# 10th National Congress of the Polish Association of Thermology

## ZAKOPANE 16th-18th March 2007- Abstracts

### FINDINGS FROM ROUTINE THERMAL IMAGING IN SUBJECTS SUSPECTED OF THORACIC OUTLINE SYNDROME

Kurt Ammer

Institute for Physical Medicine and Rehabilitation, Hanuschkrankenhaus, Vienna, Austria

In 1993 Schartelmüller and Ammer established a protocol for thermal imaging in patients suspected of Thoracic Outlet Syndrome (TOS). With some modification this protocol is routinely used since 1994 for the thermographically assisted diagnosis of Thoracic Outlet Syndrome.

About 1000 subjects underwent this investigation since thermal imaging was included in the diagnostic pathway for TOS. A temperature difference of 0. 5 or more degrees between index and little finger is regarded as a pathological finding. The results in 210 subjects are reported who were studied by thermal imaging between 2000 and 2005. The following classification was made: pathological temperature difference in one position was named “possible TOS”, pathological findings in two positions was regarded as a “probable TOS” and pathological temperature readings in three or four arm position was classified as “definite TOS”. In addition, TOS cases were labeled with “index” or “little finger” with respect to the colder finger.

Between 2000 and 2005, 418 patients (302 females, 116 males) were investigated in total for temperature symptoms of TOS. The thermal images of these 210 cases (156 females, 64 males) were quantitatively re-evaluated. In 115 image series did not show pathological findings and have been classified as normal (55 on the left hand side, 60 on the right hand side). Definite TOS affecting the little finger was detected in 49 left hands and 44 right hands, a definite cold index finger was observed in 6 hands (3 right and 3 left hand side) only. 102 image series showed temperature changes that indicated a probable TOS on the little finger (48 left hand, 54 right hand). A possible TOS (little finger) was seen in 80 hands (42 left hand, 38 right hand). The remaining cases were 9 times classified as probably TOS (index) and as ossible TOS (index) in 15 other cases. There was no significant difference in age between the different classes of TOS, with the exeption that patients with probable or definite cold index finger at the right hand side had a higher age as subjects without symptoms or with TOS symptoms at the little finger. At the right hand, males had also less definite and probable TOS symptoms at the little fingers than females.

A pathological temperature difference between index and little finger is a common finding. Only 23% of the re-evaluated image series had normal distribution of finger temperatures. A small percentage of patients presented with a colder index than little finger. These patients, mostly males, are older than patients with cold little fingers and their symptoms might be caused by compression of the median nerve at the carpal tunnel rather than by irritation of the brachial plexus in the subclavial region.

Thermal imaging is the only method that provides pictorial information of functional changes caused by compression of the brachial plexus. It is a complementary diagnostic test and can be used as outcome measure in clinical trials with patients suffering from Thoracic Outlet Syndrome.

### THERMAL SYMMETRY ON EXTERMITIES OF HEALTHY SUBJECTS

Ricardo Vardasca, Francis J Ring, Peter Plassmann, Carl D Jones

Medical Imaging Research Group, Department of Computing and Mathematical Sciences Faculty of Advanced Technology, University of Glamorgan, Pontypridd, CF37 1DL, UK

Infrared thermal imaging is being utilized increasingly in the study of neurological and musculoskeletal disorders providing data on the symmetry of skin peripheral temperature. Skin temperature measurements were carried out on 26 healthy subjects' thermograms. Temperature measurements were obtained using a computer interfaced application developed in past projects of this research unit, CTHERM, this thermographic instrument with the capability of obtaining average temperatures and standard deviation values in corresponding areas of interest on both sides of the body. In the healthy control subjects the overall temperature difference was maximum value 0.19º C on total body view and 0.16 º C on regional views. This study has confirmed with quantitative data from CTHERM software, the thermal symmetry in normal subjects, which can be used to assess thermal changes in specific pathologic states. This work has also compared the usage of total body view (table 1) with the regional views (table 2). No other studies have been carried out with the current generation of higher resolution cameras.

