analysis. The subject acclimatised at a room temperature of 23 ± 1°C for ten minutes. Standard thermographic views of all marked body sites were then captured with a Flir SC500 Thermacam thermal imager. Ten seconds of laser Doppler flux data were recorded sequentially adjacent to the tip of each triangular marker (Moor Instruments MBF3D blood flow monitor, 810nm). The sequential laser Doppler readings were then repeated twice more for each body site, and the mean laser Doppler flux over the 3 measurements at each site was calculated. The skin temperature at each body site was determined by defining a square region of interest of dimension 2cm x 2cm positioned at the tip of each triangular marker in the thermograms (Flir Thermacam Researcher 2002 image analysis software).

Results For the purposes of analysis, all 86 readings were placed into one of six groups to reflect the body region from which they were obtained (arm [11], leg [23], anterior trunk including the groin [14], posterior trunk including the buttocks [6], cheek [18] and forehead [14]) The hottest body region was the forehead, which also showed the least inter-subject variability (mean T = 33.7°C, SD = 0.7°C). The coldest region was the leg (mean T = 31.1°C, SD = 1.1°C). The anterior trunk had the greatest inter-subject variability (mean T= 32.6°C, SD = 1.4°C). The arm was

the body site with the lowest laser Doppler flux (mean = 12.4 AU, SD = 14.6 AU). The cheek exhibited the highest flux, and the greatest inter-subject variability (mean = 59.3 AU, SD = 35.3 AU). A plot of temperature versus LD flux indicated a reasonable logarithmic relationship (r = 0.47).

Conclusions Our skin flux and temperature data from children show remarkable similarities to that obtained previously from the skin of healthy adults. Flux and temperature vary across the body's surface in an almost identical manner in the adult and paediatric groups. The logarithmic relationship between skin temperature and LD flux is also essentially identical in the two groups. This study did not investigate any dynamic changes in flux and temperature in response to thermal stimuli. Our data strongly suggest, however, that the steady-state thermal and flux characteristics of the adult human skin surface are in fact already fully mature in young children.

* Skin temperature and laser Doppler flux in healthy adults: reference measurements and degree of contralateral asymmetry at six body sites (abstract).Howell KJ, Visentin M, Lavorato A, Smith RE, Harper JI, Woo P, Black CM and Denton CP. 8th Congress of the Polish Association of Thermology, Zakopane. May 2005.

AN EXPLORATORY LOOK AT THE THERMAL CHARACTERISTICS OF THE EYES IN PATIENTS WITH THYROID EYE DISEASE

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Thyroid-associated orbitopathy (TAO) is an inflammatory condition affecting the eyes of patients with Graves' disease. It is estimated that the prevalence of TAO in the UK is around 400,000. Treatment can be successful in selected cases and consists of high dose steroids, orbital irradiation and surgery. Choice of treatment is highly dependent on accurate clinical assessment as anti-inflammatory treatments are effective only during the active phase of the disease, while some of the surgical treatments are appropriate only when the disease has become inactive. The clinical assessment of TAO is fraught with difficulties because it is subjective. This pilot study therefore explores the clinical value of medical thermography for the objective assessment of the inflammatory aspects of TAO (such as redness of the lids and conjunctivae).

Eleven patients with thyroid eye disease were recruited from the regional Joint Thyroid Eye clinic. Each was requested to follow a pre-test preparation protocol prior to thermography. Patients also underwent a formal clinical assessment of the eyes to form a quantitative Clinical Activity Score (CAS). The CAS was measured within a day of thermography and gave evidence for whether the disease was likely to be active. Thermograms were collected whilst the patient lay comfortably supine and still on a measurement couch, with measurements performed in a temperature controlled thermal imaging facility under normothermic conditions. The thermal imaging system comprised a FLIR SC300 with close up lens (FLIR type 64/150) allowing the full region around each eye to be assessed in detail. FLIR ThermaCAM image processing software was employed to summarise thermal characteristics in selected regions around the eyes.

There is a range of thermal characteristics observed from the thermograms, and there are key features which separate the inactive and active disease patients. Overall, the preliminary data show that thermographic measurements can pick up areas of inflammation in the patients with active TAO (Figure 1a). In some patients with inactive disease the thermograms were difficult to interpret. Other thermal characteristics were observed, including the blink reflex and lacrimation.

