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13th Congress of the European Association of Thermology, Madrid, 2nd -5th Sepember, 2015

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Organ of the American Academy of Thermology

Organ of the Brazilian Society of Thermology

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Contents (INHALTSVERZEICHNIS)

Editorial

Obituary (NACHRUF)

Reports (BERICHTE)

Meetings (VERANSTALTUNGEN)

13th Congress of the European Association of Thermology in Madrid

Kurt Ammer

Editor in Chief, Thermology international, European Association of Thermology, Vienna, Austria

The second Congress of the European Association of Thermology took place between the 11th and 15th September 1978 in Barcelona [1]. 37 years later, the European Congress returns to Spain, the destination is Madrid this time. In 1978, thermography was a fast evolving, novel imaging technology and the congress attracted many attendents from all around the world. The book of abstract showed the titles of 334 submissions, many of them were combined with a short abstract, mostly written in English, some in French and few in Spanish. Participants from Austria, Belgium, Canada, Czechoslovakia, France, Germany, Greece, Hungary, Italy, Japan, Poland, Romania, Spain, Sweden Switzerland, the Netherlands, Tunisia, United Kingdom, USA, USSR and Yugoslavia presented their experience and study results obtained with thermal imaging. About one third of papers was dedicated to breast thermography. The conference in Barcelona attracted the highest number of papers submitted ever to a European Thermology Congress.

This year, the congress attracted 70 submissions. 2 invited lectures and the pre-conference course with 6 additional talks and 4 hours of practical sessions complete the.scientific conference programme The list of nationalities of submitting authors is of similar length as that of the conference in Barcelona 1978 and includes delegates from Austria, Brazil, Czech Republic, Germany, Italy, Japan, Lithuania, Mexico, Norway, Poland, Portugal, Romania, Russia, Slovakia, Spain, Sweden, the Netherlands, United Kingdom and USA

As for the last European Thermology Congress, held in Porto in 2012, all 70 submissions have been reviewed by two independent referees, who applied the same scoring system that was used for the evaluation of papers submitted to the congress in Porto [2]. The mean score of this years`papers prior to revison was 3.15 points (range 1 to 5). Agreement between the two referees was fair to moderate (mean difference of scoring: 0.5 ± 0.39 standard deviation, range: 0 to 1.7) The referees proposed minor revisions for 38 papers and major or substantial revision for 28 submissions. 1 author retracted his two abstracts, all other authors who were asked for major revision, responded sufficiently to the reviewers proposals as most authors did who received a request for minor revisions.

I like two thank all authors and referees for their work and cooperation, resulting in extended abstracts of good scientific quality [3] which clearly demonstrate the continuous improvement in thermology research. I am convinced that

Figure 1
Cover of the book of abstracts of the 2nd Congress of the European Association of Thermology

Figure 2
Cover of the programme of the 13th Congress of the European Associaton of Thermology in Madrid

this conference is a landmark of the progress achieved in thermology.

References

1..Ammer K. European Congress of Thermology 1974-2006: A Historical Review. Thermology international 2006; 16(3) 85-95

2. Ammer K. Refereed Abstracts from the 12th European Congress of Thermology. Thermology international 2012, 12 (3) 85

3. 13th Congress of the European Association of Thermology, 2nd-5th September 2015 in Madrid: Abstracts. Thermology international 2015, 25(3) 91-148

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European Association of Thermology

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13th Congress of the European Association of Thermology Thermology in Medicine: Clinical Thermometry and Thermal imaging

Madrid 3-5 September 2015

VENUE

Facultad de Ciencias de la Actividad Física y del Deporte - INEF
Ciudad Universitaria de Madrid, C/ Martín Fierro,7. 28040 Madrid

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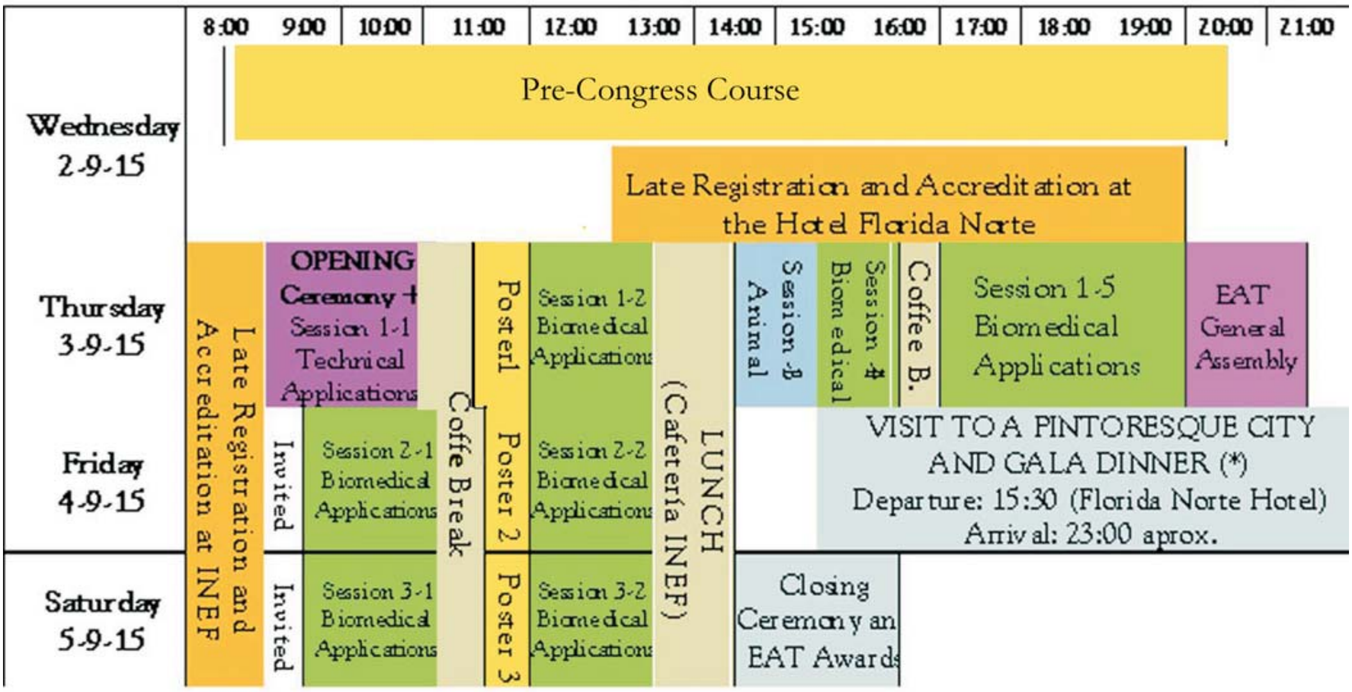
SCIENTIFIC PROGRAMME



Thursday, 3rd of September, 2015

9.00 Opening

9:00
A. Rivero (Dean of INEF): “Greeting address on behalf of INEF Madrid” (Spain)
J. Mercer: “Greeting address on behalf of EAT” (Norway)
M. Sillero: “Greeting address on behalf of the organization (Spain)

9:15 Session 1.1. Technical Applications: Hardware and software solutions for IR imaging

9:15 S1-1-1	R. Vardasca, J. Gabriel. “From thermal radiation at skin surface to image temperature values” (Portugal)
09:30 S1-1-2	B. Kluwe, P. Plassmann. “Mobile Medical Infrared Imaging Devices on Embedded Computing Platforms” (UK)
9:45 S1-1-3	G. Chernov, V. Chernov, C. Davila-Peralta, R. Rodriguez-Carvajal, M Barboza Flores. “3D infrared thermography system for biomedical applications” (Mexico)
10:00 S1-1-4	S. Sanchez-Carballido, M. Salas, A. De Castro, F. López. “Cutaneous medical analysis through active thermography supported on a thermal model of the skin. (Spain)
10:15 S1-1-5	A. Merla, D Cardone, P.Pinti, L Di Donato. “IRI – ImagePro©: A software tool for advanced processing of thermal IR imaging data”. (Italy)

10:40 Coffe Break

11:10 Poster Session 1. Miscellaneous animal and biomedical applications

P1-1	C. Ferraz, J. Moreira da Silva, L. Mendes "Assessment of stress recovery by thermography" (Portugal)
P1-2	M. Kobayashi. "The effectiveness of thermography as an assessment tool for flap engraftment in a dog" (Japan)
P1-3	S. Nica, L. Meiu, B. Mitoiu, M. Moise. "Case report-Thermographic evaluation of a patient with lymphedema of the upper limb, after mastectomy". (Romania)
P1-4	P. Rodrigues de Andrade, I. V. Vanessa Evangelista Maia, J. Almeida Ferreira, C. Franco de Medeiros Neto. "Absence of alterations in cutaneous temperature during the phases of menstrual cycle". (Brazil)
P1-5	O. Horie, H. Shibata, C. Okamoto, M. Natsuaki, M.Shibata."Assessment of fever for infection control using thermography facial thermography in patients with fever". (Japan)
P1-6	L.Laino,A Di Carlo "Possible application of telethermography in the non invasive study of the "Canceration Field". (Italy)
P1-7	R. Torres-Peralta, F. Cirett-Galán, V.Chernov, G. Chernov, J.L.Ruiz-Duarte, M Barboza-Flores. "Error detection and correction in thermographic images for time series analysis in dynamic infrared imaging". (Mexico)
P1-8	J. L. Ruiz-Duarte, V. Chernov, G. Chernov,R. Torres-Peralta, F. Cirett-Galan, Martín-Del-Campo-Mena, M Barboza-Flores. "A thermal asymmetry criterion for estimation of abnormality of breast infrared thermograms". (Mexico)
P1-9	E. Mota Silva, D. Casal, I. Iria, A. Farinho, S. Marques, E. Rodrigues, C. Pen, L. Mascarenhas Lemos, M. Angélica Almeida, D. Pais, J. Goyri O'Neill, V. Vassilenko "Evaluation of the efficacy of IR Thermography in assessing peripheral nerve regeneration in a rat model"

12:00 Session 1.2. Biomedical Applications Thermography in Surgery

12:00 S1-2-1	M. Leal Brioschi, E. Borba Neves, V. Machado Reis, G. Galindo Reisemberger. "Estimating the normal breast reference temperature in young women: a thermographic equation" (Brazil)
12:15 S1-2-2	B. Rustecki, M. Mo¿añski, J.Klimkiewicz, W.Machura, B.Kalicki, A.Jung. "Evaluation of paravertebral block for mastectomy by infrared imaging". (Poland)
12:30 S1-2-3	J. Mercer, T. Sjøberg, L.de Weerd. "Pre-, intra- and postoperative use of dynamic infrared thermography (DIRT) in breast reconstruction using a fascio-cutaneous pedicled perforator flap". (Norway)
12:45 S1-2-4	C. Di Maria, P. Hainsworth, J. Allen. "Microvascular imaging for the intra-operative evaluation of bowel perfusion". (UK)
13:00 S1-2-5	C. Vicari Nogueira, C. De Barros Fernandez, M. Brioschi, J. Pere Barret. "Infrared Thermography in Plastic Surgery: A Comparative Study of Pre and Postoperatory in different techniques of Abdominoplasty". (Brazil/Spain)
13:15 S1-2-6	A. Urakov, N. Urakova. "Thermography provides information on the oxygenation of the fetal brain in the final stage of childbirth". (Russia)

13.30 LUNCH (Cafeteria INEF)

14:30 Session 1.3. Animal Applications with a focus on equine medicine

14:30 S1-3-1	M. Soroko, K. Howell. "Thermography in equine medicine". (Poland/UK)
14:45 S1-3-2	K. Howell, M. Soroko, K. Dudek, E. Jodkowska. "Thermographic evaluation of racehorse performance" (Poland/UK)
15:00 S1-3-3	K. Howell, M. Soroko, K. Dudek. "Influence of breed, age, gender, training intensity level and ambient temperature on back and forelimb temperature in racehorses". (Poland/UK)
15:15 S1-3-4	A. Hoffmann, C. Dumke, M. Bernau, P. Kremer. "Infrared thermography – new concepts for refinement and reduction in animal use for testing of biological". (Germany)

Session 1.4. Biomedical Applications History and Future of Infrared Imaging

15:30 S1-4-1	K. Ammer. "Human Skin Temperature Measurement Based on Radiometry– A historical review". (Austria)
15:45 S1-4-2	A. Jung. "Twenty years activity of The Centre for Clinical Thermology of The Military Institute of Medicine in Warsaw, Poland". (Poland)
16:00 S1-4-3	M. Sillero-Quintana, J. Arnáiz-Lastras, I. Fernández-Cuevas, P. Gómez-Carmona. "Proposals to standardize results in human thermography". (Spain)
16:15 S1-4-4	C. Chandler. "Why thermography?" (USA)

16:30 Coffee break

17:00 Session 1.5. Biomedical Applications. Temperature measurement at the head or face

17:00 S1-5-1	C. Di Maria, J. Allen, J. Dickinson, C. Neoh. "Analysis of thermal images to quantify inflammation in Graves' orbitopathy". (UK)
17:15 S1-5-2	M. Sund-Levander, E. Grodzinsky. "Ear body temperature in healthy individuals . A population study on small children to elderly adults". (Sweden)
17:30 S1-5-3	F. Ring, D. Pascoe, R. Vardasca. "Lack of compliance to International Standards Organisation recommendations for Fever Screening with Thermography". (UK/USA/Portugal)
17:45 S1-5-4	F. Ring, R. Vardasca. "The development of an infrared thermography pandemic fever screening course for the non-researcher/scientist operator". (USA/UK/Portugal)
18:00 S1-5-5	H. Usuki, B. Nishiura, Y. Wada, J. Uemura, S. Noge, N. Maeda, M. Nishimura, E. Asano, M. Ohshima, N. Yamamoto, S. Akamoto, M. Fujiwara, K. Okano, Y. Suzuki. "Thermographic examination for hypothermia in high altitude". (Japan)
18:15 S1-5-6	D. Cardone, A. Merla. "The thermal dimension of social interactions". (Italy)
18:30 S1-5-7	E. Salazar-Lopez, E. G. Milán. "The mental and subjective skin: thermography applied to psychology". (Spain)

19:00 EAT General Assembly

Friday, 4th of September, 2015

9:00 Invited lecture. Blood flow in diabetes.

P.R.J. Vas. "Skin perfusion and diabetes". (UK)

9:30 Session 2.1. Biomedical Applications: Foot temperature

9:30 S2-1-1	J. Klaessens, A. van der Veen, R. Verdaasdonk. "Thermal Imaging, a clinical diagnostic tool for non-contact monitoring of tissue perfusion, applied in clinical trials". (The Netherlands)
9:45 S2-1-2	V. Veikutis, K. Stasiukynaitë, E. Monstavièius, A. Sakalauskaitë. "Plantar thermography as a diagnostic and prognostic tool for diabetic foot" (Lithuania)
10:00 S2-1-3	R. Vardasca, A. Marques, R. Carvalho, J. Gabriel. "Thermal Physiological Characterization of Diabetic Foot" (Portugal)
10:15 S2-1-4	J. Allen, C. Di Maria, K. Anderson. "Study of the thermovascular characteristics in patients with Willis-Ekbom disease" (UK)
10:30 S2-1-5	S. Melgosa. "Toe spacers to increase skin temperature". (Spain)
10:45 S2-1-6	J. Teixeira Oliveira, R. Vardasca, M. Pimenta, J. Torres. "Thermal imaging as a potential complimentary diagnosis method for ankle sprain lesions" (Portugal)

11:00 Coffe Break

11:30 Poster Session 2. Facial temperature and applications in surgery.

P2-1	D. Sabbagh Haddad, M. Leal Brioschi, R. Vardasca, E. Saito Arita. "Study of the facial surface skin thermal distribution by infrared thermography: facial thermoanatomy".(Brazil/Portugal)
P2-2	A. Seixas, V. Häussler, Monteiro, R. Vardasca, J. Gabriel, S. Rodrigues. "Experimentally induced pain elicits autonomic arousal in healthy subjects". (Portugal)
P2-3	C. De Barros Fernandez Nogueira, C. Vicari Nogueira, M. Brioschi, N. Maestro. "Case Report: Thermal Anatomic Aspects In Facial Palsy, And Use Of Thermography As A Healing Evaluation Method (Brazil/Portugal).
P2-4	V. Bernard, T. Andrašina, V. Mornstein, E. Staffa, V. Válek. "Infrared thermography as a tool for monitoring of radiofrequency tissue ablation inside of metal stent". (Czech Republic)
P2-5	E. Staffa, V. Bernard, L. Kubíèek, V. ž ižlavský; R. Vlachovský, D. Vlk, V .Mornstein, R. Staffa. "Thermal imaging to assess changes of foot skin temperature in patients treated with percutaneous transluminal angioplasty" (Czech Republic)

Session 2.2. Biomedical Applications Temperature Changes after Cold Challenge

12:00 S2-2-1	A. Norheim, E. Borud, J. Mercer, L. de Weerd. ""Normal" thermography among 122 soldiers in the Norwegian armed forces". (Norway)
12:15 S2-2-2	K. Howell, M. Adams, G. Hartnell, R. Smith. "Finger cooling during cold stress and surface area-to-volume ratio in healthy subjects, and patients with primary and secondary Raynaud's phenomenon". (UK)
12:30 S2-2-3	K. Leijon-Sundqvist, N. Lehto, U. Juntti, K. Karp. "Cold-water provocation of hands: an evaluation of different provocations". (Sweden)
12:45 S2-2-4	A. Urakov, M. Nasyrov, L. Chernova. "How fingers became warm after cooling". (Russia)
13:00 S2-2-5	T.D. Conwell, K.E. Lind. "Comparison of the Diagnostic Accuracy of Three Infrared Imaging Methods in Evaluating Patients with Presumptive CRPS". (USA)
13:15 S2-2-6	M. Clemente, R. Correia, D. Coimbra, R. Vardasca, J. Gabriel. "The contribution of medical thermal imaging in the study of Temporomandibular disorders (TMD) disorders in clarinet players". (Portugal)

13.30 LUNCH (Cafeteria INEF)

Saturday, 5th of September, 2015

9:00 Invited lecture.
J. A. Sobrino "Infrared remote earth sensing and global climatic change." (Spain)

9:30 Session 3.1. Biomedical Applications: Thermography and physical exercise

9:45 S3-1-1	R. Vardasca, A. Seixas, J. Gabriel, J. Vilas-Boas. "Thermographic evaluation of swimming techniques". (Portugal)
10:00 S3-1-2	J. Adamczyk, D. Boguszewski, P. Reaburn, D.Bialoszewski. Is it possible to create a thermal model of warm-up? Monitoring the training process in athletic Decathlon. (Poland)
10:15 S3-1-3	I. Fernández-Cuevas, L. Grams, J. Marins, M. Sillero-Quintana. "Skin temperatura differences between aerobic and anaerobic training". (Spain/Germany/Brazil)
10:30 S2-1-4	H. Rossas, S. Rodrigues, A. Seixas. "Skin temperature changes over the medial gastrocnemius and total work during exercise". (Portugal)
10:45 S2-1-5	A. Seixas, S. Rodrigues, V. Soares, T. Dias. "Changes in skin temperature and thermal symmetry induced by a physiotherapy occupational task". (Portugal)

11:00 Coffe Break

11:30 Poster Session 3. Evaluation of exercise or of disorders of the locomotor system

P3-1	H. Honorato dos Santos, Y. de Araújo Silva, B. Herculano dos Santos, J. de Almeida Ferreira. "Thermographic analysis of the anaerobic exercise post-recovery by cold water immersion". (Brazil)
P3-1	A. Seixas, V. Häussler, Monteiro; R. Vardasca, J. Gabriel, S. Rodrigues. "Skin temperatura is correlated with symptoms in patients with patellar tendinopathy". (Portugal)
P3-2	J. Alencar, M. Freire, R. Cardoso, J. Ferreira. "Thermographic changes in workers with shoulder disorders", (Brazil)
P3-4	J. de Almeida Ferreira, U. Franco de Oliveira, L. Caldas Araújo, B. Herculano dos Santos. "Thermographic profile of the hamstring muscles during static stretching" (Brazil)
P3-5	J. de Almeida Ferreira, B. Herculano dos Santos, Y. de Araújo Silva, U. Franco de Oliveira. "Thermographic analysis of the effect of different modalities of exercise: Aerobic and eccentric exercise". (Brazil)
P3-6	C. De Barros Fernandez Nogueira, C. Vicari Nogueira, M. Brioschi, N.Ribeiro. "Case Studies – How Thermography Can Assist Clinical Examination In Various Stages Following Trauma." (Portugal/Brazil)
P3-7	J.I. Priego Quesada. "Core and Local Skin Temperatures During Aerobic Cycling Exercise" (Spain)

12:15 Session 3.2. Biomedical Applications. Pain syndromes of the locomotor system

12:15 S3-2-1	D. Boguszewski, J. Adamczyk, A. Slupik, D. Bialoszewski. "Using thermovision in evaluation the effect of isometric and classical massage on selected physiological and biomechanical parameters of lower limbs". (Poland)
12:30 S3-2-2	J. Gabrhel, Z. Popracová, H. Tauchmannová, Z. Chvojka. "Painful leg syndrome in thermal, ultrasound and X-Ray imaging" (Slovakia).
12:45 S3-2-3	M. Leal Brioschi, E. Borba Neves, V. Machado Reis, G. Galindo Reisemberger. "Thermographic evaluation of risk factors for hip pain". (Brazil)
13:00 S3-2-4	I. Rossignoli, M. Sillero-Quintana, A. Herrero. "Infrared thermography and shoulder pain in wheelchair users". (Spain)
13:15 S3-2-5	M. Leal Brioschi, E. Borba Neves, V. Machado Reis, G. Galindo Reisemberger. "Thermographic evaluation of lateral epicondylitis in patients with fibromyalgia syndrome". (Brazil)

13.30 LUNCH (Cafeteria INEF

14.30 Closing Ceremony and EAT Awards

Abstracts - Oral presentations

Session 1.1. Technical Applications. Hardware and software solutions for IR imaging

FROM THERMAL RADIATION AT SKIN SURFACE TO IMAGE TEMPERATURE VALUES

R. Vardasca[1, 2], J. Gabriel[1]

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[2]Medical Imaging Research Unit, Faculty of Computing, Engineering and Science, University of South Wales, Pontypridd, United Kingdom

Revised version of 15.04.2015

In order to obtain thermal images of the human body, an infrared camera is needed and following specific guidelines are advised to obtain a surface temperature map of the screened area of the human skin.