| Extremities | Mean Temperature (Right) | Mean Temperature (Left) | Δ Temperature | Standard Deviation (Right) | Standard Deviation (Left) |
|---|---|---|---|---|---|
| **Upper arm** | 30.4 ºC | 30.6 ºC | 0.2 ºC | 3.0 ºC | 3.0 ºC |
| **Forearm** | 30.0 ºC | 30.0 ºC | 0.1 ºC | 3.2 ºC | 3.1 ºC |
| **Hand** | 28.5 ºC | 28.5 ºC | 0.0 ºC | 3.2 ºC | 3.2 ºC |
| **Upper leg** | 29.2 ºC | 29.3 ºC | 0.1 ºC | 1.9 ºC | 1.7 ºC |
| **Lower leg** | 29.1 ºC | 29.1 ºC | 0.0 ºC | 2.4 ºC | 2.3 ºC |
| **Feet** | 27.4 ºC | 27.3 ºC | 0.1 ºC | 2.2 ºC | 2.1 ºC |

Table 1 Results of statistical analysis of Total Body Anterior view

| Extremities | Mean Temperature (Right) | Mean Temperature (Left) | Δ Temperature | Standard Deviation (Right) | Standard Deviation (Left) |
|---|---|---|---|---|---|
| **Upper arm** | 31.9 ºC | 31.9 ºC | 0.0 ºC | 2,0 ºC | 2.0 ºC |
| **Forearm** | 31.5 ºC | 31.5 ºC | 0.0 ºC | 2,0 ºC | 1.9 ºC |
| **Hand** | 31.0 ºC | 31.0 ºC | 0.0 ºC | 2.1 ºC | 2.2 ºC |
| **Upper leg** | 30.7 ºC | 30.7 ºC | 0.0 ºC | 1.8 ºC | 1.9 ºC |
| **Lower leg** | 30.9 ºC | 30.9 ºC | 0.0 ºC | 2.4 ºC | 2.3 ºC |
| **Feet** | 30.4 ºC | 30.3 ºC | 0.1 ºC | 3.0 ºC | 3.2 ºC |

Table 2
Results of statistical analysis of Regional Body Anterior views

## BURN DEPTH EVALUATION BASED ON ACTIVE DYNAMIC THERMOGRAPHY.

Alicja Renkielska*, M. Kaczmarek**, A. Nowakowski**
J. Rumiñski**.

*Department of Plastic Surgery and Burns, Medical University Gdansk,
**Department of Biomedical Engineering, Technical University Gdansk, Poland.

Proper evaluation of the surface and depth of a burn wound, especially in the case of a severe burn, enables an appropriate choice of treatment to be made. This choice decides subsequently about the success of the entire medical treatment. Clinical assessment is currently the most frequently applied method in burn depth evaluation. Unfortunately the use of this method results in a high number of false diagnoses. Numerous other methods have therefore been introduced and none of them has been fully accepted by clinicians treating burns.

The goal of this work was to evaluate and compare the usefulness in burn depth assessment of two selected modalities of infrared imaging (IRI), namely classical static thermograpy (ST) and active dynamic thermography (ADT), which has not been applied earlier for this purpose. The last method is based on analysis of thermal transients after external tissue excitation using pulse optical heating. Commonly used clinical methods and histopathological assessment were taken as reference methods. The methods presented were employed in *in vivo* animal experiments on 3 young domestic pigs, each weighing approximately 20 kg. Analysis was made of 64 burn wounds for ST and 23 wounds for ADT. The wounds were inflicted according to the modification of Singer's procedure. The analysis also made use of bacteriological methods.

The obtained results were subjected to statistical analysis by means of the Anova variance analysis method and by comparing the average *post hoc* values with Tukey's RIR test. The accuracy, sensitivity and specificity of the methods tested with reference to the characteristic sought, namely healing of the wound within 3 weeks of the burn, have been quantitatively calculated.

Based the bacteriological results, the possibility that the thermographic findings have been influenced by the micro-organisms has been excluded.