Figure 1 (a) Patient with active disease

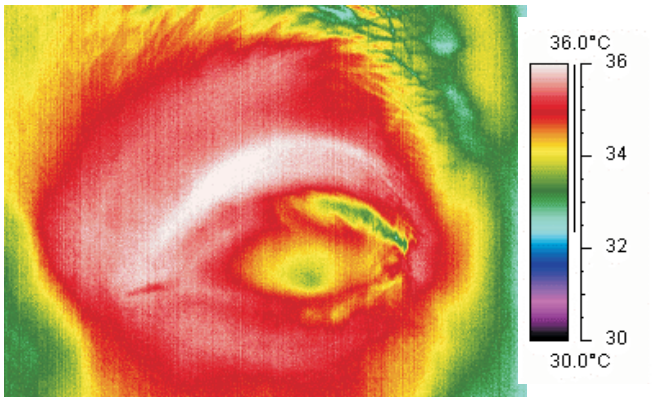
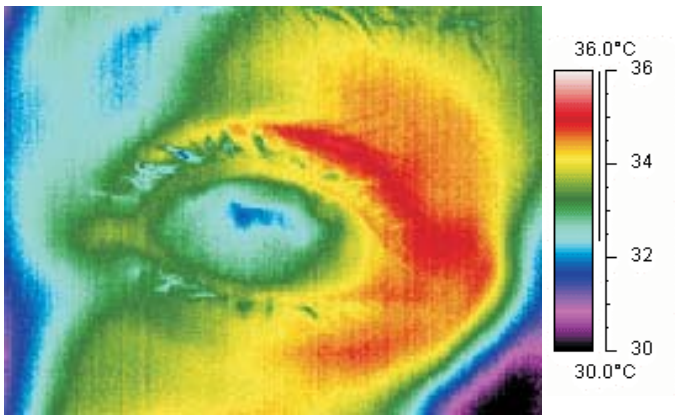


Figure 1 (b) Patient with inactive disease



Further image analysis is now needed to better understand the relationships between the constituents of the CAS score and the complex thermal characteristics of the eye, and the diagnostic accuracy of classifying active disease assessed in a larger patient group.

THERMOCHROMIC LIQUID CRYSTAL THERMOGRAPHY: APPLICATION IN NEUROPATHIC ASSESSMENT OF THE DIABETIC FOOT

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Neuropathic foot ulcers are a major complication of type 2 diabetes mellitus. Presently, clinicians rely on the evaluation of sensory neuropathy together with foot pressure measurements to assess the risk of ulceration. However, these techniques alone cannot be used to establish physiological mechanisms that lead to tissue damage and initiate ulceration. The progressive degeneration of sensory nerve pathways is thought to affect both thermoreceptors and mechanoreceptors. Therefore, the study of thermal patterns under the foot can further the understanding of the pathophysiology of the diabetic foot. Liquid crystal thermography (LCT) is used extensively in heat transfer studies. LCT is a non invasive and high resolution technique used to measure surface temperatures. Liquid crystals reflect incident light producing colour as a function of temperature. Typically, hue of the colour image is calibrated against temperature. Use of LCT in diabetic foot assessment has the important advantage of providing quantitative measurements of response thresholds compared to qualitative measurements based on sensory perception.

Adoption of the technology has been limited. However, recent improvements in the technology combined with low cost, fast video acquisition now offer potential for routine thermographic assessment of the diabetic foot. The main aim of this study is to develop a low cost LCT system capable of dynamically monitoring microvascular response to induced thermal stimulus. Specifically, the system must provide a means of assessing sub-cl inical autonomic neuropathy. Using the system we hope to determine if there is a correlation between impaired thermo-reg ulatory response and the degree of sensory neuropathy. Evidence of a positive correlation may indicate common degenerative mechanisms. An important advance offered by the proposed system is feature extraction and temporal measurements from full field plantar images using novel image processing algorithms. This paper describes development of the system, in vitro calibration and determination of useful system characteristics such as the effect of lighting conditions, hysteresis, pressure sensitivity, repeatability and the sensitivity of LCT system. Three forms of encapsulated liquid crystals were used i.e. sprayable paint, thermochromic liquid crystal sheets (TLC) and liquid crystal on latex sheets. Preliminary results show that repeatable calibrations can be obtained with sprayable paints and TLC sheets under similar lighting conditions. The hue versus temperature curve shifts towards higher hue values for the identical temperature producing a maximum of 15-20% change in hue when the lighting intensity is changed form minimum to maximum. If the lighting is sufficiently high, the change is negligible for the calibration curve. TLC sheets offer higher stability and better colour response. Encapsulated liquid crystals on latex produce poor colour response attributed to the spatial distribution of liquid crystals. These findings are supported by the microscopic images of three forms of liquid crystals used. Pre- liminary results for pressure sensitivity show that TLC sheets are insensitive to vertical pressure in the physiologically relevant range (0-2 Kg/cm). There is a shift in calibration curve during cooling (relative to heating) leading to temperature bias in both narrow band and wide band TLC sheets. It is envisaged that the LCT technique is sufficiently advanced to carry out a clinical study in order to compare thermoregulatory parameters between a group of diabetic patients with sensory neuropathy and a non diabetic control group.