Intrinsic values that each camera has and allow a quantitative measurement are the thermal range, normally the used in medicine are within the values from -20°C to +120 °C, the size of sensor array, there is a large variety (e.g. 80x60, 120x120, 320x240, 640x480 and 1024x1024), the accuracy, typically ±1% or ±2% of the overall reading, and the thermal sensitivity, value that can range from <70mK to <20mK, depending in the camera model.

An important physical property that each object has in its surface is the emissivity, which represents the ability of an object to emit thermal radiation at a temperature above absolute 0. This value in human skin can vary from 0.975 to 0.983, being the common value used 0.98 in cameras configuration.

All the previous aspects are very important to perform a correct thermal recording and to define the amount of digital space needed for a single thermogram. A thermographic record becomes permanent when it is saved to a digital support, and depending in the camera manufacturer and model it is stored with a specific codification (usually 12 or 14 bit), normally into proprietary data files or radiometric jpeg files. Proprietary file formats can only be opened through proprietary software allowing image processing and analysis. Jpeg radiometric images can be viewed with any common image software but only processed and analysed using the proprietary applications provided by the manufacturers. Another aspect is most of the currently available applications for image analysis capture and analysis only run in Microsoft Windows operating systems, and those today have a smaller share of the computational users market, other operating systems such as Apple, Linux and most recently the mobile operating systems had grown considerably and a technological adjustment is needed to encourage new users into medical thermography and facilitate the life of the existing.

This research intends to provide an outlook in the physics underneath the calculation of temperature of each pixel based in the sensor perceived thermal radiation from an object surface. The forms of storage codification are also described and the main parts of the most common proprietary and jpeg formats demystified for the production of open source, manufacturer free, software packages for thermographic images processing and analysis.

This is an important step into integration of medical infrared imaging into the DICOM standard for medical imaging and to integrate it into the health information systems, pairing thermography with the other imaging modalities in the technological availability for daily practice.

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Blundell SJ, Blundell KM. Concepts in thermal physics. Oxford University Press, 2010

Jones BF, Plassmann P. Digital infrared thermal imaging of human skin. IEEE Engineering in Medicine and Biology Magazine, 2001, 21(6), 41-48.

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MOBILE MEDICAL INFRARED IMAGING DEVICES ON EMBEDDED COMPUTING PLATFORMS

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Original version of 28.1. 2015

INTRODUCTION. Historically infrared cameras were expensive and not dedicated to medical use. Consequently clinicians were forced to use devices that were in effect constructed for engineering applications rather than medicine.

With the advent of inexpensive embedded computing platforms and similarly vastly cost reduced small infrared imagers it is now possible to create devices targeted at the medical market that offer highly specialised and bespoke functionality.

METHODS. This paper outlines the concepts behind building such a device mainly from off-the-shelf hardware with only few specialised components. This modular concept can also be extended to software aspects such as operating systems, application software and hardware drivers. An example of an instrument constructed around this concept demonstrates how medicine specific requirements can be implemented on such a platform. In particular the paper focuses on the repeatability of measurements using live overlays of anatomical structures and landmarks, calibration issues, user assistance in targeting and focusing and imaging session guidance along standard protocols.

RESULTS AND DISCUSSION. While the advantages of designing such a modular device are obvious the approach also generates a number of drawbacks. The most significant disadvantage is the fast development cycle of industrial hardware and software modules used in such instruments. This can quickly render components out of date, unusable or no longer available.

CONCLUSION. Results obtained with the example instrument demonstrate high repeatability of measurements both in terms of positional accuracy and thermal performance. These properties make the instrument highly suitable for use in trials and in everyday clinical settings.

KEYWORDS. Thermography, dedicated camera, embedded platforms, software.

3D INFRARED THERMOGRAPHY SYSTEM FOR BIOMEDICAL APPLICATIONS

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Revised version of 15.4. 2015

Many pathological processes can have an influence on the temperature distribution on the surface of a human body, and in many cases, observable changes in surface temperature are noticeable much earlier than other clinical phenomena. Because of this, infrared thermography, as a method for functional diagnostics, is gaining more and more traction in various fields of medicine, science and clinical practice. Standard thermograms, obtained using conventional infrared cameras, are two-dimensional in nature. This significantly limits the precision of the measurement of surface temperature on objects of complex shapes, such as different parts of the human body. Additionally, two dimensional images of thermal distributions make it hard to identi- fy and select the characteristic areas of the human body (regions of interest or ROIs) for which we are interested in finding the presence or absence of anomalies in the temperature distri- bution. To overcome these limitations currently there are in development several methods for obtaining 3D thermograms by combining polygonal meshes describing the complex surface with 2D infrared images [1, 2].

In this work we present a 3D infrared thermography system that consists of two off the shelf depth sensors and two thermal cameras. The depth sensors provide geometric data about the subject under study; this data is then registered with the data obtained from the thermal cameras to produce a 3D model of the subject with a surface map of the temperature distribution. When compared to traditional 2D thermal images, the 3D thermogram produced by this system posseses several important advantages that greatly improve its accuracy.

The presence of spatial information about the subject allows us to more correctly transform the thermal camera reading into real surface temperature by taking into account any surface curvature. Additionally, our system uses the spatial information about the subject to select regions of interest independently from the temperature data, in contrast with systems using solely traditional 2D thermal images which must rely on the temperature data to attempt to select the ROIs; this is a flawed approach because any features visible on a thermal image don't always correspond to an anatomical feature. Finally, an important advantage of our system is that by using spatial information it is possible to select the ROIs automatically, which increases consistency and helps remove operator error.

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2. Grubišic I. Medical 3D thermography system . Periodicum biologorum 2011; 113, 401-406.

KEYWORDS: infrared thermography, medical imaging, 3D scanning

CUTANEOUS MEDICAL ANALYSIS THROUGH ACTIVE THERMOGRAPHY SUPPORTED ON A THERMAL MODEL OF THE SKIN

S. Sanchez-Carballido, M. Salas, A. De Castro, F. López

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Revised version of 26.03.2015

Active thermography consists on producing a thermal transient state in an object with internal structure and evaluates the surface temperature evolution with time using infrared cameras. This measured temperature will be affected by the thermal properties, internal structure, intrusions and anomalies of the analyzed object [1]. The different cutaneous anomalies will be expressed as local variation, superficially or in depth, of the thermal parameters of the surroundings. The active thermography analysis allows detecting these variations of the thermal parameters in depth between normal and wounded regions. For a maximum optimization of the experimental possibilities, and a good understanding of the experimental results, it is necessary a deep knowledge of the thermal processes produced in the experimented region during the transient state. Besides it is crucial taking into account the biological thermal regulation processes as blood perfusion or metabolic heat. Nowadays, existing models provide a good understanding of the thermal processes in the skin in the passive state (without thermal excitation), but an versatile and accurate thermal model of skin during active thermography experiments is still necessary to support the active thermography experiments preparation and to obtain significant results from a medical point of view.

Attending this need, a model based on finite element methods and focus on simulation the thermal behavior of the skin in active thermography experiments is proposed in this contribution. The model reproduces a three dimensional volume of the skin from epidermis to subcutaneous tissue (until 10 mm in depth). For definition of skin tissues thermal parameters, skin layer depth and human thermal regulation constants, previously published bibliographic data have been used [2-4]. By other hand the model considers all the active thermography contour conditions as thermal source, infrared spectral band, infrared detector, cooling conditions, etc. Good agreement between results from the developed model compared with results measured from experimental active thermography experiments performed on five volunteers without any skin wound will be presented. The results obtained in this research are an unavoidable preliminary step in the development of a reliable quantitative procedure of active thermography for detection and characterization (size, depth and nature) of skin injuries for medical diagnosis.

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IRI - IMAGEPRO©: A SOFTWARE TOOL FOR ADVANCED PROCESSING OF THERMAL IR IMAGING DATA

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Original version of 13.02.2015

INTRODUCTION. Thermal IR imaging is enjoying a second youth thanks to the advent of modern, high-resolution, affordable bolometric cameras. Scientists and technicians from a variety of fields aim to use thermal IR imaging but must pay the toll of poor availability of commercial software specifically developed for satysfing advanced needs of the users. For example, although thermal IR imaging works excellently for psychophysiology, no specifically-designed software is available for this purpose.

To overpass these limitations, we created IRI-ImagePro©: a software suite specifically designed for biomedical, psychophysiological and technical applications.

IRI-ImagePro© software is a Matlab-based user interface optimized for effective processing of thermal data for psychophysiology.

Specifically, IRI-ImagePro© allows:

- Calibrating the thermal imaging system;
- Managing triggering of recordings or events;
- Automatic soft tissue tracking, if needed, of the regions of interest in the field of view of the cameras; the tracking can be optimized for real-time processing;
- Automatic detection and identification of the regions of interest over the subject's face through multimodal integration of visible and thermal imaging;
- Multimodal rendering (visible and thermal) of the subject's face;
- Automatic estimation of the subject's temperature;
- Computation of descriptive statistical parameters for the temperature distributions of the regions of interest and variations among them;
- Quantitative comparison among successive or different recordings through morphing transformation and normalization of the recorded thermograms;
- Projecting temperature distributions on an anatomical body or dermatomes maps;
- Computing of breathing rate, eye-blinking rate; low and high frequency components of the thermal sudomotor response;
- Computing and visualizing of cutaneous perfusion rate change from thermal imagery.
- Management of multiple-cameras system on request.

In this work, the software is presented and tested on real-field applications.

KEYWORDS. Thermal IR Imaging, psychophysiology, emotion, human-machine interaction, intersubjectivity

ERROR DETECTION AND CORRECTION IN THERMOGRAPHIC IMAGES FOR TIME SERIES ANALYSIS IN DYNAMIC INFRARED IMAGING

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Revised version of 16.04.2015

Infrared thermography has been studied for its application in medicine. Since its invention, the scientific community has been trying to correlate surface skin temperature with underlying malignant diseases. A new emerging modality in modern breast thermography is dynamic infrared imaging when a series of thermal images are recorded during cooling or heating. One of the challenges this process has to deal with is the exact match of points across samples, that is, how to compare the same pixel locations representing the temperature at one specific point of the torso in the different images, for example, when the subject moves between shots, as the variations in images, even when slight, could affect a lot of data. The correspondence between points is not possible if the right procedure is not performed. The main difficulty lies in eliminating the movements of the subject due to voluntary and involuntary movement. This is not always possible using mechanical stabilization and movement can disrupt the surface temperature measurements. Additionally, the sensor could capture some data erroneously, by hardware failure or external factors. In this work, we present a framework to process a series of thermographic images captured with an infrared camera that allows the matching of each point across time in the image series. We also developed a technique for sensor error or register mismatch detection and correction.

Our dataset comes from a series of thermographic images of subjects without a diagnostic of cancer, who volunteered for the study. The images are registered with a geometric transformation technique using an affine transformation to find the correspondence between the images taken at a timed interval. This method, even when practical in computer vision problems, is not precise enough for serial thermographic images for medical purposes, given the characteristics of the samples (slight change in distance and pose between shots), however further steps can be made in order to correct the mismatched areas. Capture errors can also be corrected with values closer to the real ones. We detect the unnatural variations in temperature at each point across time and mark the pixels to be corrected in the next step. The paper provides a method to correct the error, consisting on a regression analysis, which is made in the set of points that had a natural behaviour and the information is used to fill the blanks in the mismatched points.

As a result, we have a more reliable sample closer to reality that can be used for further studies, such as a time series analysis, which is a proper approach for classification of suspicious points according to their cooling pattern. Even when linear regression would increase error over uncertain data, this approach could be useful when filling missing or erroneous values in a series of body temperatures captured across time. This technique ensures fidelity to the subject providing a more precise result, since the cooling process may vary from person to person. Our contribution is a detailed description of a correction process to maximize the quality of samples that leads to more reliable results in experiments and studies involving time series analysis on thermographic images.

KEYWORDS: Thermographic image processing, medical images, infrared thermography, breast cancer

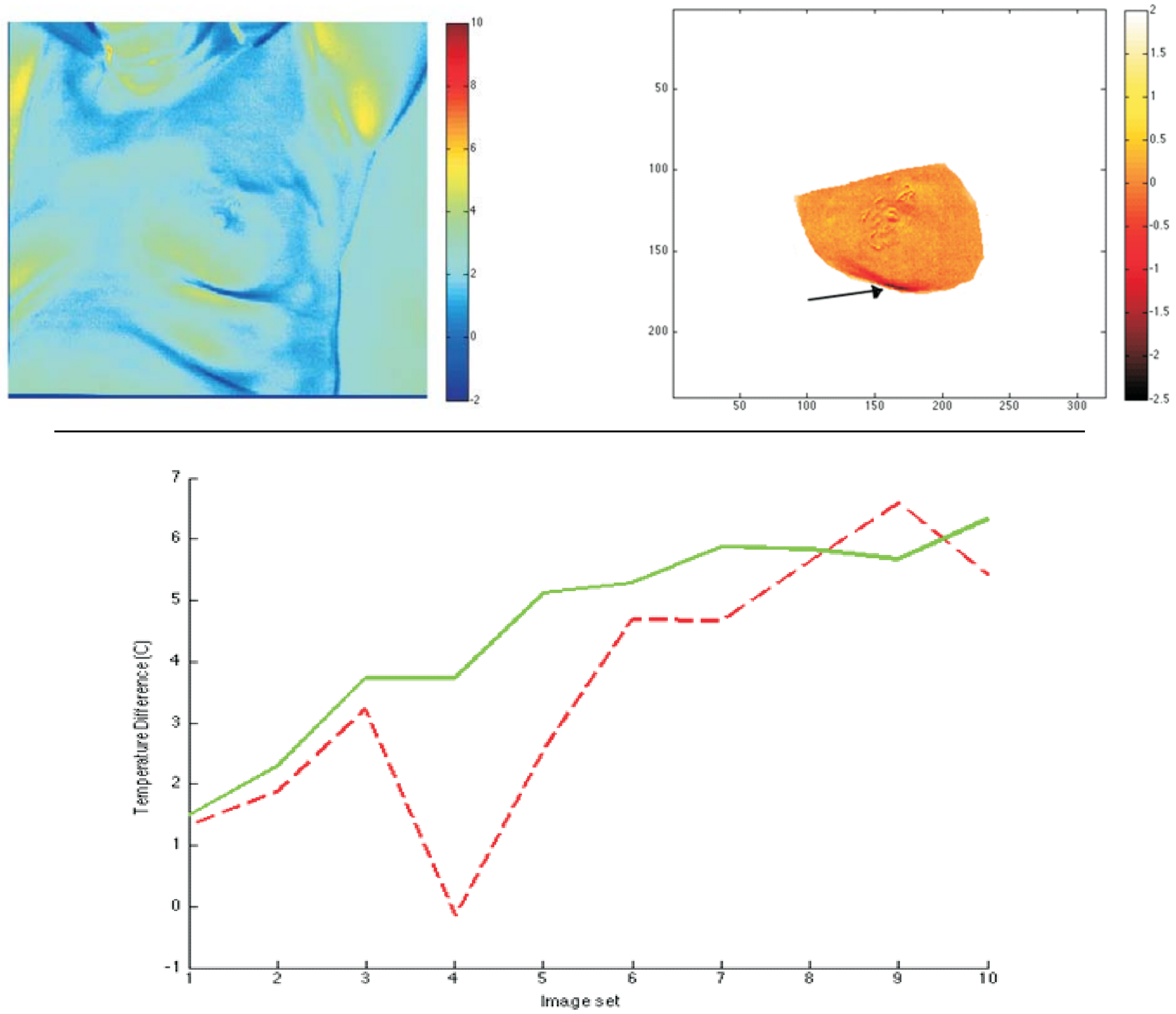

Figure 1.
A) The image shows the temperature difference between the first and fourth thermographic images in a series of ten captures of the same volunteer on a time interval of several seconds.
B) The breast is isolated, and the arrow points to a region where an error in temperature has been detected.
C) The graphic shows the difference of temperatures in a group of pixels corresponding to the complete set of thermographic images. An anomaly is detected on the fourth sample of the series (dashed line) requiring further error correction.

THERMAL ASYMMETRY CRITERION FOR ESTIMATION OF ABNORMALITY OF BREAST INFRARED THERMOGRAMS

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Breast cancer is one of the most common causes of death among women in the world. Breast infrared thermography has been emerging as a complement for X-Ray mammography in the detection of this type of cancer. The development of high resolution infrared cameras allows more complex studies focusing on early diagnosis of breast cancer via infrared thermography and image processing to be carried out. At this point, the state-of-art does not allow us to use thermography to make definite cancer diagnoses, but based on determined criteria it does permit us to declare whether or not a case is suspicious. One of the proposed criteria for this is the presence of thermal asymmetry. It is nearly impossible to have a tumour symmetrically in both breasts. The heat patterns occur asymmetrically. Hence, different temperature data distribution in each breast is expected. The objective of this paper is to propose and prove a thermal asymmetry criterion estimation.