The mean values calculated for the synthetic ATD parameter, $\hat{o}$, did not differentiate the burn wounds classified into clinical groups at the level of statistical significance. In contrast, however, they did differentiate in this way the groups established according to the histopathological criterion (shallower or deeper than 60% of dermis thickness at the measurement side). When the ADT method is employed, the results of classification based on the histopathological criterion are identical to these based on the clinical criterion "healing within 3 weeks". The calculated threshold value of the time constant $\hat{o} = 10.125$s ,accuracy, sensitivity and specificity = 100%, respectively.

ADT as the single method of choice does allow for the objective classification of burn depth on the basis of a quantitative criterion. Possessing all the advantages of ST, ADT is much less subject to the limitations of this method. When all this is taken into consideration it may be claimed that ADT meets to the highest degree the requirements of a modern diagnostic method which will evaluate burn depth and, in consequence, prove useful in the proper choice of treatment.

## STANDARDISATION OF THERMAL IMAGING SYSTEMS USED IN MEDICINE

Francis J Ring, , Peter Plassmann, Carl D Jones,
Ricardo Vardasca

Medical Imaging Research Unit, Faculty of Advanced Technology, University of Glamorgan, Pontypridd, CF37 1DL, UK

Infrared thermal imaging was first made available to medicine in the early 1960's. Despite a large number of research publications on the clinical application of the technique, the images have been largely qualitative. In 2001 an Anglo Polish collaborative study was set up to identify and resolve the sources of error and problems in medical thermal imaging. The predominant lack of control data over the last 40 years of thermal imaging in medicine has been compounded by the fact that the vast majority of publications refer to studies in diseased patients. The limited sources of normal control thermal images are rarely addressed. Similarly, there have been only a limited number of publications on standardisation of technique with thermal imaging.

The main areas of a clinical thermal imaging procedure that require standardisation are

A preparation of the patient

B standardisation of the thermal imaging system ( including calibration)

C image capture protocols

D image analysis protocols

E reporting, ar-chive and storage of images

F education and training of clinical users of the technique.

Two of these critical areas in medical thermography are described in more detail

STANDARDISATION OF THE THERMAL IMAGING SYSTEM: There are a number of thermal imagers in medical use, using different detectors and optics.

They are not equal in thermal or spatial resolution, and each depends on the manufacturer's calibration. It has been found that most camera systems, both cooled and uncooled detectors require much longer to achieve radiometric stability than stated by the manufacturer.

This means that the common practice of setting up a camera just prior to use, is frequently inadequate. Variation in the measurement from a black / grey body radiant source at a known temperature or temperatures must be established for each imaging system, and the minimum warm-up time recorded. In addition, most thermal imagers are calibrated by the manufacturer before delivery, and may not be checked again until a fault is detected. Furthermore, each manufacturer in each country may use a different reference system, resulting in a wide offset range in terms of absolute temperature. Protocols to test the camera systems used, and to reduce variables have been developed.

IMAGE CAPTURE: Image capture is a major source of variability, with varying camera angles and distances. A complete set of standard views was therefore devised, that require the camera to be mounted on a parallax free stand The most useful modification, however, has been the introduction of software generated capture masks for each standard view of the human body. This is an electronic outline written in to the software that automatically appears when each standard view is selected from the menu. This optimises the position and size of the body region being imaged and greatly improves repeatability.

## THERMOGRAPHIC ASSESSMENT OF THERMAL EFFECTS OF THE ERBIUM:YAG LASER IN ORAL EPITHELIUM PHOTOABLATION

S Zmuda[1], Elsbieta Ignatowicz[1], M- Dabrowski[2], R- Dulski[2]

[1] Military Institute of the Health Services, Department of Periodontics,
[2] Military University of Technology, Institute of Optoelectronics, Warsaw, Poland

BACKGROUND: Infrared thermography was introduced in dentistry at the end of the last century. Despite of its short history recent studies on thermal imaging system in the field of dentistry seem to be of promising use. The assessment of the thermal effects of the high-power lasers is one of the potential applications.