THERMOMETERS FOR INTERMITTENT TEMPERATURE MEASUREMENT: FACTORS WHICH CAN AFFECT BEST CHOICE AND BEST PRACTICE.

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Diverse technologies for intermittent temperature measurement have developed following environmental concerns about the use of mercury. Many are being promoted as being quick and simple to use for the clinical practitioner and convenient for the patient. To inform procurement decision-making in the NHS a comparative survey of thermometers has been compiled using manufacturer's data (MHRA, 2005).

Fifty five thermometers have been identified as available for purchase by NHS organisations, excluding models only available over the counter at pharmacies and supermarkets. For each type of thermometer a number of different models were identified: mercury in glass (12), chemical (7), electronic contact (20), infrared sensing ear (16).

Review of manufacturer's data has indicated that a range of technical and clinical factors could influence the best choice for a particular situation. Analysis of the financial factors alone suggests that the optimum procurement decision is not obvious, particularly when whole lifetime costs are considered. Clinical issues should also have a strong influence on the decision. These should include the patient's usual age and health condition, the measurement environment, measurement accuracy obtainable in clinical use and that required for effective clinical decision making.

Staff training in the new measurement technique and review of local clinical assessment protocols should be an integral part of the procurement process. This review has identified that differences in the technology and body site used for measurement can significantly alter the temperature range considered normal. The threshold for clinical action may need to be adjusted, depending on the thermometer being used.

References

MHRA (2005) Thermometer review : UK market survey 2005 available from (select 'devices information', search for '04144')

WHAT DOES A CERTIFICATE OF CALIBRATION OF AN INSTRUMENT MEAN?

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Relevant Directives or standards require organisations to provide accurate measurements, traceable to national and international standards. It is an important part of quality assurance in a lot of applications such as: health, safety, trade, environment and industrial applications.

Accurate measurements are possible through the use of well-specified and suitably calibrated sensors and instruments. Calibration needs to be carried out by a competent laboratory such as an accredited calibration laboratory.

What does a calibration certificate of an instrument, with the logo of a recognised accreditation body, mean? It means that the calibration was carried out by a laboratory accredited by an accreditation body, and within the framework of its accreditation - "Calibration."

A certificate of calibration carried out by an accredited laboratory attests:

-the guarantee of the traceable connection of measurements to the national standards

-the proof of the accreditation obtained from the organization of accreditation by the laboratory carrying out the service of calibration, and the recognition of the competence of this laboratory based on the requirements of international standard ISO/CEI 17025

-the reliability of the results of calibration and uncertainties of measurement mentioned in the certificate

-the recognition of the certificate issued at European level.

The accreditation of a laboratory gives confidence to the customers of the companies. It brings a guarantee of the technical skill of the laboratory and ensures that the produced results are valid. It answers new requirements of companies in many fields such as safety, health, environmental quality, and all sectors where risks exist which require vigilance, rigour and control.

THE ROLE OF MEDICAL TECHNOLOGY IN PERIOPERATIVE TEMPERATURE CONTROL

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During general and regional anaesthesia body temperature falls. There are a number of mechanisms at work, including changes in blood flow and modification of central thermoregulatory control. Postoperatively, hypothermia results in longer stays in the recovery area and delayed discharge from hospital.

A number of technologies are available to maintain a patient's body temperature perioperatively. They may be divided into two types: blood and fluid warmers, and patient warmers.