A method to compare statistical information - specifically, temperature data distribution- for the breasts was prepared. As shown in figure 1, both breasts are divided into sections, depending on the grid size selected. Then, sections are labeled and compared with their respective contralateral section. The method is as follows: (1) draw a line of symmetry as a perpendicular that crosses the line connecting nipple centers in the middle; (2) select the regions of interest (ROIs) for right and left breasts; (3) divide each ROI into subregions; (4) label each subregion and compare the temperature data distribution in contralateral subregions using a Kolmogorov-Smirnov test; (5) Results are presented as a matrix of true and false values for each region, where true corresponds to the presence of asymmetry for that region. The measure of asymmetry is then taken to be the ratio asymmetric subregions to total number of subregions. Several grid sizes are compared. The approach proposed is to analyze thermograms of women who have been diagnosed with cancer and "healthy" women, and compare the asymmetry ratio obtained from both groups to verify if this estimation is capable of differentiating cases with cancer from cases that are not suspicious.

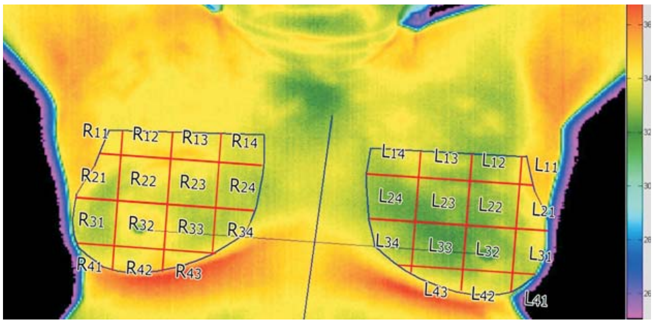

Figure.1
4x4 grid for breasts comparison and labels.

KEYWORDS: Breast cancer; infrared thermography; thermal asymmetry.

ESTIMATING THE NORMAL BREAST REFERENCE TEMPERATURE IN YOUNG WOMEN: A THERMOGRAPHIC EQUATION.

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INTRODUCTION. Thermography is a non-ionizing method that has been proposed for functional assessment and following abnormalities of the breast. However, thermal imaging can be influenced by the patient's core and environment temperature where they are being captured. The objective of this study was to develop a mathematic equation to predict the thermal behavior of the breast in young healthy women, independent of changes in ambient and core temperatures.

METHODS. Four healthy young asymptomatic women (mean age 16.9±4.7 years) were daily evaluated for three consecutive menstrual cycles. It was measured by frontal view infrared thermography the mean global temperature of both breasts (?br), maximum temperature of the inner canthus of the eyes (as an indirect reference of core temperature, ?c) and room mean temperature (?r). To analyze the thermal behavior during the menses cycle the breasts temperatures were normalized to core and room temperature by means of a mathematical equation.

RESULTS AND DISCUSSION. There were made 180 observations. The inner canthus of the eyes maximum temperature had the highest correlation with the breast mean temperature then compared with mean ambient temperature. The linear mathematical model obtained was ?br = 12.405 + (?c x 0.548) + (?r x 0.100). The proposed prediction model was able to elucidate 45.3% (adjusted R2) of temperature changing of the breast with room temperature (Figure 1). And this could be accepted as a way of estimating the reference temperature of the breast at different ambient temperatures.

CONCLUSION. The average temperature of the breast in healthy young women had a direct relationship with the maximum inner canthus of the eyes and mean room temperature and can be estimated mathematically. This study suggests that an equation could be used in clinical practice for estimating the normal breast reference temperature in young women, regardless of the day of the cycle, and thus assists in evaluation of other anatomical studies.

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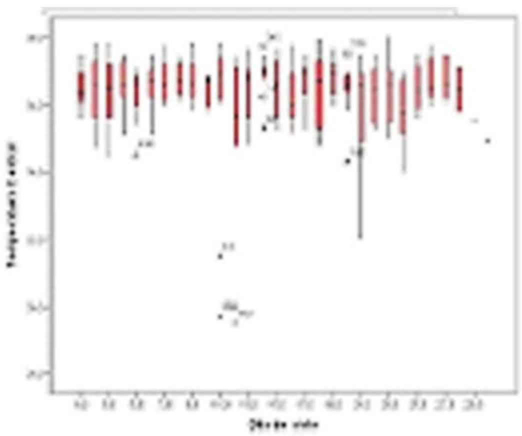
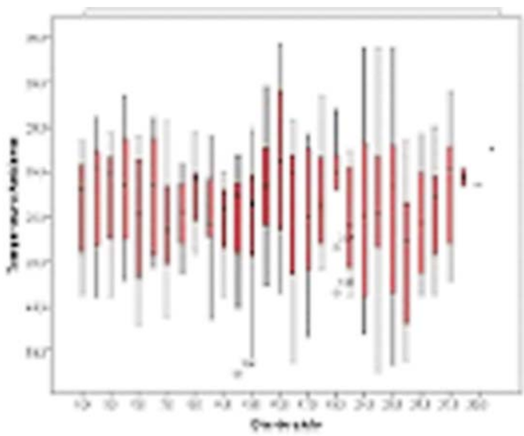
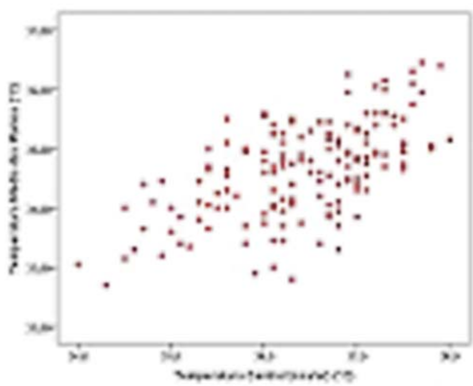
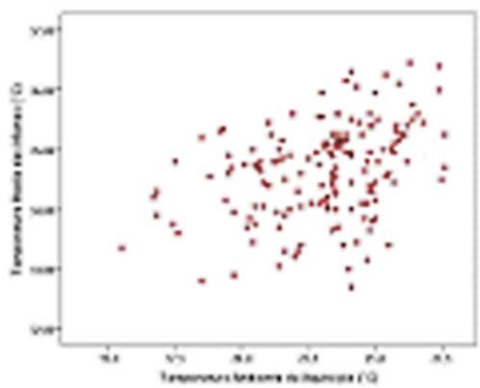
KEYWORDS. Breasts; Temperature; Metabolism; Thermography; Menses







Correlação Pearson = 0,605 p<0,01



Correlação Pearson = 0,368 p<0,01

INFRARED IMAGING EVALUATION OF PARAVERTEBRAL BLOCK FOR MASTECTOMY CASE REPORT AS A START FOR EVALUATION OF EFFICACY STUDY.

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Thoracic paravertebral block (TPVB) is the technique of injecting local anesthetic adjacent to the thoracic vertebra close to where the spinal nerves emerge from the intervertebral foramina. It is effective in treating acute and chronic pain of unilateral origin from the chest and abdomen [1-5]. This technique causes pain relief with pulmonary function preservation and great hemodynamic stability [6-8].

A study was conducted comparing TPVB using single-level technique and multi-level technique. 30 patient presented for elective mastectomy were enrolled and randomized into two groups: one (S) (n=17) that received single-level TPVB at Th3, and other (M) (n=13) received multi-shot technique at Th2, Th4, Th6. We used 0.5% ropivacaine with addition of fentanyl in total volume 0.3 ml/kg IBW (ideal body weight), divided to 3 equal parts in second group.

Before TPVB an 20 minutes after we recorded an infrared image of the breast region using a FLIR i7 infrared camera to detect of temperature changes caused by blocking sympathetic nerve fibers. Three regions of interest (upper, middle and lower) were defined at the lateral aspect of the breast to evaluate changes of temperature in dermatomes corresponding to the blocked spinal nerves [8].

Table 1 shows the distribution of temperature changes in the 3 regions of interest. In group S no temperature change in any ROI was observed in 7 patients. 6 patients presented with in temperature increase in all regions. In group M (n=13), a rise of temperature in all 3 ROIs was detected in 6 patients, but no temperature change in any ROI was detected in 3 subjects only.

		Upper ROI		Middle ROI		Lower ROI	
	n	t↑	t ↔	t↑	t ↔	t↑	t ↔
S (single level)	17	10	7	8	10	9	8
M (multiple levels)	13	6	7	10	3	10	3

t↑=temperature increase t ↔=temperature unchanged

We observed no differences in drug usage during anesthesia and similar low pain levels after surgery in both groups. Groups appeared to be to small to achieve statistical significance.

In conclusion similar pain reaction in both groups confirms previous investigations [8-12]. We assume that raise of temperature in middle and lower region rather than the upper one is related to a caudal spread of anesthetic drug [13-15]. The relatively higher number of patients with temperature increase in M group may be caused by more complete nerve blocks than achieved in the single-level technique.

The study will be continued for more reliable data.

KEYWORDS. Paravertebral block, mastectomy, analgesia, infrared image, monitoring

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PRE-, INTRA- AND POSTOPERATIVE USE OF DYNAMIC INFRARED THERMOGRAPHY (DIRT) IN BREAST RECONSTRUCTION USING A FASCIO-CUTANEOUS PEDICLED PERFORATOR FLAP

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INTRODUCTION. Thoracodorsal artery perforator (TAP) flaps are fasciocutaneous flaps based on perforators from the thoracodorsal vessel axis and are harvested from the upper back. The TAP flap is frequently used in breast reconstruction often in combination with a breast implant to create enough volume. Survival of the flap depends on the perfusion of the flap through the selected perforator. Perforator selection is frequently based on CT angiography and Doppler ultrasound. Based on our experiences on the use of dynamic thermography (DIRT) in breast reconstruction with the voluminous abdominal DIEP flaps (de

Weerd et al. 2011) we designed a study to evaluate the use of DIRT in TAP flap breast reconstruction.

METHODS. Six patients scheduled for TAP breast reconstruction underwent preoperatively CT angiography and Doppler ultrasound for perforator selection. Preoperative DIRT was performed using a desktop fan at room temperature over the donor area of the flap for 2 min. The rate and pattern of rewarming was recorded for 3 min. Thermal images were recorded with a FLIR SC645 infrared camera mounted on a stand enabling the camera to be positioned directly above the area of interest. Images were stored on a laptop PC for later processing (FLIR Research IR). Intraoperatively recordings were made during the whole surgical procedure. The images were visible to the surgeon. The area of interest before and after dissection as well as at the end of the surgical procedure was exposed to a mild cold challenge using a metal plate at room temperature in contact to the skin surface. Postoperatively similar DIRT procedures were performed on day 1, 3 and 5, now with the transposed flap as the area of interest.

RESULTS AND DISCUSSION. Preoperatively, DIRT provided adequate information on the location of the selected perforator. Analysis of the rate and pattern of rewarming of the hot spots allowed selecting a powerful perforator. All selected perforators with DIRT were associated with an audible Doppler sound. Although in some patients perforators could be identified on CT angiography, this was not in all cases possible. Intraoperatively, torsion, kinking as well as venous congestion could be identified with DIRT. After dissection of the flap the location of the first appearing hot spot could be associated with the area where the perforator entered the flap. Postoperatively, DIRT revealed that the reperfusion of the TAP flap is a dynamic process. Flaps that developed perfusion problems had a rewarming pattern that could indicate such perfusion problem.

CONCLUSION. The use of DIRT in the preoperative, intraop erative and postoperative phase of TAP breast reconstruction provides the surgeon with valuable information, not only eliminating the use of ionizing radiation through CT-angiography but also helping to reduce operative time.

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KEYWORDS. TAP flap, thermography, surgery, fascio-cutaneous pedicled perforator flap, DIRT.

MICROVASCULAR IMAGING FOR THE INTRA-OPERATIVE EVALUATION OF BOWEL PERFUSION.

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INTRODUCTION. Good bowel perfusion is key for a good outcome in colorectal resections. Bowel perfusion is currently assessed intra-operatively only by investigation of clinical signs such as pulsatility and bleeding. Modern microvascular technology could have an important role in this context. [1].

METHODS. The literature was reviewed using the PubMed database to determine the current role of microvascular technology in colorectal resection surgery. Main search terms included: microvascular, colorectal resection, and anastomosis. Advantages and disadvantages of each technique were considered. Key criteria included: cost of equipment and consumables, need to use contrast agents, speed of data acquisition, ease to use in the operating theatre environment, possibility to perform imaging measurements. Technologies that had only been investigated in clinical applications other than colorectal resections, but could hold promise for this application, were also considered. All study types were included. Thermal imaging (TI) and laser speckle contrast imaging (LSCI) were identified as the two technologies holding most promise against the above criteria. A specific protocol for the use of this instrumentation in an operating theatre was developed, taking into account Infection Control, Electrical Safety, and time constraints.

RESULTS AND DISCUSSION. Two main groups of technologies were identified from the literature: those that perform single point measurements, and those that perform imaging measurements. Single point measurement techniques included near infra-red spectroscopy and laser Doppler flowmetry. These have been both investigated in animal models and in humans with promising preliminary results. However, considering the complexity and the heterogeneity of the bowel micro-circulation, the limitations of single point measurements appear obvious. The most common imaging technique in the literature is near-infrared angiography (NIR-AG). NIR-AG has also shown promising results; however, it requires expensive instrumentation and the use of a contrast agent. The possibility to use TI and LSCI during colorectal resection surgery has been investigated in this pilot study with promising results. LSCI and TI are not as expensive as other techniques, they are contactless, and do not require contrast agents. The protocol developed followed the requirements for Infection Control and Electrical Safety set by The Newcastle upon Tyne Hospitals NHS Foundation Trust. Measurements could be performed within less than 10 minutes, in the context of a 4-hour procedure.

CONCLUSION. Thermal imaging and laser speckle contrast imaging have been identified as two technologies holding some promise for the intra-operative assessment of bowel perfusion during colorectal resection surgery. A suitable measurement protocol has been developed. A pilot study is now underway to evaluate the potential clinical value of these two techniques. [2].

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KEYWORDS. bowel, colorectal resection, microvascular, perfusion, thermal imaging..

INFRARED THERMOGRAPHY IN PLASTIC SURGERY: A COMPARATIVE PRE- AND POSTOPERATIVE STUDY IN DIFFERENT TECHNIQUES OF ABDOMINOPLASTY

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INTRODUCTION. Abdominal plastic surgical techniques have changed many times since its beginning. A revolution started in the eighties with the liposuction introduced by Illouz (1980) and his posterior abdominoplasty without undermining. Actually, abcominplasties without undermining have been developed.

Infrared Thermography is a method that captures heat alterations of the skin within the infrared spectrum, with a special camera, making possible the study of the skin vascularization and function. In medicine thermography has been developed and studied by many authors (e.g. Brioschi (2010).

However, there are few references in the literature about thermographic studies of the skin microcirculation when comparing different surgical techniques.

METHODS. We studied with infrared thermography 4 groups of 10 patients, before and after: 1) Lipoabdominoplasty (LAP), 2) Abdominoplasty with preservation of the superficial fascia (APSF) and 3) Modified Classic Abdominoplasty (CAP), with little undermining and 4) control (CT).The room temperature was 20º C. The examination was made before and after the surgeries and perforated vessels were marked and compared.The results were evaluated quantitatively (number of vessels) and qualitatively (thermogram pattern) with the control group and between the groups. The results were analyzed statistically and qualitatively (spectrum of the color).

RESULTS AND DISCUSSION. In the prospective study the 3 groups were homogeneous with the control pre operatively ($F=1,6683$ and $p = 0,1910$) and heterogeneous post operatively ($F = 22,0968$ and $p = 0,0000$). This means that the surgery was the agent of the changes.

The LAP patients had the biggest preservation in number of perforated vessels (mean 11,8 before surgery and 10,8 after surgery). They also had the best quality of thermographic images and were the only group that could be compared with the control (mean 12,1), with low rates of complications. They maintained 91,52% of the perforated vessels.

The APSF group had few complications too, compared with LAP group. They maintained a reasonable thermoregulatory function (color spectrum), although the number of the perforator had de- creased, maintaining 65,46% of the perforator (mean 10,4 before and 6,6 after surgery)

The CAP group had the biggest destruction in perforator vessels and the worst thermoregulatory function, with the highest complication rate. They only maintained 49,01% of the perforated vessels in the post operatory (mean 10,2 pre and 5 post operatively).

CONCLUSION. Infrared thermography is an objective, simple and useful method for the evaluation of the abdominal skin vascularization and function. The preservation of perforator vesseles was best with the LAP techniques, and worst with the CAP technique.

The only group compared with the control was the LAP. Further studies are necessary to evaluate functional postoperative changes.

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KEYWORDS. Infrared Thermography, Abdominoplasty, Lipo- abdominoplasty .