OBJECTIVE: The aim of this study was thermographic analysis of temperature distribution on the surface of oral mucosa during laser ablation (removal) of the epithelial tissue being inflamed.

MATHERIALS AND METHODS: The study describes the case of women with severe type of bullosus oral lichen planus. Lesions in the form of erosions and blisters were removed with the Er:YAG laser. Temperature elevation at the time of laser irradiation was measured by thermovision.

RESULTS: Thermal images taken during the surgery were analyzed. The assessment included the temperature distribution, the range of temperature changes including the maximum as well as the rate of cooling of oral mucosa at the time of laser application.

CONCLUSIONS: Results obtained in this study suggest, that thermal imaging system is a useful tool for monitoring thermal effects of laser on oral soft tissues. The Er:YAG laser beam can significantly increase the temperature in the interaction site. Monitoring of temperature distribution improves the safety of laser treatment due to control both laser parameters and optical fibre position (i.e. the distance between fibre and the surface of oral mucosa).

## LIQUID-CRYSTALLINE CONTACT THERMOGRAPHY IS COMING BACK

S. J. Klosowicz[1], K. L. Czupryñski[1], W. Borys[1], H. Jaremek[2] , J. Stêpieñ[3], M. Aleksander[4]

[1]Military University of Technology, Warsaw, Poland,
[2]GREHEN Ltd, Poland,
[3]Glammeron Manner Ltd, Poland Division
[4]State Higher Educational School, Nowy Sacz

Liquid-crystalline contact thermography (LCCT) has been developed for at least 40 years, mainly in medical applications. It would seem that rapid development of thermovision revealed some disadvantages about this method. However, very recently some new concepts regarding its technology and usage has been introduced.

The physical principle of LCCT operation is selective light reflection from a cholesteric liquid crystal layer giving a possibility to assign the color of a liquid crystal layer to its temperature. Usually such materials have been used in the form of a thermosensitive foil of multiple usage. In such a foil liquid crystal droplets of micrometer size are embedded in an elastic polymer matrix. In comparison with other thermovision systems LCCT is simpler and cheaper; moreover, it does not include artificial processing of an image. On the other hand, thermographic foil has to be placed on the patient skin, which introduces several problems with interpretation of the thermogram. The measurement standards are the same for both methods.

Recently a new approach to LCCT technology and interpretation of thermal images obtained by this method has been developed. It allows to use LCCT for screening diagnostics made by patients themselves. In fact this application potentially can be adopted as an alternative method for early disclosure of several kinds of cancer. In case of a cancer indications such autodiagnosis should be confirmed by other objective methods interpreted by professionals.

## HEART MONITORING BASED ON DYNAMIC THERMOGRAPHY – IN-VIVO EXPERIMENTS ON ANIMALS

M. Kaczmarek*, A.Nowakowski*, J. Siebert**, J.Rogowski**, B. Trzeciak**, J. Topolewicz**, W. Stojek***

*Dept. of Biomedical Engineering, Gdansk University of Technology, Narutowicza 11/12, 80-952 Gdansk
** Medical University of Gdansk/University Centre for Cardiology, Debinki 7, Gdansk
*** University of Gdansk/Department of Animal Physiology, Kladki 24, Gdansk

The aim of this study is the development and analysis of application of new tools for continuous inspection of open- heart cardiosurgical interventions, suitable in clinical environment. Our focus is on IR-thermal imaging for monitoring of isurgical interventions such as CABG in treatment of ischaemia and other heart dysfunctions. In this presentation, we discuss.the preliminary results of *in-vivo* experiments on animals using an IR thermal camera and newly developed procedures of dynamic thermography.