Blood and fluid warmers are designed to ensure that the temperature of blood and fluids infused into a patient are close to body temperature. There are several design constraints. There is an inevitable temperature loss between the warmer and the patient. However, biological fluids must not be heated to much above 40 C or else thermal degradation may occur – this is of particular importance for blood and blood products. In addition, the warmers may be required to cope with a wide range of infusion rates, extending to over 400 mlmin. Three designs of fluid warmers will be discussed: cassette, coil and counter-current. In a cassette system a thin layer of fluid is warmed either by conduction or infrared radiation. For the second system heat is transferred from a warm core to a coiled tube containing the infusate, and the counter-current systems rely on a warmed fluid (water) flowing in the opposite direction to the infusate in a coaxial tube system.

Patient warmers fall into two categories: warming blankets and warming mattresses. Both have a role to play depending on the nature of the surgical procedure. However, the mattresses must have appropriate pressure relieving properties.

The role and success of this technology will have an impact on maintaining the throughput of day-case surgical patients, who should be fit for discharge within a short time.

EVALUATION OF THE SENSOR TOUCH THERMOMETER

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The SensorTouch thermometer is a device that performs an infra red measurement of the skin temperature. The aim of the measurement is to assess the skin temperature above the Superficial Temporal Artery (STA). This study evaluates the validity and the accuracy of the SensorTouch thermometer.

Two experiments were performed to test the validity of the SensorTouch when the body temperature was measured with a rectal sensor, if possible, with an oesophageal sensor and with the SensorTouch. In the first experiment the measurements were performed by TNO experts and in the second experiments by naive students. Both experimental studies started with the subjects in a cold environment after which they entered the warm chamber. In the warm chamber they started to do exercise after 30 minutes. In both studies the typical response of the oesophageal temperature was to rise 5 minutes after the start of the exercise. The rectal temperature started to increase after approximately 15 minutes of exercise, a delay of about 10 minutes. After 30 minutes of exercise (on average) the core temperature (as measured rectally and in the oesophagus) had risen to 37.5°C in the first experiment and 38.0°C in the second experiment.

After entering the warm chamber the SensorTouch underestimated the core temperature during the first 10 minutes. After that, still during the rest period, the SensorTouch was not significantly different from the core temperature, with an average difference of 0.5°C (SD 0.5°C) in the first study and 0.3°C (SD 0.2°C) in the second study. The largest differences between the SensorTouch and the core temperature existed 15 minutes after the start of the exercise. Then the SensorTouch was significantly higher than the core temperature. In 50% of the subjects, in both experiments, the overestimation was more than 1.5°C; the core temperature was on average only 37.3°C. This meant a clinically important overestimation. In both studies the difference decreased towards the end of the experimental sessions. Unfortunately we could collect no data on longer exposures due to the limited duration of the experiments in study 1 and due to fatigue in study 2. In the second experiment we were able to compare the SensorTouch to other non-invasive methods of measuring body temperature: Infra-red Tympanic (IRTT), sublingual and axillary. The measurements in the axilla and sublingual did not represent core (rectal) temperature well. In the stable rest period, before exercise, the difference between rectal temperature and the SensorTouch was much smaller than between IRTT and rectal temperature: 0.3°C (SD 0.2°C) and -0.7°C (SD 0.5°C) respectively. Just after the start of the exercise, the SensorTouch was significantly higher than the rectal temperature, which was equal to oesophageal temperature. As stated above, the differences between rectal temperature and the SensorTouch ranged widely in this period, from -1°C up to +4°C. In the same period the Tympanic temperature (IRTT) remained significantly lower than the rectal temperature. During the latter part of the exercise period the differences decreased. We have no data on extended periods of hyperthermia, in which sweat rate and increased body temperature are stable.

The SensorTouch did not provide reliable values of the body temperature during periods of increasing body temperature, but the SensorTouch might work under stable conditions. During exercise the IRTT followed the changes in rectal temperature better than the SensorTouch. However, we had no data on longer exposures in which the thermoregulatory system may become in a stable condition.