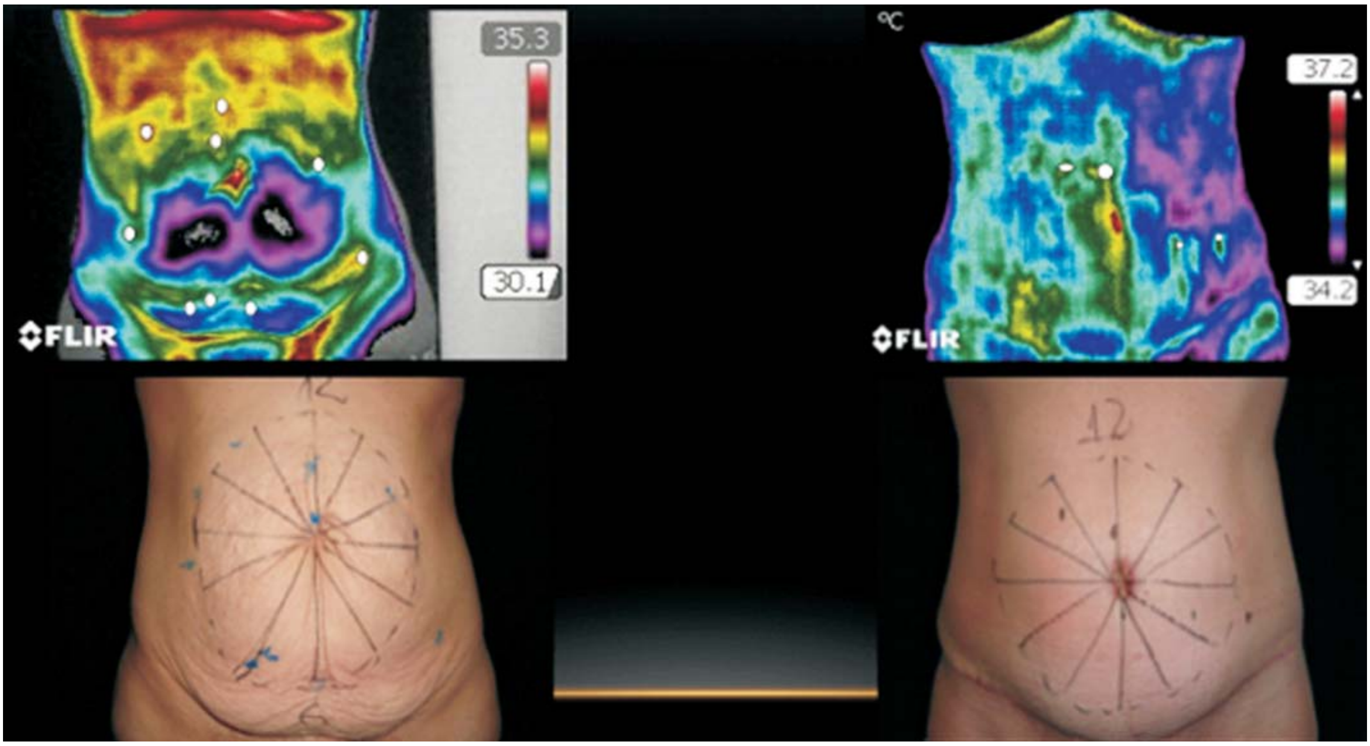

Figure 1: lipoabdominoplasty -LAP

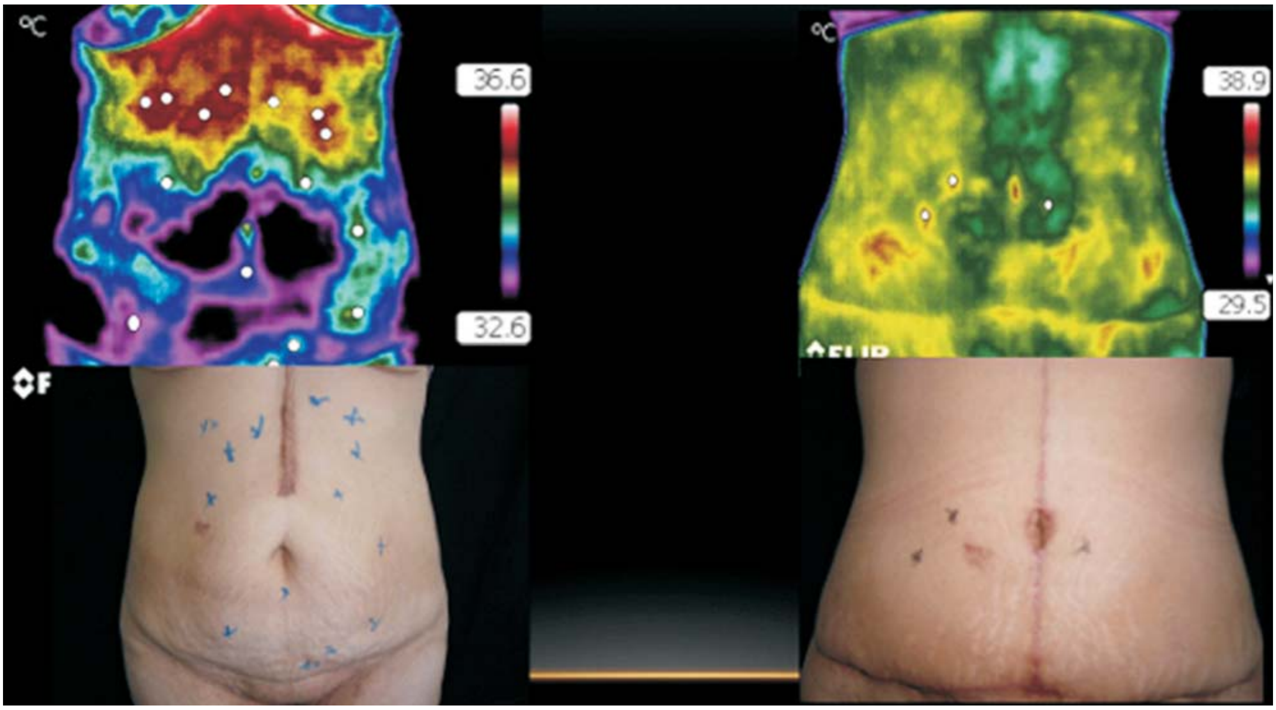

Figure 2:abdominoplasty with preservation of superficial fascia - APFS

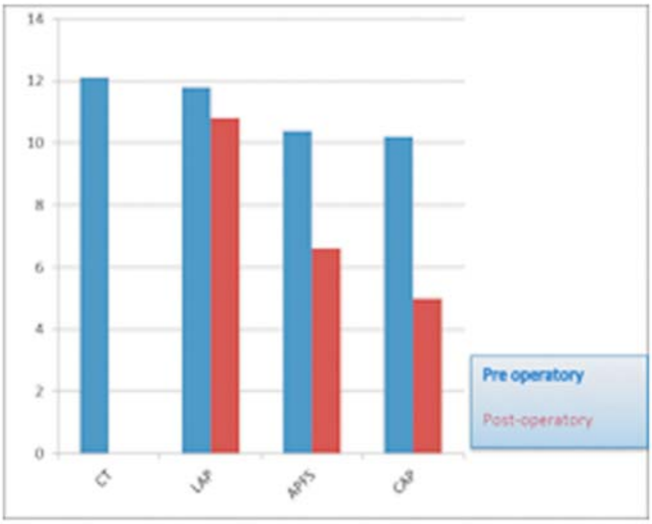

Figure 3:
Number of perforators prior and past surgery

THERMOGRAPHY PROVIDES INFORMATION ON THE OXYGENATION OF THE FETAL BRAIN IN THE FINAL STAGE OF CHILDBIRTH

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Revised version of 15.04.2015

INTRODUCTION. Local temperature determines the viability of tissue ischemia and hypoxia [1], and may be use for diagnosing hypoxia or ischemia [2]. The aim of this study was to investigate whether infrared thermography (IRT) can provide an indirect method of assessing oxygenation of the fetal brain in the final stage of childbirth.

METHODS. The study was conducted in 20 pregnant women with no signs of placental insufficiency (NEF) and intrauterine hypoxia of the fetus and 15 women with signs of NEF and low prenatal fetal resistance to hypoxia (Gauskhneht test). In addition there was a single case of a pregnant woman with an entwined cord around the neck and chest of the fetus. Infrared thermography was performed using thermal imager Thermo Tracer TH9100XX (NEC, USA) in the temperature range 26 - 36 °C. The temperature of the air in the delivery room was in the range 24 - 26°C. Mean temperature of the head was obtained from a region of interest [2].

RESULTS AND DISCUSSION. The head temperature of newborns in childbirth and immediately after ranged between 31.6and 36.1°?. In normal (20 babies) the temperature in the central seam in some newborns exceed the temperature of the skin over the bones of the skull on average by 2.8 ± 0.21°C ($P < 0.05$, $n = 20$). The temperature of the parietal part of the head were very similar in the absence of symptoms of NEF and low stability of the newborn to hypoxia (Gauskhneht test).

In 15 newborns with signs of NEF and low resistance to hypoxia there were significantly greater variations in the temperature on parietal part of the head. In 5 newborns we observed unusual temperature distribution on the skalp with local areas of hypothermia during the final stage of childbirth. The thermal images in such cases were normalised following oxygen therapy.

If oxygen therapy does not normalize to thermal images, we propose to initiate other life preservation procedures for a newborn with cranio-cerebral hypothermia, whilst the head temperature of the newborn should be monitored by thermal imaging until the onset of spontaneous pulmonary respiration.

CONCLUSION. IRT of the head of the newborns in the final stage of childbirth may be used to assess the degree of availability of oxygenation in the cerebral cortex of the fetus and to evaluate the effectiveness of resuscitation.

KEYWORDS. Thermography, intrauterin fetal hypoxia, injuries, obstetrics

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Session 1-3 Animal Applications with a focus on equine medicine

THERMOGRAPHY IN EQUINE MEDICINE

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INTRODUCTION. Thermography is an imaging technique which can detect body surface temperature changes across the horse which may indicate inflammatory, vascular or neurological disorders. Therefore thermography has been widely used in veterinary medicine in diagnosis of limb injuries including tendonitis, inflammation of the stifle, carpal and tarsal joints, and bucked shins [1]. For back abnormalities it has been applied in neuromuscular disease of the thoracolumbar region, muscular and spinous process inflammation of the thoracic vertebrae, subluxation of the third lumbar vertebrae, supraspinal and interspinal ligament inflammation and intervertebral inflammation of the thoracolumbar vertebrae (2]. During the healing process thermography can quantify the regression of inflammation and monitor the efficacy of anti-inflammatory medication (3]. Thermography can also indicate areas of inflammation that could account for a decreased level of sporting performance, determine a source of pain or detect musculoskeletal overloads. It also plays a role in equine rehabilitation for the detection of upper limb muscle strain, muscle inflammation, croup and caudal thigh myopathy. Once abnormalities have been detected, thermography can determine the effectiveness of different types of therapeutic and rehabilitation applications.

The proper use of thermography to evaluate surface thermal patterns requires a controlled environment and rigorous adherence to an imaging protocol in order to eliminate errors of interpretation. Indoor thermography measurement standards have been established in equine veterinary practice (4]. To enhance the diagnostic value of thermography the examination room should be: maintained at the recommended ambient temperature, sheltered from the sunlight, and with no air draughts. Examination should be performed on the horse at rest and before training, to avoid the changes in body heat balance and blood circulation related to working muscles. This review considers the evidence for the utility of thermography in equine practice, and presents guidelines for correct thermographic examination.

KEYWORDS. infrared thermography, equine medicine, diagnosis, injury.

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THERMOGRAPHIC EVALUATION OF RACEHORSE PERFORMANCE

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Revised version of 06.04.2015

INTRODUCTION. The study was aimed at identifying the key thermographic diagnostic areas essential for monitoring the effect of training on racehorses.

METHODS. The study involved monitoring 15 racehorses in 13 imaging sessions over a period of 10 months. Temperature measurements were made at a total of 46 regions of interest (ROIs) at the distal parts of the limbs (40 ROIs) and the back (6 ROIs) using an Infratec Variocam HR infrared camera (640 x 480 pixels; spectral range, 7.5-14 μm). In order to account for the influence of ambient temperature on each ROI measurement, values were adjusted to a constant ambient temperature of 12°C, estimated using regression analysis. The horses in the study were divided into two groups based on the value of success rate in racing competition. The average prize won by horses competing in the 2012 season was €400/race. "Successful" horses (n=3) earned > €400/race, whereas "unsuccessful" horses (n=12) earned < €400/race.

RESULTS AND DISCUSSION. During the research period none of the horses were identified as injured by routine veterinary investigation. Over the 10-month study period, the ambient temperature in the stable ranged between 2.8°C and 22.7°C. Successful horses had significantly warmer adjusted ROI temperatures than their less successful counterparts at both carpal joints, the 3rd metacarpal bones, the left fetlock joint, the left front short pastern bone, the left tarsus joint, and the caudal part of the thoracic vertebrae.

CONCLUSION. The study tested a protocol for recording body surface temperature in racehorses which was shown to increase reliability by adjusting for variations in ambient temperature. When analyzed on the basis of sporting performance, the protocol identified 14 ROIs that were associated with superior performance, the majority of which were at the limbs on the left side.

KEYWORDS. Thermography, racehorses, sport performance, training.

INFLUENCE OF BREED, AGE, GENDER, TRAINING INTENSITY LEVEL AND AMBIENT TEMPERATURE ON BACK AND FORELIMB TEMPERATURE IN RACEHORSES.

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Revised version of 06.04.2015

INTRODUCTION. A previous thermographic examination of racehorses identified thirteen important regions of interest (ROIs) at the back and forelimbs for monitoring the impact of training (1]. However, that study did not consider the influence on ROI temperature of breed, age, training intensity level or gender.

METHODS. The present study adopted a multivariate analysis approach to determine whether the aforementioned factors, along with ambient temperature, significantly influenced ROI temperature in the key body regions of racehorses. Thermography measurements were obtained from 53 clinically healthy racehorses (34 mares, 19 stallions) of three breeds (27 Polish Half Breed; 11 Arabian; 15 Thoroughbred), aged 2-4 years. All horses were trained for flat racing at Partynice Race Course. Horses were trained in 3 training intensity levels: light, medium and high. Each horse had thermography performed up to 13 times during the racing season.

RESULTS AND DISCUSSION. Backward stepwise multiple linear regression indicated that ambient temperature and breed contributed significantly to the model explaining the temperature of all 13 ROIs. In addition, training intensity level contributed significantly to the model only at the caudal part of the thoracic vertebrae, the lateral aspect of the left third metacarpal bone, and the lateral and medial aspects of the left fetlock joint. Neither gender nor age contributed to the model significantly at any ROI.

CONCLUSION. Our data suggest that ambient temperature, breed and training intensity level affect racehorse body surface temperature at some areas of the back and forelimbs.

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KEYWORDS. Infrared thermography, racehorses, training.

INFRARED THERMOGRAPHY - NEW CONCEPTS FOR REFINEMENT AND REDUCTION IN ANIMAL USE FOR TESTING OF BIOLOGICALS

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Revised version of 10.04. 2015

INTRODUCTION. Technical developments in high resolution infrared thermography (IR) provide further prospective opportunities for their use in biomedical research. Several. new experimental settings to reduce the burden in animal experiments by IR-thermography were recently developed and presented: Safety testing of vaccines in pigs species, Pyrogenic assay on rabbits, detection of respiratory frequency and thermometry in Guinea-pigs, Mice model to investigate oral Ovalbumin allergy and Tumor modeling in nude mice

METHODS. RESULTS AND DISCUSSION. Vaccination of pigs with some vaccines causes a significant increase of the surface temperature at the vaccinated side, indicating a high reactivity. IR-thermography to replace pyrogenic assay on rabbits underlies a higher variability, comparing to rectal thermometry. Thus, only pronounced pyrogenic activity can be detected by this method. Thermal studies in guinea pigs are helpful in monitoring the decrease of body temperature. However, thermoanalysis of skin reactivity is lesser recommended. Mice model to study clinical aspects of food allergy seems to be a prospective application in thermal monitoring. Evaluating the tumor status in nude mice by IR-thermometry allows earlier detection of efficacy in therapeutic intervention and provides the opportunity for advanced human endpoints.

CONCLUSION. IR-thermography holds the potential to reduce pain and discomfort of animals involved in biomedical studies. Additionally, more qualified research data could be obtained. Methodological limits are related to peculiarities of animal physiology, like fur, skin thickness and metabolic properties in small laboratory animals (1,2]. .

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Session 1-4 Biomedical Applications History and Future of Infrared Imaging

HUMAN SKIN TEMPERATURE MEASUREMENT BASED ON RADIOMETRY- A HISTORICAL REVIEW

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Revised version of 15.04.2015

INTRODUCTION. Although Herschel detected infrared rays by using mercury thermometers when he measured the temperature of each of the spectral colours, mercury thermometers are not sensitive enough to register the compared to sunlight weak heat radiation of human skin. Seebeck`s detection of thermo-el ectricity that is the conversion of temperature differences directly into electricity allowed to design thermoelectric generators which could be used also as a thermocouple to sense heat radiation. A series of thermocouples form a thermopile. The Italian physicists Nobili and Melloni designed a thermopile which was able to register human heat radiation at a distance of 10 m.

METHOD: A literature search was performed in Google Scholar with the terms "radiometer", "bolometer", "skin temperature, " "human" and limited to the time period between 1860 and 1935, Original publications were retrieved and the following papers of interest are reported.

RESULTS AND DISCUSSION: In 1878, the German physiologists Christiani and Kronecker reported in a short paper their results of skin temperature measurements that have been obtained by collecting thermal radiation from the skin by a copper bowl and a thermopile placed in the focal plane of this collector.

In Zürich Masje and his tutor Eichhorst regarded thermopiles as non-reliable instruments for measuring heat rays. They adapted in 1885 Baur´s radiometer and used a grating of tinfoil of 20cm² area to measure skin temperature placing their bolometer at distance of 5cm to the skin. Masje conducted a number of experiments measuring the heat emittance of naked human skin in different anatomical regions, at various room temperature and after immersion of one arm in water of different temperatures. He found reduced heat radiation in cool skin and increased radiation from warm skin areas.

Stewart, who became later Professor of Physiology and Histology at Western Reserve University School of Medicine in Cleveland, USA, started 1885 in Manchester to repeat Masje´s experiments and published the results in 1891. Different to the investigators in Zürich, Stewart was more interested in the temperature of skin covered with clothes than in the surface temperature of naked men. He measured skin temperature by a thermistor and used a grating of lead paper for measuring the amount of heat radiation. He provided data about the behavior of skin temperatures of the undressed anterior surface of the left forearm at room temperatures of 18.4 or 20.2°C respectively. He reported a maximal decrease in temperature by 1.7 or 2.4°C occurring 27 or 20 minutes after onset of the experiment. The temperature remained constant about this minimum value for another 40 minutes when the experiment was broken off. He also measured skin temperature and heat radiation simultaneously and determined the difference between skin and room temperature. The greater the gradient from skin to air, the more heat radiation was detected.

In America, the first application of bolometers for skin temperature measurement was reported by astrophysicist L.B. Aldrich in 1928. The study is the result of grant given by the New York Commission on Ventilation for investigating the contribution of radiated heat from pupils to the temperature conditions in the classroom. Aldrich´s report starts with unpublished data from a pilot study of 1921 in which the astrophysicist and former co-worker of S. P. Langley conducted together with the physiologist F. G Benedict skin temperature measurement by a rubber-backed thermo-element and the Melikeron, a black-body like designed radiometer, in a nude subjects. The final study consisted of two parts, the first investigating 3 adults and 7 children in still air, the second 2 adults and 8 children exposed to no, moderate or fast air movements. The pilot study of Abbot found that temperature measurements based on radiometry overestimated skin temperature determine by the thermos-element on average by 1.9°C. In the final study, in which a new, improved version of the Melkerion was used, the agreement between the mean temperature obtained with both measurement devices was closer (difference 1.1°C). This study addressed also the contribution of convective cooling and radiation from the walls of the examination rooms on the accuracy of surface temperature measurements.

The German physicist Bramigk wrote in 1923 his thesis on "Measurement of heat radiation from the human skin" and designed together with the physician R. Cobet a radiometer which provided temperature values related to the heat radiation emitted from a 2.5cm² area, collected by concave mirror that reflected the heat energy to a thermopile generating thermoelectricity. The deviations of the galvanometer were calibrated with empirical data derived from cadaver skin, resulting in the temperature difference between skin temperature and temperature of the thermo-element. The later was displayed at a mercury thermometer. The sum of both temperature values are equal to the skin temperature under investigation.

However, radiometric skin temperature measurements were not accepted in clinical thermometry.

The American physiologist Hardy used a radiometer based on the design of Cobet & Bramigk to determine the infrared emissivity of skin. By establishing an emissivity of skin of 0.98 at wavelengths above 6 µm, he clearly identified the skin as the primary source of infrared radiation (not the clothes as Stewart argued) and rejected the idea of Masje that heat exchange with the environments affects skin emissivity.

CONCLUSION: It took about 75 years before the advantages of skin temperature measurements became vaguely recognised. Today, so called thermal signatures of health or disease, already proposed by Masje, are still under debate and far apart from acceptance in clinical medicine..

KEYWORDS. Historical review, radiometer, thermopile, skin temperature,.

TWENTY YEARS ACTIVITY OF THE CENTRE FOR CLINICAL THERMOLOGY OF THE MILITARY INSTITUTE OF MEDICINE IN WARSAW, POLAND

Anna Jung

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INTRODUCTION. The Centre for Clinical Thermology of Military Institute of Medicine was founded in 1995. The first investigations were performed in cooperation with team co-workers from Military Technical Academy of Warsaw (Prof.Józef Zmija) and The Inframetrix Company.

Our experience of thermography has been obtained through different studies and courses : in Boston (USA) Inframetrix Company, Glamorgan University (UK), Stockholm (Sveden) Flir Company. We had a long term cooperation with the University of Glamorgan, Pontypridd (UK) and Institute of Electronics, Technical University of Lodz(Poland).

During successive years of investigations we have realized several projects. In 2004 an English- Polish collaborative study was set up to identify and resolve the sources of pandemic fever using medical thermal imaging as a screening tool in airports. Next, a joint British and Polish research project resulted in the framework for an international database of thermal images of the human body. Recent studies undertaken have provided a framework for thermal imaging systems to be used as medical devices in population studies.

In a different study the role of infrared thermography in the diagnosis of inflammatory processes (abscesses, peridontal infiltration, inflammatory processes of the skin and surrounding tissues, ethmoid and maxillary sinusitis) were performed. In 2001-2003 we were co-workers in British Council Poland Project which aimed to establish a protocol for standardization of thermal imaging in medicine. In 2003 the member of our team (Piotr Murawski) was the author of the software programme " Image Therma Base" to capture and analyse thermographic images. A Further application concerned the application of thermography in the detection of pathology of the venous system and monitoring vasodilating processes. Lastly, the study of heat loss in patients undergoing general anesthesia during operations have been performed, using the inner canthus of the eye as a thermographic target for monitoring patient heat loss in surgery.

Results of our activities have been published in 67 papers and 119 congress presentations.Two books "Thermographic methods in medical diagnostics" by A.Jung, J.?uber (MEDPRESS, Warsaw 1998) and " A casebook of infrared imagine in clinical medicine" by A.Jung, J.Zuber, F.Ring (MEDPRESS, Warsaw 2003) were edited. " A casebook …" is during the second on-line edition in the UK by the Institute of Physics.