MATERIAL AND METHODS: The IR-camera AGEMA THV-900 SW/TE of 0.1°C resolution was used for capturing of thermal images and sequences presented in this paper. It was placed at the distance of 0.75 m from the pig's chest, in the plane perpendicular to it. The steady state temperature distribution on the tested surface is recorded using an IR camera. Next, external thermal excitation is applied to force thermal transients at the tested surface. Recording of temperature allows calculation of such thermal parameters as thermal time constants, dependent on the state of the tested structure. We apply external pulse excitation (step function) lasting several seconds, using halogen lamps for generation of heating or a cryotherapy device (CryoFlow 1000) for cooling. IR camera is applied for capturing of series of thermal images allowing measurements of temperature transients on the tested surface.

The i*n vivo* animal experiments were performed according to all legal regulations and permission by the Gdansk Ethics Commission for Experimentation on Animals. Introduction of ischaemia to the heart muscle was done by clamping the left descending artery (LAD). Thermal state of the heart is monitored using an IR thermal camera and simple recording of radiation emitted by the observed surface of the heart. Additionally, thermal properties of the heart muscle are calculated from active dynamic thermography (ADT) experiments based on external thermal excitation.

RESULTS: Natural re-warming phase for the cooling procedure as well as natural cooling phase for the heating procedure are more suitable for characterisation of tissue by thermal parameters because the heat transfer in these phases is mainly depended on thermal properties of tissues (thermal capacity, thermal conductance) and not on properties of excitation sources. Thermal properties of the heart for the heating excitation (halogen lamps) and cooling excitation (CRYOFLOW) for natural processes (cooling and re-warming phases respectively) for regions K1 and K2 are shown in Figure 1. For both procedures time constants for affected tissue are longer than for healthy tissue (grey cells in Table 2). Heat exchange (transport) in natural way for affected tissue is slower than for healthy tissue mainly due to strongly decreased blood circulation in this affected region. The experiments prove that any impairment in blood circulation in tissue is manifested by slower heat transport and by longer time constants of exponential thermal model.

ACKNOWLEDGEMENTS: This research was performed under the grant 3 T11E 01027 from the Polish Ministry of Science.