INFRARED TYMPANIC TEMPERATURE AND EAR CANAL MORPHOLOGY

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Recent publications indicate that the InfraRed Tympanic Temperature (IRTT) underestimates the core temperature of the body when the ear canal is long, curvy and narrow. In order to further investigate these observations, a study was performed in ten subjects. The IRTT was determined and compared to the esophageal temperature (Tes). Also, the oral and rectal temperature were monitored. Tes is considered as a good reference temperature of the body core. A three dimensional print of the ear canal was made to determine the ear canal morphology. The core temperature of the subjects was increased by at least 1°C during the experiment in order to investigate the dynamics of the core temperature assessment. Two devices were used to determine the IRTT: the Braun PRO 1 and the predecessor of the Braun IRT3020 (code name IRT3000P). The IRTT on average underestimated the core temperature, as measured by Tes, by 0.38°C. The IRTT was related to ear canal morphology. The circumference of the ear canal at the distal bend in the ear canal and the visibility of the tympanum were the most important parameters. About 22% of the variance in delta T (IRTT-Tes) was explained by ear canal morphology for the steady state resting period. Wide ear canals and good visibility of the tympanic membrane were related to a smaller delta T. A good visibility of the tympanic membrane was generally found in the absence of cerumen. The IRT3000P showed better results than the PRO 1 (delta T: -0.31 °C (SD 0.27°C) and -0.44 °C (SD 0.30°C) respectively). Also, the IRT3000P was less dependent on ear canal morphology. The dynamic response of the measured core temperatures was determined by the decrease or rise in core temperature after the heating period was ended. The esophageal temperature dropped by 0.22°C. The IRTT and oral temperature showed an identical increase of 0.19°C. The slow reacting rectal temperature had an after rise of 0.49°C. We conclude that the tested infrared ear thermometers seriously underestimated core temperature, particularly in subjects with small, curvy ear canals.

PERFORMANCE OF THE PORTABLE IVN320-P FOCAL PLANE ARRAY THERMAL IMAGER

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A new portable thermal imager made in Germany (DIAS INFRARED GMBH) uses a focal plane array uncooled bolometric detector with 320 x 240 pixels. This camera has a number of novel features, including full touch screen controls on the backlit LCD display, single shot image capture, from real image display. The standard lens has a field of view of 29 x 22, with a range of supplementary lenses available.

Digital output is via a standard USB2 port. Basic software includes radiometric facilities, with a sensitivity of 0.08C at 30C. The temperature range can be set from 5C span to 25C. The inbuilt digital storage allows for up to 124 images, at 16bit file format.

Fig. 1 The IMPAC IR Camera

A series of laboratory tests have been performed at the University of Glamorgan, which include spatial resolution, stability of temperature measurement and linearity of field. Full stability from start up was achieved in less than 1 hour, although the camera was usable in 5 minutes.

Fig.2 The IMPAC camera and heated resolution chart

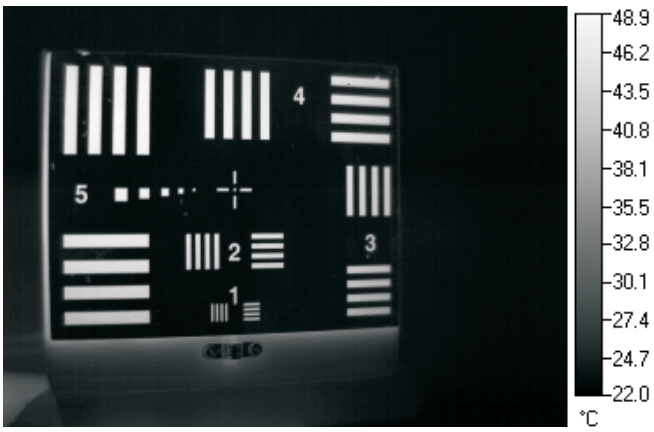

Fig.3 Thermogram

This low cost camera shows good performance characteristics that make it suitable for clinical thermography, with radiometric facilities for temperature measurement. It is possible that it will be compatible with other software systems already in use in the medical field.

AUTOMATED OVERLAY OF VISUAL AND THERMAL IMAGES FOR THE ASSESSMENT OF MORPHOEA PATIENTS

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Morphoea is a rare skin disorder characterised by an initial phase of inflammation, followed by progressive fibrosis and ultimately atrophy. Infrared thermography has been shown to be of value in the detection of active morphoea in children. Simultaneous capture of both thermal and visual images of the patient allow the physician to relate the anatomy to the extent of skin involvement and also to evaluate the development of disease and treatment. For this it is necessary to overlay the two images and produce a superimposed image. Due to differences not only in modality but also resolution and geometry (camera position and perspective) overlaying the two images is a non-trivial task and hence and an automated solution sought after.