In 1998 the Polish Society of Thermology was established by our team of the Center Clinical Thermology of the Military Institute. Every year, connected with certifying course, annual conferrence of that society with national and international participants have been held. On two occasions we have hosted the organisation of EAT Congresses (Krakow, Poland 2003 and Zakopane, Poland 2006)..

KEYWORDS. Clinical Thermography, Military, Poland, Warsow.

PROPOSALS TO STANDARDIZE RESULTS IN HUMAN THERMOGRAPHY

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INTRODUCTION. One of the problems for a practical application of infrared thermography (IRT) is the great amount of factors affecting the skin temperature (Tsk) results. Apart from the intrinsic and extrinsic individual factors, both technical factors as the protocol and camera used and environmental factors as ambient temperature or humidity lead thermologists to obtain results with a wide range of variability, especially when data from different studies are considered. As an example, Ammer [1] recently published a comprehensive literature review about the temperature of the human knee obtaining quite variable temperature results on them. These differences make difficult to compare or discuss our results with others from different studies published in literature or even with our results obtained in another study.

METHODS. We propose several methods to standardize the measurements to allow comparing the results from different studies carried out under in different conditions.

RESULTS AND DISCUSSION. We propose several methods to standardize the measurements to allow comparing the results from different studies carried out under in different conditions.

a) Equations to estimate standard conditions values.

Ambient temperature has a direct relationship with the Tsk measured by IRT. In one of our practical studies [2] the Tsk of 31 ROI of the lower limb was tracked in 25 professional soccer players along a 6-weeks preseason. The training facilities did not allow us to control the environmental conditions in some of the 31 evaluations performed. The range of temperatures was between 18.0ºC and 31.0ºC with and average ambient temperature of 22.7ºC with a standard deviation of 3.1ºC. The correlation analysis showed an almost perfect direct relationship between the room temperatures (T-r) and Tsk measured (Tsk-m) in all the considered ROI for both the maximal (Tsk-m = 0,184 * T-r + 29,047; R2= 0.876) and averaged (Tsk-m = 0,198 * T-r + 27.757; R2=0.857) values.

Of course the validity of these equations could be easily criticized. A comprehensive study performed with appropriated randomized acclimatization periods to different ambient temperatures into a climate chamber for a big group of subjects could determine the effect of different temperatures and humidity levels on the Tsk registered by IRT and establish a more reliable set of equations to standardized the Tsk to ideal environmental conditions.

b) Proportions analysis.

Another possible solution for comparing our data with others registered with another camera or under different environmental conditions would be to calculate the proportions among the different ROI's. Considering that the relationship between both sets of data is linear and direct, the proportions between ROI's should keep always constant independently of the environmental conditions and the camera used.

With this approach we would deal with percentages of Tsk considering a reference value (or coefficients dividing the percentage by 100) instead of using the Tsk values registered by IRT.

c) Normalization of temperatures.

Normalization is a common technique to compare data from different sources. Knowing the average (?) and standard deviation (?) values of a set of ROI (even of the whole body), they can be used to calculate the standardized "Z" value of all the considered ROI when the data follow a Gaussian distribution. Those "Z" values will be comparable among different studies because they become independent of the general averaged temperature and their standard deviation.

In a similar way, Phantom model [3] was established after recording many anthropometric variables in a big sample of subjects (male and females). The result was a metaphoric and "unisex" model that could be used as a reference for any subject or group of subjects. The Z values are represented into a graph with the "0" in the middle of the "X" axis and the results are spots in the graph with their variable names in the "Y" axis. This graph allows detecting in a glance which variables are under- or over-normal values.

A "Thermal Phantom Model" would normalize and equalized the Tsk considering the average whole-body temperatures (or any other reference for Tsk or even core temperature) from both my subject and the Phantom. In that way, any ROI with an abnormal Tsk will be detected by comparing the results obtained with those of the equivalent ROI in the model. In the same way, the characteristics of the different groups (i.e. specialization asymmetries or specific warm or cold ROI) will be out of the normal ranges. However, the creation of this thermal Phantom model would be only possible through a coordinated multinational project in order to agree in the ROI to be included into the model, collect a considerable amount of data from people with different races, genders and ranges of age and, finally, obtain the averaged values and their standard deviations to insert in the obtained equations of the model.

CONCLUSION. They are many possibilities to compared and analyze our thermal data apart from the original data. Some of them have been suggested in this work, but only including these proposals in the upcoming software's for thermographic analysis will generalize their usage in the normal thermology practice.

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KEYWORDS. Thermal data, Data standardization, Data analysis, Data normalization

WHY THERMOGRAPHY?

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INTRODUCTION: I have attended and even hosted many Thermology related conferences in the U.S. My experience is that practitioners of thermography are motivated to attend these conferences not only to increase their knowledge of scientific research related to thermography, but also to seek the company and experience of others as it relates to their thermography businesses. This abstract addresses #3 of the EAT goal to improve the respective understanding between practitioners of thermology techniques. I assume "technique" in this context is referring to imaging technique; however, I would like to address understanding the technique of marketing thermology. I have found that this is a highly sought-out subject, as we can never have too many ideas for improving the financial rewards of hard work. If someone can take away new marketing ideas that help them understand the practical side that appeals to the patients and encourages them to attend for thermography, they would be indeed grateful.

TRADITIONAL MARKETING: Worldwide, we see promotional materials and websites, (which by definition is a method of reaching out to existing patients and the community), which are designed to explain what thermography is to the reader and how it's done:

- What it is and what it is not
- What it does
- What it sees
- How it works
- History of Thermography
- Published studies
- Frequently asked questions
- Providers of thermography equipment point to technical aspects and specifications

Also, when having a direct conversation with patients or potential clients, there is a tendency to refer to the above explanations.

CREATIVE THERMOGRAPHY PROMOTION: The largest and most successful companies are successful because they take a different approach. The theory is that people do not buy WHAT you offer or HOW you offer it (see the list above), they buy WHY you offer it. In general, people are least interested in what you offer, and that is traditionally how we promote.

To approach promotion with a new perspective, we must examine and identify for ourselves WHY we believe in thermography or WHY we believe it is beneficial to the patient. People are attracted to those who hold the same beliefs that they value themselves. If we lead with what we believe and not with what we offer, marketing experience has shown that we will attract more people. We can establish a relationship so the person feels a common connection, even in a few moments of conversation…..or in written material or the media.

Example: The iPhone has such a huge following because it is promoted as an experience. Apple believes we should have devices that make our lives easier and their customers believe that as well. It doesn't matter what Apple sells, their customers now just believe in what they do. Others have launched similar products with far less success; i.e. the Watch Edition.

Example: Mammography leads with the message that mammograms can "save your life"…not "we will compress your breast with radiation".

In thermography, we can, and should take the same approach. For instance, we do not have to compete with mammography, nor should we. Patients who believe strongly in mammography will not be convinced that there is any other reliable way for them to screen their breasts (the save your life message). However, someone who holds the belief that mammography will not save their life and there must be a safer way to monitor their health will respond to a statement that begins with "We believe….." (Why we do it).

We lead with our own belief and the WHY we offer thermography and then support that with the HOW and WHAT. Example: The Home page or the first page of the brochure should only express WHY and if they connect with that message, the following pages support that statement with the HOW and WHAT.

This simple marketing strategy has proven to be highly successful at the highest levels. This is an opportunity for brainstorming some WHY reasons that we offer thermography and what patients value most. We can put this strategy into practice and provide leadership to improve the worldwide respective understanding between practitioners of thermology (promotion) techniques and move our industry forward. There is an old saying "nothing happens until there is a sale". Thermographers need patients and we need more thermographers spreading the word about the value of thermography.

ANALYSIS OF THERMAL IMAGES TO QUANTIFY INFLAMMATION IN GRAVES' ORBITOPATHY

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Revised version of 13.04.2015

INTRODUCTION. Inflammation of the eyes is the hallmark of active Graves' orbitopathy (GO) as opposed to inactive GO. Medical thermal imaging (TI) can indirectly detect inflammation by assessing the level of temperature associated with the underlying inflammatory process. [1] However, raw images can lead to confounding results and further post-processing with an appropriate imaging analysis algorithm is required.

METHODS. This study included 17 GO patients with active disease and 13 sex- and age-matched patients with inactive disease, as defined by the Clinical Activity Score (CAS). TI measurements were performed following a cool-room tissue inflammation study protocol, with room temperature set to 18 °C. Patients followed precise pre-test instructions for at least 3 hours before measurement, avoiding facial cosmetics, talc powder, smoking, and caffeine. Room lights were dimmed during the measurement for the patient's comfort. A FLIR SC300 thermal camera was utilised to capture thermal images of the face of the patients. The emissivity parameter was set to 0.98 and the camera was powered up in the cool room for at least 2 hours prior to the measurement commenced.

To analyse the thermograms, seven regions of interest (ROIs) were drawn for each eye, as defined from a clinical atlas. Temperature mean and standard deviation from all ROIs were then combined in order to quantify the overall level of inflammation, spatial variability, and right-left differences in each patient. This algorithm was developed specifically for this application and defined five parameters. [2]

RESULTS AND DISCUSSION. All parameters were found to be higher in patients with active GO, compared to patients with inactive disease, with two of them reaching statistical significance at the 0.05 level. The best diagnostic performance was obtained using a binary logistic regression model that combined all five parameters. Details of the results can be found in [2].

In summary, the results from this study indicate increased overall temperature and right-left asymmetry in patients with active disease, which is consistent with the presence of inflammation. Future work should study the value of this technique for assessing GO patients prospectively, and its sensitivity to determine response to therapy. If successful, this technique could provide a more effective and cost-efficient pathway for the treatment of these patients.

CONCLUSION. This study has introduced a thermal imaging measurement protocol specific to GO, and developed a bespoke image analysis algorithm aimed to characterise and quantify the signs of inflammation in this patient group. The potential clinical value of this novel thermal imaging analysis algorithm for the assessment of patients with Graves' orbitopathy has been successfully demonstrated.

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KEYWORDS. Graves' orbitopathy, image analysis, inflammation, thermal imaging, thyroid eye disease..

EAR BODY TEMPERATURE IN HEALTHY INDIVIDUALS - A POPULATION STUDY ON SMALL CHILDREN TO ELDERLY ADULTS.

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BACKGROUND. During the past decade, measurement in the ear is introduced as an alternative to other methods. Ear thermometer can be set to either measurement without adjustment (ear mode) or adjusted to the temperature in the mouth, rectum or in the pulmonary artery. In clinical practice, these adjustments are used to compare temperatures at different sites, although this has no scientific basis. This causes confusion as body temperature, except for variations among individuals, also varies within individuals when measured in different places at the same time. Overall, there is a great deal of uncertainty in clinical practice for assessment of body temperature, especially when measured with an ear thermometer. The purpose of this study was to establish the normal variation of ear body temperature in non-infected children and adults.

METHOD. The study has a descriptive design. The sample consisted of 2637 non-infected children and adults in Jönköping County, Sweden (1598 (61%) female), divided into 736 (28%) children aged 2 to 4 years, 427 (16%) adolescents aged 10-19 years, 738 (28%) adults aged 20 to 65 years and 658 (25%) elderly aged 66 to 101years. The sample was recruited through child and school health care, orthopedic elective hip or knee surgery and senior housing. Individuals who had difficulty communicating and/or to read Swedish text or with ongoing infection were excluded. The temperature was measured in the right and left ear once with Genius 2 (Covidien, USA) or Thermoscan Pro, (Braun Gillette, Kronberg, Germany), in the ear mode. The thermometers were calibrated according to standard procedure by the medical engineering department at the county hospital before the study. Data were analyzed with mean + SD and Student's t-test. Significance level was $p < 0.05$.

RESULTS Mean right ear temperature was 36.4°C + 0.6°C. Related to age the mean ear + SD temperature was 36.4°C + 0.6°C in children 2 to 4 years, 36.5°C + 0.5°C in adolescents 10-19 years, 36.4°C + 0.6°C in aged 20-65 years, and 36.3°C + 0.5°C in elderly 66-100 years in ordinary housing and 36.6 °C + 0.6°C in elderly nursing home residents. Body temperature in adolescents and nursing home residents significantly differed from the other groups, $p < 0.001$.

Individuals with chronic heart disease, post stroke, impairment in physical functioning in daily life, and those on daily medication with paracetamol and similar drugs had a higher mean temperature of 0.1°C to 0.3°C, $p < 0.05$ to $p<0.001$. Also, individuals who had been taking paracetamol or similar drugs, reporting cycling/running the same day the measurement was performed, or had a sore throat or allergy the last three days had a higher mean temperature of 0.1°C to 0.3°C, $p < 0.05$ to $p<0.001$. The individual definition of fever, i.e.DiffTemp, was 1.4°C + 0.7°C, range -1.4°C to 5.1°C from normal body temperature (n = 1970) for all age groups, except adolescents who reported an increase of 1.1°C + 0.7°C as fever, $p<0.001$.When dividing to gender, men defined a higher increase as fever compared to women, 1.5°C + 0.7°C versus 1.3°C + 0.7, $p<0.001$.

CONCLUSION: This study clearly establishes that the traditional definitions of normal body temperature as 37°C should not be applied when the ear site is used. Ear body temperature seems stable over life, with some small differences related to age and chronic conditions. It also seems of value to consider symptoms of sour throat, allergy and medication with paracetamol and similar drugs and physical activity before measurement. Instead of cut-off values for fever, we suggest to use DiffTemp™, i.e. a difference of approximately 1.3°C in children and adults and 1.1°C in adolescents along with malaise, should be considered as fever.

KEYWORDS Ear body temperature, healthy individuals, children, adults, elderly, DiffTemp™, fever

LACK OF COMPLIANCE TO INTERNATIONAL STANDARDS ORGANISATION RECOMMENDATIONS FOR FEVER SCREENING WITH THERMOGRAPHY

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INTRODUCTION. In the last year, EBOLA infection has seriously affected West Africa, reviving concerns about screening in travelling passengers for fever at exit and arrival ports and airports. In 2008/9 two detailed reports outlined the minimal technical requirements for an infrared thermal imaging system for use in mass fever screening. The second document detailed the requirements for deployment, quality assurance and management of such systems.

METHODS. The recommended method is to have a radiometric and calibrated thermal imager positioned close to the face of the subject to record an image of facial temperatures. Specifically, the inner canthus of the eye is the prime target, with a minimum distribution of pixels to give the temperature, which is related to the internal carotid artery. It was noted that this required the subject to stand still briefly close to the camera lens in order to obtain meaningful temperature measurements. During the recent Ebola crisis, there have been many reports in the world press of fever screening in airports. Most of these are either showing images of the passengers walking at some distance and angle from the camera, or at worst only had held radiometers are being used. Many different target sites are being used including hands and arms, and most are at a distance from the subject.

RESULTS AND DISCUSSION. It is therefore not surprising that there is a reported lack of success in detecting fever in passengers, andthe situation is further confused by the relatively long latent period with EBOLA before fever symptoms can be found- up to 3 weeks. The ISO committee meeting in January at Dublin (Ireland) and again in June at Berlin (Germany) are revising and reinforcing the information and guidance for successful fever detection using a thermal camera. The results of the Warsaw Children's fever study forms part of the evidence that when correctly applied there is a clear separation between normal and febrile subjects when measurement at the inner canthus of the eye. Website examples showing subjects wearing spectacles must be informed of this ineffective methodology assuredly leading to failure of fever detection. It will also be necessary to reinforce the message that even high resolution imagers are unable to provide evidence of raised temperature at the inner canthi of eyes when used remotely from the subject and also set high at an angle to image a passing crowd. The ISO committee meeting in January in Ireland and again in Berlin in June are revising and reinforcing the information and guidance for successful fever detection using a thermal camera. The results of the Warsaw Children's fever study forms part of the evidence that when correctly applied there is a clear separation between normal and febrile subjects when measurement at the inner canthus of the eye. Website examples showing subjects wearing spectacles must be informed of this ineffective methodology assuredly leading to failure of fever detection. It will also be necessary to reinforce the message that even high resolution imagers are unable to provide evidence of raised temperature at the inner canthi of the eyes when used remotely from the subject and also set high at an angle to image a passing crowd. Regular literature searches are being made to trace any publications on studies on effectiveness / cost effectiveness of screening for fever. Only one Korean study has indicated a small percentage of passengers identified in an airport over 12 months with fever. Unfortunately, this study does not follow the ISO recommendations and is based on moving crowd surveillance, rather than individual temperature measurement, which is not recommended to be efficient for fever screening.

CONCLUSION. Efforts are now being made to strengthen the detail in the ISO documents for correct use, to widen the scope of the infectious diseases that are applicable, and update the reference section to include recent studies that confirm the correct procedures. There is a clear need for training the persons who are responsible for deployment of thermal cameras.

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KEYWORDS.Fever, temperature screening, thermography, EBOLA

THE DEVELOPMENT OF AN INFRARED THERMOGRAPHY PANDEMIC FEVER SCREENING COURSE FOR THE NON-RESEARCHER/SCIENTIST OPERATOR

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INTRODUCTION. The International Standards Organization committee for the "Deployment, implementation, and operational guidelines for identifying febrile humans using screening thermography" have provided standards for pandemic screening. The standards are based on the physical requirements of the equipment, the guidelines and procedures for the pandemic screening process, and the supportive research that validates this methodology. Despite internationally recognized standards, the screening processes currently deployed at most airports around the world are not in compliance with these pandemic screening requirements. Failure to implement research based, standardized procedures produces observations that are not reliable, not valid and only provide an illusion of a pandemic fever screening process.

Part of the failure of this pandemic screening process may be the basic understanding of the screening thermographic process. Several members of the Pandemic Screening committee has discussed the need for basic information and training modules that could be delivered on-line and would be written for the non-researcher/scientist operator. These materials would be available for public information and designated screening personnel could be tested on the material to receive a pandemic screening certificate..

METHODS. Modules may include:

1) The potential of a pandemic outbreak, the spectrum of pandemic infectious diseases;

2) Routes of transmission incubation and latent periods

3) The infrared imaging system basic principles of operation;

4) Utilizing infrared thermography technology for pandemic screening;

5) Pandemic screening plan and organization;

6) Pandemic screening procedures; and

7) References..

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KEYWORDS. Pandemic fever screening, infrared thermography, training modules.

THERMOGRAPHIC EXAMINATION FOR HYPOTHERMIA IN HIGH ALTITUDE

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Revised version of 13.04.2015

INTRODUCTION: Hypothermia is a critical situation in mountain climbing and in many cases is fatal. There is little knowledge on how the body reacts to cold exposure at high altitude. In this study we used thermography to measure temperature changes of the forehead and hands in climber's after they stop walking at high altitude.

SUBJECTS AND METHODS: The subjects were seventy-four climbers, forty-nine males and twenty-five females. The avergae age was 26.2±10.4 years. The subjects had walked for more than five hours in the mountains before arriving at a mountain lodge at an altitude of 2550m. Immediately after arrival the temperature of the forehead and dorsum of the hands were measured with a portable Infrared camera. Repeat measurement were made 5, 10 and 15 minutes after arrival.

RESULTS AND DISCUSSION: (1) The temperatures of foreheads and hands of the male subjects increased during the first 5 minute period after arrival, thereafter remaining stable. On the other hand, the forehead and hand temperatures of the female subjects did not change in the first five minutes. In the next five minutes, the temperature of their hands decreased sharply, while there was no significant change of the forehead temperature. (2) The temperature of foreheads of male and female subjects measured in normothermia was not changed in the 15 minutes. The temperature of hands of the same subjects tended to increase in the first 5 minutes, and it decreased in the next 5 minutes. On the other hand, the temperatures of foreheads and hands of male and female subjects measured after a prolonged exposure to cold environment at arrival increased in the first 5 minutes, and did not change after that.