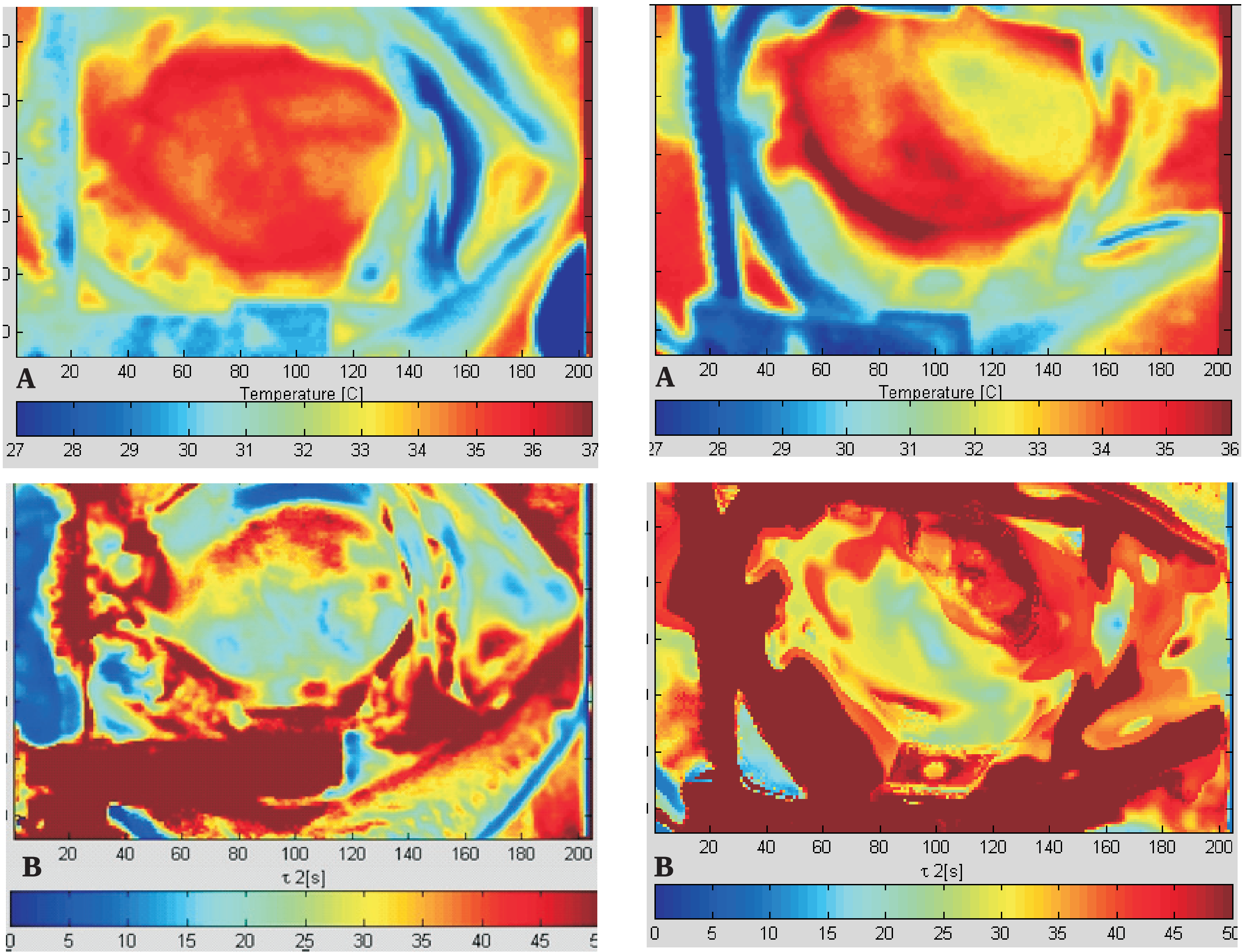



Figure 1 Healthy heart before clamping LAD    Heart 25 minutes after clamping LAD

A / Static IR-images; B / ADT parametric images for cooling 30 seconds by forced air flow (CryoFlow 1000) of the temperature $5^0$C; captured during 90 seconds at the phase of natural recovery (self-re-warming), taken before and 25 minutes after clamping LAD

## TEMPERATURE MEASUREMENTS IN CHILDREN FOR FEVER DETECTION

Francis J Ring[a] ,J Zuber[b], A.Jung[b] B.Kalicki[b], P.Rutkowski[c] Carl D Jones[a],

a Medical Imaging Research Unit, Faculty of Advanced Technology, University of Glamorgan, Pontypridd, CF37 1DL, UK
b Pediatric, Nephrology & Allergology Clinic, WIM, Warsaw Poland
c Flir Systems AB  Warsaw Poland

The interest in the use of thermal imaging as a means of screening passengers for fever, has become a major issue since the SARS epidemic in Asia, and the continuing risks from Avian influenza (H5N1 virus). A convenient target for imaging in this situation e.g. airport, is the human face. Reports from Asia indicate that measuring the temperature of the frontal face can indicate fever when maximum temperatures of 380C are reached. This should be most evident at the inner canthus of the eye. To investigate the temperature of a cohort of children in the Pediatric Clinic in Warsaw, we have performed two short studies of 5 days duration.

METHOD: Children of ages from 3 months to 17 years were examined with the IR camera and their temperatures were measured with a conventional thermometer used in the arm axilla. In the first study ( July 2006) 57 subjects were thermogrammed, a full frontal face, using a FLIR Thermacam B series. An external reference source was used to maintain regular checks on the camera. In the second series, November 2006, 38 subjects were examined with the same technique, but using the new Thermacam B640. In the second series some additional temperature measurements were made with a Braun ear radiometer.

RESULTS; In the first series, none of the children tested had active fever at the time of examination. Some had a recent history of raised temperature, but this had resolved by the time they attended the clinic. In the second series there were three readings clearly raised over the 38oC level, and this was found in the auxiliary thermometer reading also. In the first series, no correlation was found between auxiliary and eye temperatures measured by the separate techniques. In the second series however, a better correlation R2 = 0.501 was obtained. The camera software on both occasions provided a direct readout of maximum temperature from a region of interest placed over both eyes during the recording.