Image registration algorithms transform one of the images (called the moving image) with relation to the other (the fixed image) to find the best alignment of the two pictures. In our work we use an intensity based image registration approach which has the advantage that it does not require a priori definition of some control points which have to coincide in both images. Hence, the task of geometrically aligning the images is done in a completely automatic fashion without the need of user intervention. We employ DARBS, a distributed blackboard sytem, to perform the registration in a hierarchical way in order to speed up the process and distribute the workload. Affine transform and normalised cross correlation are used as parameters for the registration algorithm. Experimental results based on a number of patients show accurate overlay of thermal and visual images.

STANDARDISATION OF INFRARED IMAGING: A REFERENCE ATLAS FOR CLINICAL THERMOGRAPHY - INITIAL RESULTS

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Medical thermography has been developing for 45 years. However, defined protocols for technique and the ability to apply quantitative methods to medical thermograms have been employed only in recent years (Ammer and Ring 2000*). Despite the considerable literature referring to diseases and abnormal thermograms, few papers give reliable data on normal findings. There is a common need to establish a reference database of normal thermograms from which the abnormal findings can be reliably assessed.

Existing protocols and agreed international standards for technique have been examined to identify sources of error and variability in thermograms obtained from human subjects. The result of this study can be summarised in eight separate areas, and solutions to each area have been introduced and tested.

1patient preparation and information.

2Camera systems, standards and calibration.

3Patient position and image capture.

4Image analysis.

5Image storage.

6Image exchange

7Image presentation.

8Information, protocols and resources

Each of these areas were forund to be sources of error, artefact or ommission in clinical practice. Any combination of these problem areas led to a lack or reproducibility, and possible misinterpretation of the results.We have now put in place protocols, definitions and software modifications to correct or minimise the effect of these problems. Each new procedure has been tested and verified.

Having clarified the above procedures, we are now in a position to present initial data from The Reference Atlas for Clinical Thermography. We have used the results for the total body views to calculate mean body surface temperature. Unlike earlier methods complex calculations are not required to estimate surface temperature based on multiple local temperature measurements.

Reference

*Ring EF and Ammer K, The Technique of Infrared Imaging in Medicine. Thermology International 2000 January;10(1):7-14.

MEDICAL SUB-SURFACE THERMOGRAPHIC IMAGING BY PASSIVE MILLIMETRE WAVE RADIOMETRY.

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We present the development and initial trial results of a novel medical imager which maps body temperature emanating from below the surface of the skin. The new imager, called MISTM (Medical Imager for Subsurface Temperature Mapping), uses a mechanically scanned radiometer to record passively the natural thermal emission of the body in the millimetre waveband. Millimetre waves occupy the spectral region between microwaves and the infrared.

Thermal infrared (TI) thermographic imaging is a well known technique and offers high spatial and thermal resolution but suffers from poor penetration depth, essentially just measuring skin surface temperature. In contrast, contact probe microwave thermography has demonstrated penetration depths of several centimetres but such instruments do not really form true images and data acquisition is very slow.

MISTM achieves non-contact imaging of sub-surface temperature by operating at a waveband around 3mm. Whilst the dielectric properties of tissue at millimetre wavelengths are not well characterised, the achievable penetration depth is expected to be of the order of a millimetre. Since the imager is passive and non-illuminating, the technique is inherently safe for subject and operator. Images are recorded from areas up to approximately A4 in size (150x100 pixels, each 2.24mm square), in a maximum imaging time of 3 minutes, with a thermal resolution of 0.6K.

MISTM was developed in conjunction with clinicians and medical physicists from Ninewells Hospital, Dundee, and is easy to use and operates reliably. It is presently undergoing data gathering trials in the Vascular Lab at Ninewells which compare MISTM with a TI camera (TIC) and a laser Doppler imager (LDI). Initial results are very encouraging and indicate good agreement between all 3 modalities at low ambient temperatures, but a lack of thermal contrast at higher ambient temperatures has resulted in less agreement. Work is ingoing to collect more data and to cross-check instrumental effects such as absolute thermal calibration.

The MISTM imager (left) and an example image of a hand (right).