It is well known that the heat production of the human body at rest is different from that during physical activity. Skin temperature seems to change when the climbers stop walking. It seems that the climbers subjectively feel "hot" just after arriving, despite the fact that their skin temperature is low. For this reason it is important that the climbers should be aware about the reaction of the body in such a situation in order to prevent a hypothermic accident. The results of this study show there is difference between the reaction of the male's body and that of female's body. It was also demonstrated that the reaction of skin temperature after short exposure to normal indoor temperature is different from that after prolonged cold exposure.

CONCLUSION: These results indicate that the countermeasures for the hypothermia in high altitude should take into account the gender and the environmental temperature of climbers.

KEYWORDS: Thermography, High altitude, Hypothermia, Mountain climbing, Gender.

THE THERMAL DIMENSION OF SOCIAL INTERACTIONS

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Original version of 13.02.2015

INTRODUCTION. The evaluation of the psychophysiological state of the interlocutor is an important element for setting congruent interpersonal relationships and communication. Thermal infrared (IR) imaging has proved to be a reliable tool for non-invasive and contact-less evaluation of vital signs, psycho-physiological responses, affective states and social bonds. Thermal IR imaging is gaining growing attention in many fields, from psychometrics to social and developmental psychology, and from the touch-less monitoring of vital signs and stress, up to the human-machine interaction.

The reliability and validity of this method was proven by comparing data simultaneous recorded by thermal imaging and by golden standard methods. An almost exclusive feature of thermal IR imaging in stress research is its non-invasiveness. In a recent study, Engert et al. (2014) explored the reliability of thermal IR imaging in the classical setting of human stress research. Thermal imprints were compared to established stress markers (heart rate, heart rate variability, finger temperature, ?-amylase, and cortisol) in healthy subjects participating into two standard and well- established laboratory stress tests: the cold pressor test and the trier social stress test. The thermal responses of several regions of the face proved to be change sensitive in both tests. Although the thermal imprints and established stress marker outcome correlated weakly, the thermal responses correlated with stress-induced mood changes. On the contrary, the established stress markers did not correlate with stress-induced mood changes. These results suggest that thermal IR imaging provides an effective technique for the estimation of sympathetic activity in the field of stress research.

Thermal IR imaging is becoming much more than a simple promise to be of use for gathering information about affective states in social situations.

As outlined above, emotions may possess a thermal signature. In addition, the thermal modulation of real and natural social interaction among individuals can be studied non-invasively through thermal IR imaging, even recording thermal signatures from more individuals at once.

This work presents the state of the art of thermal IR imaging in psychophysiology and in the assessment of affective states. The goal is to provide insights about its potentialities and limits for its use in studying intersubjectivity, also including human-artificial agent intersubjectivity.

KEYWORDS. Thermal IR Imaging, psychophysiology, emotion, human-machine interaction, intersubjectivity.

THE MENTAL AND SUBJECTIVE SKIN: TEMPERATURE CHANGES AS A MARKER OF EMOTIONS.

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Thermography is a relatively new technique for studying human behavior. In this talk we examine a series of studies (1) employing the analysis of thermograms (2) to test emotional statements by presenting emotional images to different populations. In order to determine whether temperature changes can be considered valid and reliable somatic markers of subjective experience, correlation analyses are applied to the thermal changes in the regions of interest (ROI) of the face, mainly nose and forehead, with respect to different variables particularly involved in emotional tasks, such as empathy rates, arousal experience or task performance.

The literature review of the topic must include the technique of thermography as the main cue concept in the search. Accordingly, we include "thermography", more specifically "infrared thermography", and relate it to different psychological processes, where it has been applied. Thus, "thermography of mental states" refers to the study of the technique across cognitive processes of psychology. Therefore, in a second step we specify the terms such as "thermography & mental workload" (3), "thermography & stress" (4) and "thermography applied to emotions (5) and feelings" (6) in order to examine the utility of thermal imaging as a marker of emotion.

In our first study we explore whether changes in valence and arousal (components of emotion) are related to changes in temperature. We find an effect on both variables manifested in significant changes in the temperature of the tip of the nose. Therefore, a so-called "the valence effect" reveals a facial thermal increment, with positive images, and an "arousal effect", where there is a facial thermal increment with arousal.The second study tests whether, when empathy is considered a kind of arousal state, under negative empathy conditions a thermal decrement occurs, while under positive empathic conditions a thermal increment is found. The results reveal that empathy is associated with lower temperatures in the tip of the nose; however, the positive or negative valence of the stimuli does not appear to be relevant, though the low level of arousal is. The final study tests the relation between the subjective experience of the feeling of love, subjective temperature changes and real temperature changes. The results suggest that feelings of love trigger high arousal and positive valence emotions, which are associated with a warm face in subjective and physiological terms.

Since thermography can provide markers for physical changes, we postulate that it is an appropriate technique to determine which specific thermal patterns exist for which specific emotional states.

KEYWORDS: thermography, emotion, feeling, arousal, valence

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THE CONTRIBUTION OF MEDICAL THERMAL IMAGING IN THE STUDY OF TEMPOROMANDIBULAR DISORDERS (TMD) DISORDERS IN CLARINET PLAYERS

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Temporomandibular disorders (TMD) is a term that embraces different conditions involving the temporomandibular joint (TMJ), the masticatory and postural muscles of the cranio-cervical mandibular complex (CCMC) and the associated structures. Common findings such as pain or/and dysfunctional symptoms or signs like limitations in jaw opening, TMJ sounds and asymmetric jaw movements are the most relevant features present in TMD. The etiology factors of TMD are multifactorial.

The importance of an exhaustive history and a correct clinical examination to evaluate clinical signs and symptoms is most important when the dentist is studying TMD. Therefore to complement the clinical examination of the dentist, there is the possibility of applying infrared thermography in detrimental structures of the CCMC such as the TMJ, the masticatory and postural muscles.

Medical thermal imaging, a non-invasive and non-ionizing physiological medical imaging method, which can be used as compli-

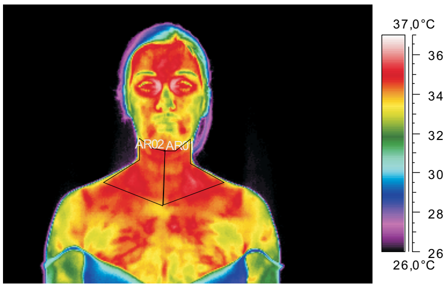

Figure 1
Frontal view with the sternocleidomastoid muscle ROIs.

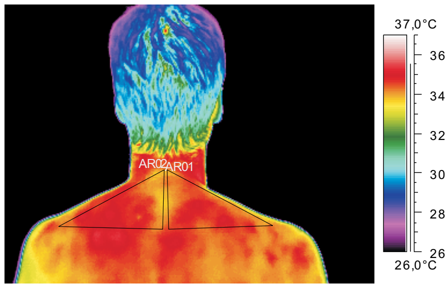

Figure 2
The dorsal view with the trapezius ROIs.

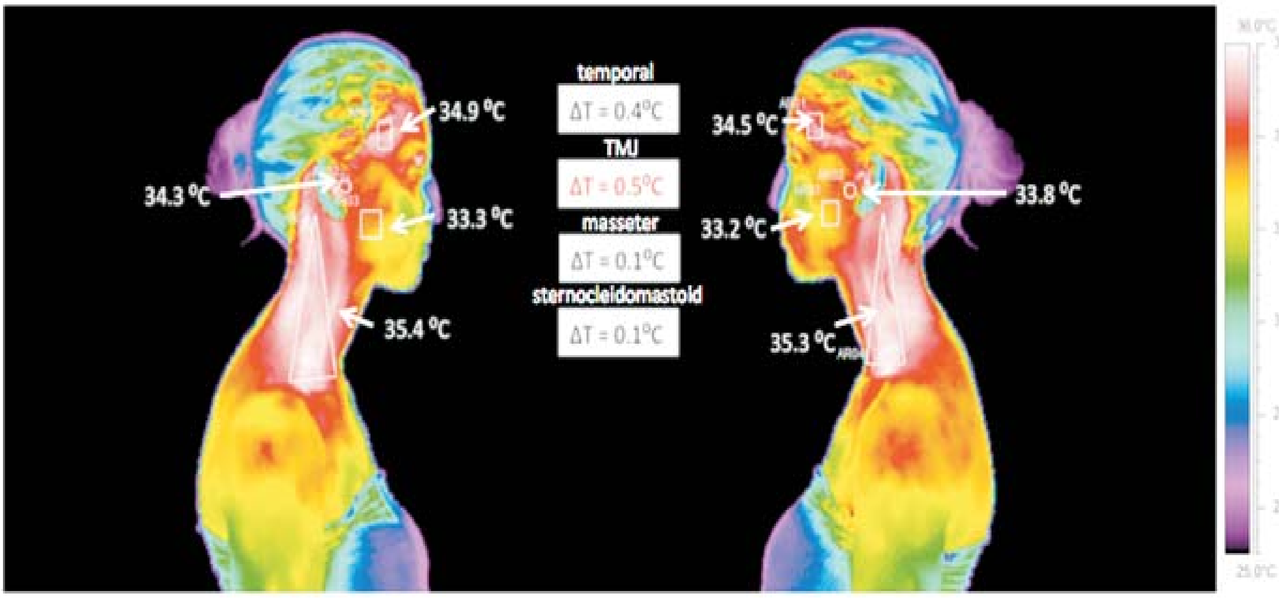

Figure. 3
The lateral views with the temporal muscle, temporomandibular joint (TMJ), masseter muscle, sternocleidomastoid muscle ROIs, with an example of the measured mean temperature and thermal symmetry values, the TMJ has a value of 0.5°C

mentary diagnostic tool and can be an appropriate for analyzing muscle function, which can provide an image of the correspondent thermal effect of the individual muscles or the temporomandibular joint. This will provide a quantitative assessment of the CCMC of the clarinet players, since they engage in parafunctional activities or the adoption of awkward postures due to their practice.

Clarinet players often present orofacial region muscle hyperactivity during their embouchure. There is specificity in the biomechanics of the temporomandibular joint that is being subjected to pressure during their daily performance, which in many cases can reach up to five hours. This can lead to the presence of orofacial pain with inflammation and alteration in the normal function of CCMC structures. It is common to have complaints of wind instrument players regarding their teeth that can have the presence of a certain kind of mobility, pain on the area of the TMJ, stiffness and discomfort on the cervical region and also tension type headaches. These are the main issues that can affect clarinet players regarding the head and neck areas. Nevertheless, sometimes it is frequent to have musicians in a dental appointment referring pain in a tooth such as 2nd molar, where after a clinical examination and correct diagnosis, it was possible to observe in an x-ray that the tooth had no problem such as a cavity or dental decay, but the origin of the pain is related to the presence of myofascial pain, which induces a referred pain to a different area of its origin. In these cases it is crucial to use thermal images to obtain more data regarding the study of TMD.

Seven professional clarinet players were screened before their practice and following the guidelines of the Glamorgan protocol, using a thermal camera FLIR A325sc. Frontal (Fig. 1), lateral and dorsal (Fig. 2) views were used. For this study, regions of interest (ROIs) were defined and used, which were the temporal muscle, temporomandibular joint, masseter muscle, sternocleido- mastoid muscle and trapezius. The thermal symmetry value was used to assess the thermal findings of the ROIs.

The thermographic procedure confirmed the presence of TMD at the temporomandibular joint in two subjects (thermal symmetry >= 0.5°C) at lateral views (e.g. Fig. 3), which was confirmed with the RDC examination and other subject has shown a value of thermal symmetry of 0.7°C at sternocleidomastoid muscle, complaining of pain at that ROI. In all other ROIs this quantitative parameter was < 0.5°C.

When applying medical thermal imaging in clarinet players for the study of TMD, it allows to "fill in the gap" of human-machine interface for evaluative procedures in order to complement prevention, diagnosis and treatment to TMD. However, this was a pilot study for a larger characterization of different types of musicians.

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THERMAL IMAGING, A CLINICAL DIAGNOSTIC TOOL FOR NON-CONTACT MONITORING OF TISSUE PERFUSION, CLINICAL STUDIES IN OUR HOSPITAL..

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INTRODUCTION. Non-contact imaging applying normal video cameras, thermal cameras and multi-spectral cameras can give diagnostic information from the tissue such as the temperature, tissue perfusion and tissue oxygenation. Changes in these physioogical measurements can be related to clinical interventions or differentiate between healthy and diseased tissue or can be used to monitor the effectiveness of a treatment over time for an individual patient.

The new generation of small practical easy to use (no special cooling systems or calibration procedures) thermal cameras with high image and temperature resolution have stimulated the use of thermography in the clinic.

METHODS. Thermal imaging can be useful to image physiological processes, perfusion, inflammation, friction and breathing. Temperature changes can be induced or provoked to observe dynamic changes to differentiate between healthy and abnormal responses.

In our medical center several medical specialism's have become interested in the potential of thermal imaging and various feasibility studies have started:

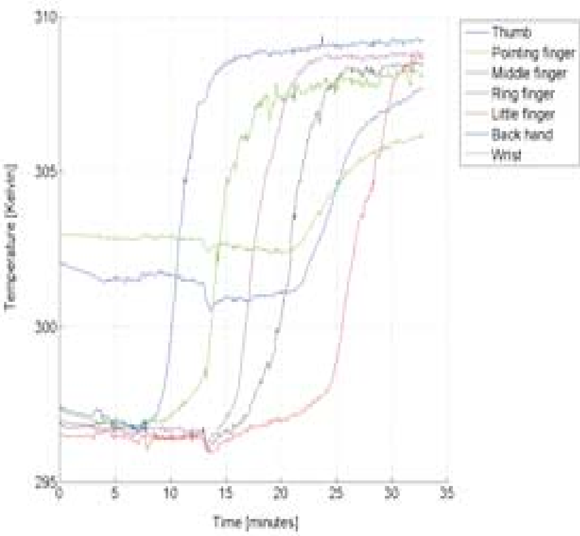
- Cardiology: prediction of spasm of artery in arm.
- Urology: cause of impotence after radical prostatectomy
- Anesthesiology: effectiveness of anesthetic block and pain treatment, non-contact monitoring of vital functions
- ENT surgery: monitoring the tissue perfusion during harvesting and quality of reperfusion of the skin flap.
- Plastic surgery: perfusion quality of skin flap for breast reconstruction, effectiveness of cryo treatment of hypertrophic scars, burn wound skin transplantation
- Dermatology: objective and sensitive imaging of allergic reactions.

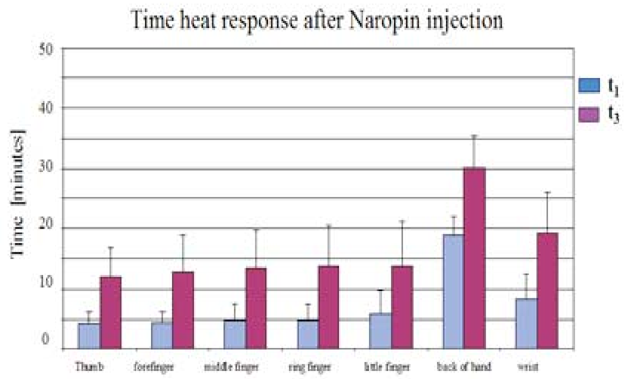
RESULTS AND DISCUSSION. The results of one study will be presented: arm block anesthesia.

A prospective observational study was performed on 22 patients during a local anesthesia before undergoing hand surgery. A thermal camera is used to monitor the temperature response of the hand and fingers caused by the anesthesia procedure. The goal is to achieve an early objective prediction of the effectiveness of the regional block which can result in a more efficient workflow. The anesthetic will cause vasodilatation of the blood vessels in the hand and fingers, this results in a temperature increase. The temperature change and the time response of the heating is correlated with the standard cold sensation test. The temperature response curve is characterized by the time after the anesthetic injection till the temperature starts rising (t1), the time till maximum temperature level is reached (t3) and the maximum temperature change. The results of the temperature responses for successful blocks are shown in the figure on the right, the fastest response is seen in the fingers of the hand with an average t1 of 5 minutes.

CONCLUSION. The clinicians appreciate the ongoing thermography projects for the technology for it real-time presenting of the thermal images and analyses. Thermal imaging can helps to improve the treatment or can become a new diagnostics tool. In the anesthetic block thermal monitoring project we observed that thermography is an early predictor for the success or failure of the procedure.

KEYWORDS. Thermography, perfusion, clinical, non-contact, monitoring.





On the left an example of the temperature increase in one hand as a result of the injection of the anesthetic (Naropin) at t=4 minutes. The temperature increase can be up to 10 degrees (average 8 ± 2 degree) in successful blocks. In unsuccessful blocs the temperature increase is much lower 2 ± 1 degree. On the right the time heat response in the fingertips of all successful blocks (n=17), the results show that the average t_1 response is about 5±1 minute

From the preliminary assessments (table 1) it can be observed that the average values of thermal symmetry per grade group and ROI are: F (1.1, 0.4 and 1.2), A (1.1, 0.2 and 2.2) T (1, 0.9 and 3.1) and LT (2.5, 0.5 and 1.3) respectively (Grade I, Grade II and Grade III). Calculating a gradient index based in the both ankle 45º view based in the formula: Non- Affected Limb (T ROI - A ROI) - Affected Limb (T ROI - A ROI), the obtained mean value for Grade I is 0.1, Grade II is 1.1, Grade III is 1.4, promising being an interesting discriminatory indicator.

In the studied regions of interest, which broadly represent the injury site (except the toes area), the thermal profile has been compared with the clinical diagnosis grading and ultrasound evaluation performed. Further patients shall be enrolled in the study pool in order to assess correlation significance between clinical grading of sprained ankle lesions and its thermal variations.

CONCLUSION. The performed study indicates a trend when comparing clinical diagnosis of ankle sprain lesions and their thermal profiles. However, a wider sample is needed to confirm significant correlation between these methods and propose thermographic analysis as a potential indicative tool to aid the early grading of ankle sprain injuries.

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KEYWORDS. Thermography, ankle, clinical, diagnosis.

Session 2-2 Biomedical Applications Temperature Changes after Cold Challenge

"NORMAL" THERMOGRAPHY AMONG 122 SOLDIERS IN THE NORWEGIAN ARMED FORCES

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Original version of 25.02.2015

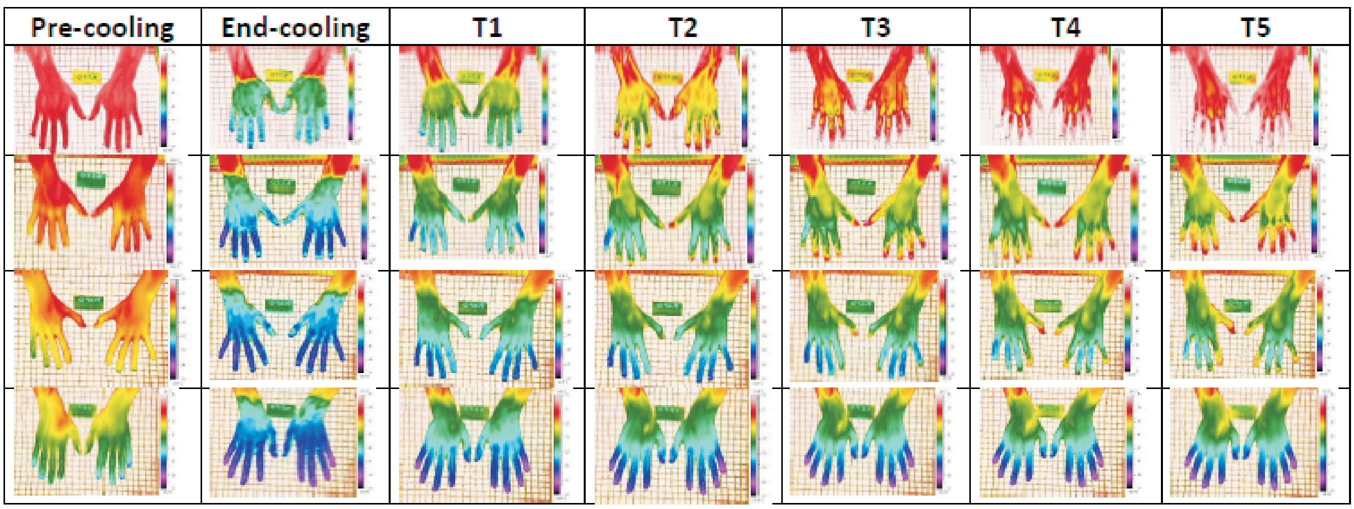
INTRODUCTION. The Norwegian armed forces experience annually a substantial number of freezing and non-freezing cold injuries (NFCI) during winter training. Being able to identify subjects who may be at high risk for obtaining cold injuries at the start of their military training may help in reducing the numbers of such injuries. The main aim of this study was to investigate whether such individuals could be identified from thermographic surveys of the microcirculation in the skin of the dorsal aspect of the hands subjected to a mild cooling at the start of their military service. One of the main questions is to whether the thermographic response to a standardized cold challenge at the start of their military training can be used as a predictor of their level of risk.