The highest temperature was found in one subject (age 6 yrs) with 390C at the arm axilla and 38.60C at the eye. A few hours before, the subject complained of fever symptoms, measuring 37.50C at the axilla and 37.40C at the eye canthus. After two doses of antibiotic her temperature fell to36.70C axilla, and 36.40C eye, both in normal limits. Another subject with tonsillitis (age 2 years) recorded 38.60C at the eye, and 38oC axilla. Another 2 yr old registered 37.7 underarm and 37.3 at the eye. However ear radiometry was lower, 35.6 and 36.0 left and right respectively.

The radiometric measurements from the ear were only performed in 16 subjects, but no correlation was found with the other two methods, probably due to small sampling.

Although the number of fever subjects was small, the data indicate that raised temperatures could be rapidly found with the IRT camera, and raised temperatures were confirmed both by thermometry and clinical diagnosis.

# News in Thermology

## 8th Course on the Theory and Practice of Infra Red Thermal Imaging in Medicine

E. Francis Ring

Medical Imaging Research Unit, Faculty of Advanced Technology, University of Glamorgan
Pontypridd, CF37 1DL, UK

The 8th Course on the theory and practice of thermal imaging was held at The University of Glamorgan on 4-6th July 2007 (figure 1). Since the first course at The University was held in 2001, approximately 80 people have completed the course. The have been a number of changes in the course content since that time. This year, again Prof. Graham Machin of the National Physical Laboratory, and visiting Professor, lectured on traceability and calibration of thermal imagers and Dr Rod Thomas from Swansea, visiting Fellow at Glamorgan presented the subject of detectors and cameras. Prof.Kurt Ammer presented thermal physiology and clinical applications of thermal imaging, with aspects of standardisation and technique by Prof. Francis Ring. Dr Peter Plassmann lectured on self testing and quality assurance of thermal imagers, and on the image processing software CTHERM. Practical sessions included image capture (figure 2), and image processing, the latter takes place in a computer-training laboratory (figure 3), where everyone is able to work on a separate workstation, and the instructor can use a projected image for demonstration. The final session of the programme included and overview of the future for thermal imaging and a lecture by Prof. Ammer reviewing past conferences, scientific journals and societies working in thermal imaging for medicine, veterinary science and biology.

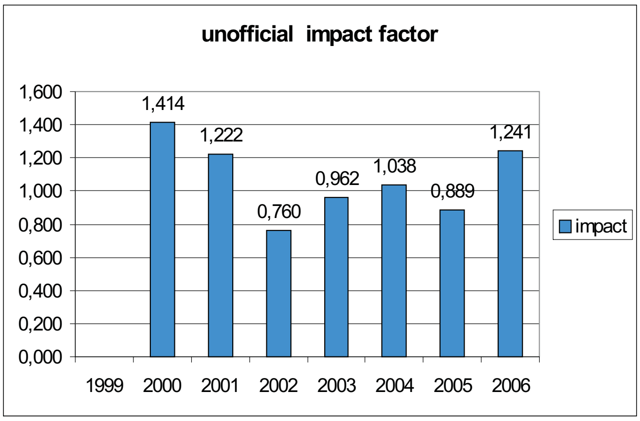
This is the only course of its kind, where physicians, engineers, physicists technicians etc. can all benefit from this practical programme. The emphasis of this course is to improve background understanding of the techniques and the correct use of standardised practice to improve re- liability. It does not set out to teach anyone how to diagnose clinical diseases. The short course is recognised by The Faculty of Advanced Technology at the University of Glamorgan.This year, for the first time, a one-day workshop based on the theoretical aspects of the course was given at Auburn University prior to the International conference on Medical Thermology in May. (1) In earlier years,

Figure 1
Participants of the 8th Course

other journals. These citations were checked for the time interval between publication of the cited article and the citation. A hand search was performed through all issues of Thermology international to obtain the number of published articles and also of self-citations to articles published in a time period of two years. Table 1 shows the cumulated findings from the search in Google Scholar and in Thermology international.