In this study 122 new recruits were subjected to a standardized cooling and recovery protocol of the hands (cold water immersion - 20ºC for 1 min). Thermal images of the dorsal aspect of the hands were taken prior to, immediately after and at 5 minute intervals during the spontaneous rewarming period. During the imaging process the hands rested on a thin nylon grid placed 4 cm above a uniform heating plate (ca 40ºC).

As shown in the figure there was a large variation in the re-w arming responses. Indeed some individuals had re-warming patterns that we considered may indicate underlying pathology. Following the end of their winter training all subjects will be tested for a second time in order to see whether their response to the standard cooling protocol has changed and whether these changes and/or their response to the initial test can in anyway be correlated to risk for getting a cold injury. This will be of especial interest for those soldiers who received a cold related injury during their military training.

Detailed results of the inter- and intra- individual variation in the responses of the recruits following the initial cooling test will be presented. The validity and reliability as to what should be regarded a normal thermographic response to a cold challenge will be discussed..

KEYWORDS. thermography, army, frostbite, standard.



Dynamic infrared thermography among 122 self-defined healthy Norwegian army soldiers, subdivided into 4 groups of rewarming patterns. The thermographic images from all 7 time-points is a subject to this visual analysis; pre-cooling, end-cooling=T0, and thereafter each minute (1,2,3,4 and 5 minutes) after the cold challenge (T1-T5).

PLANTAR THERMOGRAPHY AS A DIAGNOSTIC AND PROGNOSTIC TOOL FOR „DIABETIC FOOT“

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Original version of 17.02.2015

INTRODUCTION. Thermal imaging has been shown to be a useful technique in the clinical management of the diabetic foot, because an increased plantar foot temperature is a key sign of underlying inflammation. Several diabetic foot complications such as neuropathic ulcers, osteomyelitis and Charcot foot have been identified at increased temperature locations. Increased plantar foot temperature may even be present a week before a neuropathic ulcer appears. Angiopathy, microangiopathy, and neuropathy induced angiopathy play an important role in the patho-ge nesis of the diabetic foot. They are responsible for subtle skin temperature changes, in these cases IRT (infrared thermography) is becoming the investigation of choice in the evaluation of the diabetic foot. Aim of study was to assess IRT usage in differentiation between foot neuro- and angiopathy, evaluating the temperature criterion in diabetic patients.

METHODS. We examined 64 patients, divided in to 3 groups: control (n-17) non diabetic volunteers, diabetics without ulceration on anamnesis (n-36), and diabetics (n-11) with ulcers in presence or episodes of ulceration in past. Neuropathy was defined using: 10g monofilament touch, vibration, pain, temperature perception disorders, when obtained data were compared with thermography results. Tissues of both feet's were observed visually, whereas the micro temperature changes were supervised and registered with IRT camera "ThermaCAM P640" (FLIR Systems, USA). Protocol of investigation included standard 10-15 min adaptation in room temperature (20-24 C°), in sitting position with the lower extremities hanging freely. Thermal/digital images were made from external and plantar sides. Thermographic views were analyzed with "FLIR tools" computer software.

RESULTS AND DISCUSSION. We founded significant thermal differences between neuro- and angiopathic foot. Differences in first spot temperature between the ipsilateral and contralateral foot in second group patients were at maximum 3,3 °C, in third group were - 4,4°C. Second spot temperature asymmetry in second group patients were at maximum 1,8 °C, in third group were - 2,8°C. Fourth spot temperature between the ipsilateral and contralateral foot in second group patients differences at maximum 1,7 °C, in third group - 3,5°C. Differences in seventh spot temperature - in second group patients were at maximum 2,2 °C, in third group were - 2,1°C. Diabetes mellitus (DM) patients with polyneuropathy were accompanied by seriously impaired thermoregulation. We consider use of IRT a valuable diagnostic tool for easy detection of potential DM induced neuropathy. Further studies are required to establish the value of IRT in visualization of early sub-clinical complications.

CONCLUSION. The imaging techniques such as infrared thermography together with standard neurologic testing are valuable additional method for evaluating the skin temperature changing associated with development of early diabetic foot complications.

KEYWORDS. thermography, diabetes, foot injury, diagnostic.

THERMAL PHYSIOLOGICAL CHARACTERIZATION OF DIABETIC FOOT

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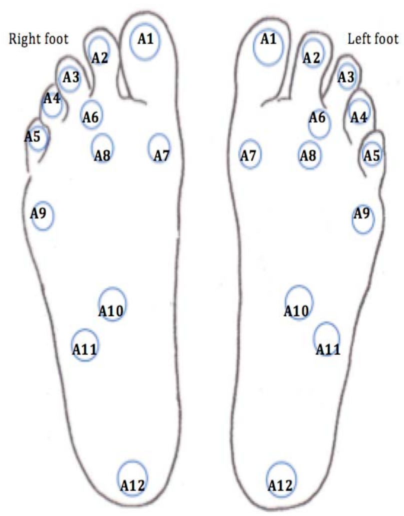
Revised version of 14.04.2015

INTRODUCTION. Diabetes affects around 13% of the Portuguese population and one in seven patients are at high risk of developing diabetic foot. This condition involves several anatomic-pathological and peripheral neurological disorders, which affect the peripheral microcirculation. This might have serious consequences such as: ulcers, ischemia and amputations. A practical and inexpensive monitoring and assessment tool is needed for evaluating treatments progression, and to promptly act in case of regression.

METHODS. Medical thermography was used to monitor the temperature distribution on the planar feet view, following a standard capture protocol. This information is directly related with the physiological mechanisms underlying temperature changes detectable in diabetic feet, allowing real-time physiological assessment, providing a window to the peripheral microvascular and autonomic nervous systems, which are related with the pathology. The blood glucose level was also measured. A total of 50 patients were investigated, being 30 neuropathic, 2 of ischemic and 18 neuroischemic. Regions of interest (ROI) were defined according to the angiosomes and most frequent areas where diabetic ulcers occur (Fig. 1). For assessing the findings a statistical evaluation was performed.

RESULTS AND DISCUSSION. With the proposed methodology it was possible to discriminate ($p<0.05$) between different blood glucose levels at the ROIs: A4R, A6R, A7R, A8R, A10R, A11L E A11R, and age differences at the ROIs: A10R and A10L. No significance was found in the Body Mass Index and in the discrimination of ulcer type. Most of the patients revealed to be more affected in the right limb, which was the dominant extremity, pointing that there is a relationship between prevalence and dominance. Thermal symmetry was useful for assessing treatment outcomes in situations where only one limb was affected.

CONCLUSION. The results of this experiment allow studying diabetic foot disease more extensively, enabling a better knowledge of its pathophysiology. The use of thermography con-



firmed the influence that blood glucose level and age has on the condition. The obtained results can be used as reference for future research studies in the area and the proposed methodology can be improved to become used in daily practice, helping clinical professionals in the diagnosis and treatment assessment, providing better care and reducing the associated costs.

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KEYWORDS. Diabetic foot, medical thermal imaging, thermal symmetry.

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The authors would like to thank the Diabetic Foot Clinic at the Hospital Geral de Santo António SA, which is part of Centro Hospitalar do Porto at Porto Portugal and the collaboration of all patients examined in this study

STUDY OF THE THERMOVASCULAR CHARACTERISTICS IN PATIENTS WITH WILLIS-EKBOM DISEASE.

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INTRODUCTION. Willis-Ekbom disease (WED) can significantly affect the quality of life, with the most characteristic symptoms being restless legs and burning sensation at the feet especially during sleep. Abnormal thermovascular characteristics have been suggested, but not fully investigated yet.

METHODS. This study recruited 12 WED patients and 12 sex- and age-matched healthy controls. Thermograms of the feet of each subject were acquired at three different room temperature stages: normothermic (23 °C), hot (30 °C), and cold (18 °C). Measurements were performed in a state-of-the-art humidity- and temperature-controlled facility within the Microvascular Diagnostics Service at Freeman Hospital. A FLIR A40 thermal camera was utilised, with the emissivity parameter set to 0.98. [1]

Regions of Interest (ROIs) were manually drawn for each subject on one selected thermogram per each room temperature stage. The thermovascular characteristics of the feet were quantified using the temperature mean and temperature standard deviation within the ROI. [2].

RESULTS AND DISCUSSION. The measurement protocol was well tolerated. There were no significant differences in the feet temperature mean between WED patients and healthy controls at any of the measurement stages. The feet temperature standard deviation was always lower in WED patients compared to healthy controls during all measurement stages; however, this only reached statistical significance during the hot stage (0.8 ± 0.2 °C versus 1.1 ± 0.4 °C, $p < 0.05$).

Higher room temperatures are recognised to increase WED symptoms and this is consistent with the fact that the difference in foot temperature standard deviation in this study only reached statistical significance during the hot measurement stage. Decreased temperature standard deviation are representative of more uniform spatial temparture distribution in the foot of WED patients compared to healthy subjects. This novel finding suggests impaired spatial relative cooling at higher room temperatures in this patient group, which may have clinical relevance. [2]

CONCLUSION. This is the first study that performed a comprehensive investigation of the thermovascular characteristics in patients with Willis-Ekbom disease and in comparison to healthy subjects. The results have shown differences between the patient group and healthy subjects that may have clinical relevance, and suggesting a possible mechanism for the sensation of burning feet. This finding deserves to be explored further. The protocol used also provides an experimental paradigm to test therapeutic interventions for the future.

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KEYWORDS. microvascular, restless legs syndrome, thermal imaging, thermovascular, Willis-Ekbom disease.

TOE SPACERS TO INCREASE SKIN TEMPERATURE

S. Melgosa

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Revised version of 03.04.2015

BACKGROUND: Misalignment of toes may be associated with low skin temperature, low blood circulation and other problems.

Generally, toe spacer works just for one or two toes, but not treating all toes. This case study shows how toe spacer "Correct Toes" work in all toes, improving correct alignment, restore natural foot shape and improve blood flow.

Correct Toes is made of silicone, easy to put on and off and to wear during normal life if used with wide toe box shoes.

METHOD: To investigate the influence of toe spacers on skin temperature we use infrared thermal imaging. This technology provides an image of skin temperature easy to compare between foot with toe spacers and without.

We used a Flir T640bx thermal camera in a male and a female subject. Different individual toes presented with misalignment, more severe in the male than the female.

After acclimatization of subjects for 15 minutes in a room with 22ºC ambient temperature, in bare foot standing position. We put one "Correct Toe" spacer on one foot and but not on the other, placed between on the second to fourth toe. Small and big toes just touched the toe spacers, but also separated the treated toes from each other.

After new acclimatization of subjects 30 minutes later, skin temperature difference appears in both foots, showing higher skin temperature, probably due to better blood flow, in the foot with toe spacers than in the foot without Correct Toes.

The infrared images of a male and a female subject in figure 1 show regions of interest at the big toe and in the tarsal region, where we measured temperatures.

RESULTS: A difference in skin temperature was detected between the foot with toe spacers and without. We observed more

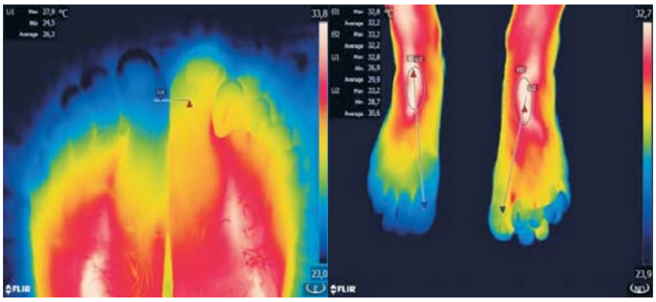

Figure 1
Right image: Male foot with and without toe spacer
Leftmage: Female foot with and without toe spacer

than 3ºC temperature difference between big toes in the male subject and almost 2ºC in female big toe. No other apparent reason is responsible for the skin temperature difference between both feet. Other benefits provided by toe spacers, are an almost correct toe alignment and restoration of the natural foot shape.

CONCLUSIONS: As skin temperature is associated with perfusion, increased skin temperature may indicate an improved blood flow rate in toes treated "Correct Toes" spacers.

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THERMAL IMAGING AS A POTENTIAL COMPLIMENTARY DIAGNOSIS METHOD FOR ANKLE SPRAIN LESIONS.

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INTRODUCTION. A sprained ankle is a frequent medical condition where the ankle ligaments can be torn, either partially or completely. Worldwide, approximately 1 ankle sprain occurs per 10,000 person-days and sprained ankles are estimated to be responsible for 15-25% of all musculoskeletal injuries. Ankle sprains can result in considerable time lost to injury, as well as long-term disability in up to 60% of patients [1, 2].

Ankle sprains can be classified as grade I, II, and III, ranging from mild to severe (I to III) based on the extent of damage and number of ligaments affected. This distinction is of utmost importance given the differentiated treatment applied based on the grading.

Diagnosis of a sprained ankle relies mostly on the medical history and physical examination. This physical examination implies a set of provocative manoeuvres to be conducted in order to ascertain the grading of the lesion. This step is not consensual given its ability to potentiate the lesion of the ligaments and worsen the outcome. Ultrasonography is time consuming and dependant on the experience of the radiologist. Given the inflammatory/ischemic nature of the pathological sprain process, a valuable alternative might arise from infrared thermography in the grading of the lesions without invasive procedures and without the need of more expensive and complex analysis, such as MRI, not usually available in the emergency setting.

METHODS. A total of 6 patients (characterization at table 1) at the emergency room of the Hospital S. João, Porto, were admitted and a detailed medical history and physical examination was performed. The diagnosis of sprained ankle and its subdivision in grades I, II and III was performed according to the currently available guidelines [1]. Before performing the thermal images collection an x-ray of the ankles was taken to verify the existence of bone fracture. The thermographic recording of both ankles was conducted using a thermal camera FLIR E60SC (integrated real resolution of 320 x 240 pixels, precision of $< 0.05°C$ and accuracy of $\pm 2\%$ of the overall temperature range) in a room with controlled and stable air temperature ($22\pm0.6°C$), humidity ($41\pm8\%$), and airflow of <2m/s2 and absence of incident lightning The collected images (views in figure 1) were recorded according to the Glamorgan protocol [3] after a 15 minutes acclimatization period and stored in a database, for data analysis it was used the software package FLIR Researcher Pro 2.10. A trained musculoskeletal radiologist performed ultrasound imaging afterwards to verify the ligament rupture.

RESULTS AND DISCUSSION. The six patients included in this initial study presented sprain ankle lesions based on the evolution time. The main process of lesion was inversion of the affected ankle. The patients had no other injury in further joints. When comparing both affected and non-affected, a trend was observed where the injured limb experienced a pattern of decreased temperature, which is coherent with hypothermia occurring within 24 to 48 h after injury onset. This effect is possible based on reflexive sympathetic vasomotor changes.

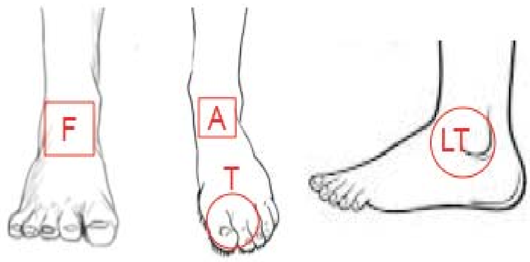

Figure 1
The regions of interest used in the study per foot (views: at left - feet anterior, at center - ankle 45º, at right - lateral ankle; F – Front ankle,

Table 1 – characterization and results of the sample (BMI – Body Mass Index, A.L. – affected limb, T.I. – time of injury, F – Front ankle, A – Anterior ankle, T – toes, LT – lateral ankle, R – right, L – left)

Patient charcterization							Thermal symmetry				Index	
#	Age	Gender	BMI	Grade	A.L.	T.I. (d)	F	A	T	LT	R	L
1	16	M	18.2	III	Left	1	0.2	N/A	N/A	0.8	N/A	N/A
2	27	M	23.8	III	Left	0	2.1	3.1	2.6	2.2	-6.4	-5.9
3	51	F	28.2	I	Right	1	1.5	1.5	1.1	2.7	-2.8	-3.2
4	14	F	22	III	Right	0	1.4	1.3	3.6	0.9	-5.2	-2.9
5	13	M	20.2	I	Right	0	0.6	0.6	0.9	2.3	-7.6	-7.3
6	37	F	24.6	II	Right	15	0.4	0.2	0.9	0.5	-5.7	-4.6

From the preliminary assessments (table 1) it can be observed that the average values of thermal symmetry per grade group and ROI are: F (1.1, 0.4 and 1.2), A (1.1, 0.2 and 2.2) T (1, 0.9 and 3.1) and LT (2.5, 0.5 and 1.3) respectively (Grade I, Grade II and Grade III). Calculating a gradient index based in the both ankle 45º view based in the formula: Non- Affected Limb (T ROI - A ROI) - Affected Limb (T ROI - A ROI), the obtained mean value for Grade I is 0.1, Grade II is 1.1, Grade III is 1.4, promising being an interesting discriminatory indicator.

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Session 2-2 Biomedical Applications Temperature Changes after Cold Challenge

"NORMAL" THERMOGRAPHY AMONG 122 SOLDIERS IN THE NORWEGIAN ARMED FORCES

A. Norheim [1], E Borud [1], J. Mercer [2], L. deWeerd [3]

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Original version of 25.02.2015

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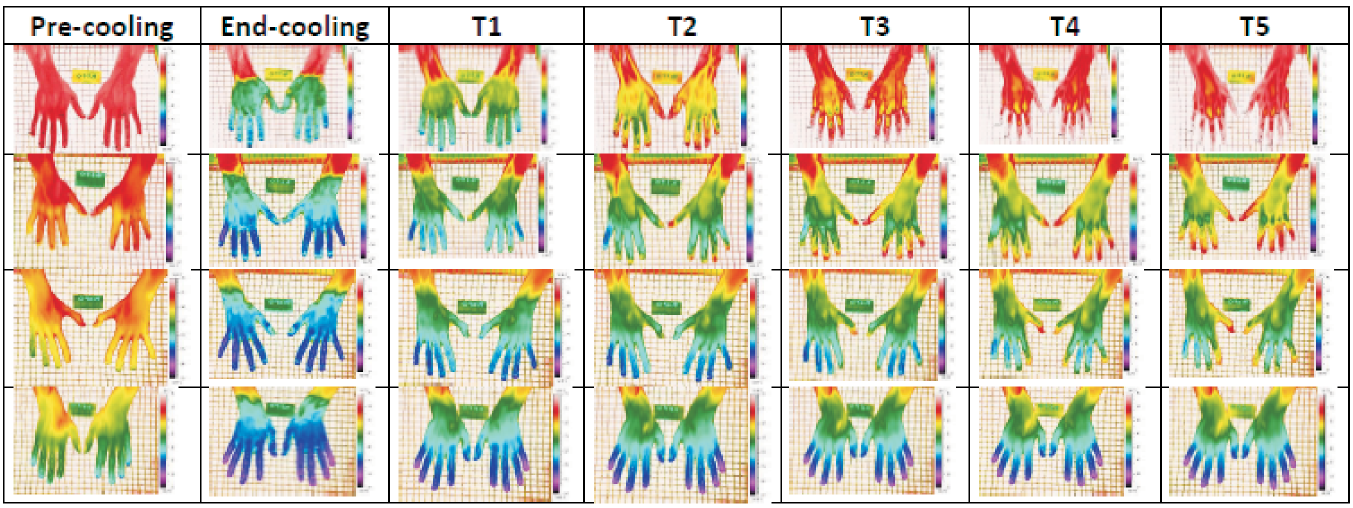
In this study 122 new recruits were subjected to a standardized cooling and recovery protocol of the hands (cold water immersion - 20ºC for 1 min). Thermal images of the dorsal aspect of the hands were taken prior to, immediately after and at 5 minute intervals during the spontaneous rewarming period. During the imaging process the hands rested on a thin nylon grid placed 4 cm above a uniform heating plate (ca 40ºC).