| | articles | selfcited | cited | citations | 2 years articles |
|---|---|---|---|---|---|
| 1999 | 13 | 19 | 3 | 22 | |
| 2000 | 16 | 36 | 5 | 41 | 29 |
| 2001 | 11 | 27 | 6 | 33 | 27 |
| 2002 | 14 | 15 | 4 | 19 | 25 |
| 2003 | 12 | 24 | 1 | 25 | 26 |
| 2004 | 14 | 24 | 3 | 27 | 26 |
| 2005 | 13 | 15 | 9 | 24 | 27 |
| 2006 | 16 | 34 | 2 | 36 | 29 |
| 2007 | 16 | 17 | | 17 | 32 |

Figure 1 shows the impact factors based on the data from table 1.




Due to its wide scope of topics, Thermology international fits into various categories of ISI academic journals. The five most appropriate are “Biology”, “Biophysics”, “Radiology, Nuclear Medicine & Medical Imagin**g**“, “Rehabilitation” and “Thermodynamics” The following defintions are provided by ISI for these five categories (4)

**Biology**
The Biology category includes resources having a broad or interdisciplinary approach to biology. In addition, it includes materials that cover a specific area of biology not covered in other categories such as theoretical biology, mathematical biology, **thermal biology,** cryobiology, and biological rhythm research.

This category includes 64 journals with a median impact factor of 1.135 (5).

**Biophysics**
Biophysics covers resources that focus on the transfer and effects of physical forces and energy-light, sound, electricity, magnetism, **heat, cold,** pressure, mechanical forces, and radiation-within and on cells, tissues, and whole organisms

This category includes 66 journals with a median impact factor of 2.332 (5).

**Radiology, Nuclear Medicine & Medical Imaging;**
Radiology, Nuclear Medicine & Medical Imaging covers resources on radiation research in biology and biophysics. Resources in this category focus on interventional radiology, investigative radiology, neuroradiology, radiotherapy, and oncology. Nuclear Medicine resources are concerned with the diagnostic, therapeutic, and investigative use of radionuclides. Medical Imaging resources are concerned with **computerized medical imaging** and graphics

This category includes 85 journals with a median impact factor of 1.665 (5).

**Rehabilitation**
Rehabilitation covers **resources on therapy** to aid in the **recovery or enhancement of physical**, cognitive, or social abilities diminished by birth defect, disease, injury, or aging.

This category includes 27 journals with a median impact factor of 1.300 (5).

**Thermodynamics**
Thermodynamics includes resources that focus on the areas of physics examining the transformations of matter and energy in physical and chemical processes, particularly those processes that involve the **transfer of heat and changes in temperature.** Relevant topics in this category include cooling and heating systems, cryogenics, refrigeration, combustion, energy conversion, and thermal stresses.

This category includes 27 journals with a median impact factor of 0.854 (5).

The current unofficial impact factor of Thermology international is 1.241, which is above the median impact of journals in the categories Biology and thermodynamic, slightly below that of rehabilitation journals and definitely below the impact of Radiology, Nuclear Medicine & Medical Imaging and of Biophysics, which shows with 2.332 the highest impact of all categories appropriate for Thermology international.

References

1. Piek S, Kröling P, Ammer K, Stucki G. PMR-relevante Zeitschrif- ten. Eine Liste wissenschaftlicher Zeitschriften für Physikalische Medizin und Rehabilitation, sowie verwandter Fachbereiche. Phys Med Rehab Kuror 2004: 14: 254-262

2. Cockeril MJ. Delayed impact: ISI’s citation tracking choices are keeping scientists in the dark. BMC Bioinformatics 2004, 5:93

3. The PLoS Medicine Editors. The impact factor game. PLoS Med 2006; 3(6): e291

4.http://admin.isiknowledge.com/JCR/static_html/scope_notes / SCIENCE/2006

5. http://portal.isiknowledge.com.