As shown in the figure there was a large variation in the re-w arming responses. Indeed some individuals had re-warming patterns that we considered may indicate underlying pathology. Following the end of their winter training all subjects will be tested for a second time in order to see whether their response to the standard cooling protocol has changed and whether these changes and/or their response to the initial test can in anyway be correlated to risk for getting a cold injury. This will be of especial interest for those soldiers who received a cold related injury during their military training.

Detailed results of the inter- and intra- individual variation in the responses of the recruits following the initial cooling test will be presented. The validity and reliability as to what should be regarded a normal thermographic response to a cold challenge will be discussed..

KEYWORDS. thermography, army, frostbite, standard.



Dynamic infrared thermography among 122 self-defined healthy Norwegian army soldiers, subdivided into 4 groups of rewarming patterns. The thermographic images from all 7 time-points is a subject to this visual analysis; pre-cooling, end-cooling=T0, and thereafter each minute (1,2,3,4 and 5 minutes) after the cold challenge (T1-T5).

FINGER COOLING DURING COLD STRESS AND SURFACE AREA-TO-VOLUME RATIO IN HEALTHY SUBJECTS, AND PATIENTS WITH PRIMARY AND SECONDARY RAYNAUD'S PHENOMENON.

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Original version of 26.02.2015

INTRODUCTION. In biological systems, surface area-to-volume ratio (SA:V) is a key parameter influencing heat loss to the environment. We investigated the temperature drop during cold challenge in each of the five digits of the hand, and compared it with the SA:V of each digit, as estimated by a very simple model.. METHODS. Twenty control subjects with no symptoms of peripheral vasospasm, 20 patients with primary Raynaud's phenomenon (RP), and 20 patients with RP secondary to scleroderma all underwent cold challenge of the hands in water (15°C for one minute). Thermograms of both hands were recorded before, and immediately after cold stress. The width of each digit was determined from each baseline thermogram in "Image J" analysis software (National Institute of Mental Health, Bethesda, USA. http://imagej.nih.gov). SA:V was estimated by considering each digit to approximate an open-ended cylinder, a geometric shape for which SA:V is given by 2/r, where r is the radius of the cylinder.

RESULTS AND DISCUSSION. Preliminary results from 5 healthy subjects are presented in Table 1. This shows the median drop in temperature for each of the five digits of the hand, along with SA:V calculated by the simple model. Beginning with the radial side of the hand (the thumb), there was a progressive increase in SA:V moving towards the ulnar side of the hand (5th digit), with SA:V being 25% higher in the 5th digit than the 1st. Temperature drop during cold challenge showed a similar trend, with the 5th digit also experiencing a 25% larger temperature drop than the thumb. Considering all 50 studied digits together, overall there was a weak correlation between SA:V and temperature drop (r=0.18). However, when considering the ten digits together in each of the individual subjects, the correlation was moderate in the three females (r=0.67, r=0.46, and r=0.60), and strong in the two males studied (r=0.76 and r=0.89).

Table
Median temperature drop in 5 patients

Digit	SA:V (cm^{-1}) Median (IQR)	Temp. Drop (°C) Median (IQR)
1st (Thumb)	2.12 (0.24)	7.1 (0.8)
2nd (Index)	2.23 (0.14)	8.5 (3.1)
3rd (Middle)	2.28 (0.15)	8.7(2.1)
4th (Ring)	2.42 (0.28)	9.0 (1.3)
5th (Little)	2.67 (0.17)	8.9 (1.6)

CONCLUSION. Hand cold challenge is employed to assess vasospastic conditions, but there is an incomplete knowledge of the factors which limit the test reliability. Our data suggest that differences in the geometry across the digits of the hand have an important influence on cooling during cold challenge.

KEYWORDS. Thermography, cold challenge, Raynaud's phenomenon, scleroderma

COLD-WATER PROVOCATION OF HANDS: AN EVALUATION OF DIFFERENT PROVOCATIONS

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INTRODUCTION: Infrared thermography is used, predominantly in medical research, to study skin perfusio [1]. Cold water provocation has been used in many studies with different cooling duration and temperature and with or without gloves [2].

In the present study different types of cold water provocation of the hands were investigated. Thermal response was measured with infrared thermography.

METHODS: Eight males (22-66 years, mean 34) participated in the study. Different procedures were evaluated: water temperatures 10.0°, 12.0° and 15.0°C, bare hands, the use of gloves or plastic bags. The mean hand skin temperature in 18 predefined Regions Of Interest (ROIs)/hand was measured. After cooling, the palmar aspect of the dried hands was imaged using thermography while rewarming for approximately 6 minutes. The test was in a randomized order.

Temperature comparisons were made at the baseline temperature, directly after cooling, during rewarming, and final - end of measurement. The cooled temperature was taken as the first measurement directly after the cold-water provocation and the temperature difference was calculated as the difference between the baseline temperature and the first values after cooling.

RESULTS AND DISCUSSION: Hands in plastic bags and with water at 10.0°C for 30 seconds showed a difference in average temperature between baseline and cooled temperature of 6.8°C (SD ± 2.0°C), when provoked for 1 minute the difference was 8.8°C (SD ± 2.1°C).

The mean difference in average temperature between baseline and cooled temperature for hands in gloves and with water at 10.0°C for 30 seconds was 6.8°C (SD ± 1.6°C).

Table1.
Mean hand skin (Tsk) temperature (°C); baseline, difference between baseline and cooled temperature, final temperature.

Bare Hands	Mean T_{sk} value (°C)		
	Baseline	Diff.	Final
10.0°C (30sec)	30.9±1.8	9.3±1.7	30.2±1.9
12.0°C (30sec)	31.4±1.5	7.9±1.9	30.4±2.2
15.0°C (30sec)	30.5±1.7	6.6±1.1	29.8±2.5
12.0°C (60sec)	30.6±1.9	9.4±1.5	28.4±3.5
15.0°C (60sec)	30.0±2.6	7.2±3.0	29.9±2.4

The average final temperature for hands with different types of protective dressing and provoked with water at 10.0 °C for 30 and 60 seconds was 0.1°C higher than the baseline.

In the provocation tests with cold water at 12 °C and 15 °C , for 30 and 60 seconds the rewarming process monitored during 6 minutes showed an initial rewarming rate of 1.7 °C/min (SD ± 1.7 °C). No significant difference was found in initial rewarming rate when comparing provocation tests with cold water at 10.0 °C and different types of protective clothing or bare hands; bare hands vs. hands in plastic bags (CI: -0.8-0.09 °C/min); bare hands vs. hands in gloves (CI:-0.7-0.2 °C/min) and hands in plastic bags vs. hands in gloves (CI: -0.2-0.4 °C/min).

A smaller cooling effect, by approximately 2.5 °C, was found with protective dressing. This could be explained by the isolating effect of the plastic material and trapped air between the plastic dressing and the hands.

Even if this study has a limitation in the relatively small sample, we conclude that protective devices do not add any advantage when using cold water provocation as we do. Some questions arise from the present study and one is if shorter provocations times at a higher temperature would be as a good method. This need to be further investigated.

CONCLUSION: The cooling water and cooling time had a more pronounced effect on the temperature drop when the response in hand skin temperature was measured than cooling with or without protectives.

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KEY WORDS: Infrared thermography; cold induced; cold exposure; hand skin temperature; vascular response

HOW FINGERS BECAME WARM AFTER COOLING

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INTRODUCTION. It is well known that in cold conditions, the temperature of the bare hands of a person depends on the flow rate of the warm arterial blood [1]. However, the mechanisms of maintaining heat in the palms and fingers, with the purpose of adaptation to cold are still not well understood [2].

METHODS. Was studied the dynamics of an infrared image of the fingers and palms of the hands after cold test in 2 patients during inhalation anesthesia and 4 days after cessation of anesthesia and in 10 healthy adult male volunteers prior and 30 minutes after ingestion of ethanol at a dose of 0.4 g/kg body weight. All subjects underwent a cold test, which was performed by immersion of the hand for 2 minutes in water from melting snow [2]. Infrared thermography was performed using thermal imager ThermoTracer TH9100XX (NEC, USA) in the temperature range 26 - 36°C. The temperature of the air in the examination room was in the range 24 - 26°C [1]. Mean temperatures of the palm and finger pads, and the time for recovering to baseline temperature were recorded.

RESULTS AND DISCUSSION. At baseline, the temperature of the central portion of the palm was 1.90 ± 0.75°C (P ? 0.05, n = 10) higher than in the fingertips. After cold test, temperature in the central part of the palms increased more pronounced than in the fingertips. The temperature reached initial values in the center of the palms within 28.65 ± 0.95 minutes, and in the fingertips within 36.3 ± 1.12 minutes ($p \le 0.05$, n = 10). It was observed, that alcohol intake raises the temperature of the hands. Before the cold test, but within 30 minutes after administration of ethanol, the temperature of the pads of the fingers increased by 1.45 ± 0.22 in all subjects and in the central part of the palms by 1,15 ± 0,19 °C compared to baseline reading prior to alcohol intake ($p \le 0.05$, n = 10). After cold test, pads of the fingers rewarmed at the same time with the palm and reached baseline values within 15.15 ± 2.45 minutes ($p \le 0.05$, n = 10).

During general anaesthesia, the temperature of the tips of the fingers have reached their baseline values within 14 and 15 minutes after cold test. And 4 days after recovery from anesthesia, the temperature in the hand recovered after cold test in the central part of the palm tafter 30 minutes, in the fingertips within the 37 and 38 minutes.

CONCLUSION. Anaesthetics interfere with the mechanisms of human adaptation to cooling. Alcohol intake and inhalation anesthesia reduce the time for temperature recovering of hand and fingers after cold exposure.

KEYWORDS. Thermography, man, cooling, ethanol, anesthetics.

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COMPARISON OF THE DIAGNOSTIC ACCURACY OF THREE INFRARED IMAGING METHODS IN EVALUATING PATIENTS WITH PRESUMPTIVE CRPS

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INTRODUCTION. Complex Regional Pain Syndrome, Type I (CRPS) is a potentially disabling neuropathic condition characterized by regional pain that is often disproportionate to, or occurs in the absence of, an identifiable inciting event.

METHODS. A retrospective chart review of two hundred ninety nine (299) consecutive patients referred to the infrared diagnostic imaging center to rule out Complex Regional Pain Syndrome (CRPS) were evaluated to compare the physical examination findings with three separate and distinct IR imaging methodologies. The patients were referred by their primary care provider carrying a presumptive diagnosis of CRPS. Prior to IR imaging, all patients underwent a focused clinical examination utilizing the modified (Budapest) IASP criteria for diagnosing CRPS as the gold standard. The three separate and distinct IR imaging methodologies were compared with the clinical examination findings. Test validity measures (sensitivity, specificity, positive predictive value, negative predictive value, P-value-difference between the specified test and chance) were calculated. Receiver operating characteristics (ROC) graph analysis was performed for each of the three individual IR diagnostic testing methodologies.

RESULTS AND DISCUSSION. Functional infrared imaging (fIR) method, utilizing three distinct IR signature indices, demonstrated a high sensitivity of 83.9% (95% confidence interval: 72.3 and 92.0) and specificity of 99.2% (95% confidence interval: 97.0% and 99.9%) with a significant correlations ($p<.0001$). The ROC curve analysis (95% confidence interval) revealed a 91.5% area under the curve (AUC) (figure 1).

Quantitative IR imaging method, which obtains side-to-side computer generated quantitative 1°C delta T (ΔT) of the region of interest (ROI), demonstrated a sensitivity of 38.7% (95% confidence interval: 26.6% and 51.9%) and specificity of 84.8%

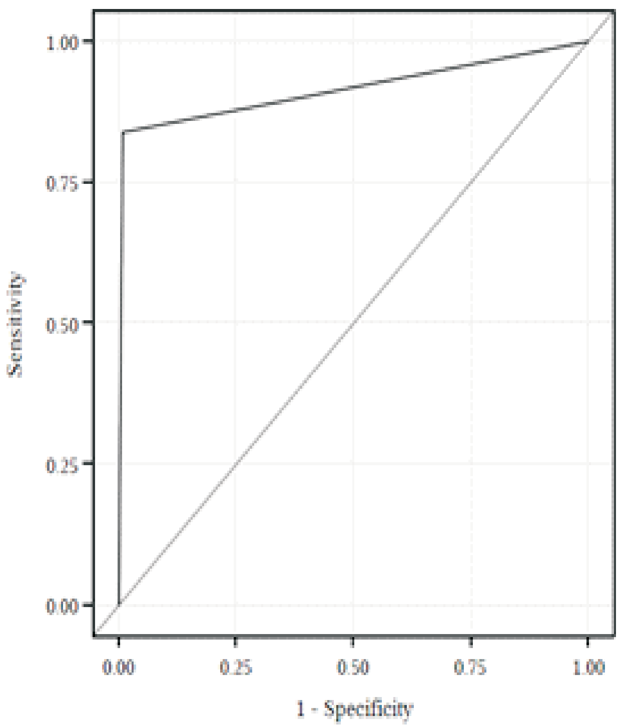

Figure 1
Functional IR Imaging Methodology, ROC Curve Graph (AUC = 91.5%)

(95% confidence interval: 79.6 and 89.1) with significant correlations ($p<.0004$). The ROC curve analysis (95% confidence interval) revealed a low 61.8% area under the curve (AUC) when utilizing this diagnostic IR imaging methodology for evaluating patients with presumptive CRPS.

Qualitative IR imaging method, which compares an equal or greater to 1°C ΔT utilizing a 10° C color palate comparing side-to side region of interest (ROI), demonstrated a sensitivity of 91.9% (95% confidence interval: 82.2 and 97.3) and specificity of 14.4% (95% confidence interval: 10.1 and 19.5 with a poor correlation ($p<.013$). The ROC curve analysis (95% confidence interval) revealed a 53.1% area under the curve (AUC) when utilizing this diagnostic IR imaging methodology for evaluating patients with presumptive CRPS.

CONCLUSION. Functional IR is a highly sensitive and specific IR imaging diagnostic methodology in evaluating patients with presumptive CRPS. Quantitative and qualitative IR imaging methodologies are not recommended for the evaluation of patients with presumptive CRPS due to the low sensitivity and low specificity, respectively, with unacceptably low AUC percentiles.

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KEYWORDS. thermography, CRPS, sensitivity, specificity, Receiver operating characteristic (ROC) curve.

PAINFUL LEG SYNDROME IN THERMAL, ULTRASOUND AND X-RAY IMAGING

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Revised version of 27.03.2015

INTRODUCTION. In the majority of patients, who admitted for treatment of pain in the leg area, X-ray inspection represents the only performed imaging examination. This examination very reliably informs us of the traumatic and degenerative changes in the bone-and-joint apparatus. Most of patients at our diagnostic center undergo additional musculoskeletal ultrasound and thermal imaging examination.

The musculoskeletal ultrasound examination informs us of structural changes in the soft tissue leg structures. The information on pain in disorders of the musculoskeletal system is mediated by various types of released neuromediators, acting on various receptor types, depending on the type and depth of damage, or is possibly mediated by activation of the sympathetic nervous system. With thermal imaging these different types of pain are reflected by a different temperature activity and different pattern above the disturbance region.

METHOD: This is a retrospective study, in which we evaluated X-ray (RTG), musculoskeletal ultrasound (SMS), thermal imaging (TMV) and myoskeletal (MM) examinations of 58 patients (34 men, 27 women) aged 12-70 (average age 43.2), who were admitted to our center between January 2011 and December 2012 for treatment of pain suffered in the leg area. Our objective was to determine the correlation between the results of RTG, TMV, SMS and MM findings of palpable and subjectively reported pain sensations and describe the thermal patterns characteristic for different types of pain information (inflammatory, sympathicotonic).

RESULTS: We discovered a more than twofold higher correlation between the TMV, or possibly SMS examination and the MM examination, compared to the correlation between the the X-ray and MM examination. We present thermal changes associated with different types of pain.

CONCLUSION: We conclude that apart from the X-ray inspection, TMV and SMS examination is also required for making a timely and correct decision for the adequate treatment method for painful leg syndrome.

KEYWORDS. pain, leg, thermography, musculoskeletal ultrasound, X-ray imaging.

Session 3-1 Biomedical Applications. Thermography and physical exercise

THERMOGRAPHIC EVALUATION OF SWIMMING TECHNIQUES

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Revised version of 15.04.2015

INTRODUCTION. Exercise is known for affecting human thermoregulation, as the heat generated by muscle leads to increased heat dissipation through the skin. Therefore, medical thermal imaging can be a powerful tool for physical activity and sports performance assessment.

Previous studies have demonstrated that it was possible to identify thermal effects associated with exercise. Merla et al [1] provided some disclosure about differences in temperature distribution in runners identified during treadmill exercise; Chudeka et al [2] detected some correlations between physiological parameters and thermal response to volleyball practice. Arfaoui et al [3] have considered the possibility of using thermography to characterize swimming exercise, in a pilot study (1 athlete). However, analyzing the available literature it is possible to identify a lack in representative data on the application of thermography in sports, and more specifically in swimming, which is the interest of this research.

This study aims to develop a methodology to investigate swimmers and verify whether there is a considerable increase in skin temperature during different swimming techniques (crawl and backstroke) and, if confirmed, to identify the most affected regions. The athlete's thermal symmetry was also assessed before and after swimming.

METHODS. The study was conducted on 10 active male swimmers, age (17.20± 0.90) and Body Mass Index (22.10± 1.30). The experimental procedures and recording took place in a covered swimming pool, with a length of 25 meters, with water temperature (26.4 ± 0.4 °C), room temperature (29.9 ± 0.8°C) and humidity (57.6 ± 3.2%). The participants have performed their activity in two consecutive days at the same time, being in the first day the technique crawl and in the second backstroke.

For the capture, it was used a FLIR A325 thermal camera, with spatial resolution of 320x240, a sensitivity of 70mK and an accuracy of ±2% of overall . Full body thermograms of different views were recorded: anterior, lateral (right and left) and dorsal.

The capture protocol consisted of the swimmer being subjected to a 10 minutes acclimatization period in the pool, maintaining a static position and immersing all partsof the body, except the head. To avoid the negative influence of water in thermograms, the swimmer was quickly dried with microfiber towels, avoiding any friction.

RESULTS AND DISCUSSION. Regarding the differences in temperature distribution associated with exercise, in all ROIs the ΔT is greater than zero, which indicates an increase in skin temperature.

The regions with higher ΔT, for both techniques, are the upper limb (arm and forearm) and upper trunk region (thoracic, upper back and middle back).

Although the abdomen and lower back are located in the trunk, they do not indicate significant differences in temperature, as well as, in the neck and leg regions.

The temperature difference between left and right regions did not exceed more than 0.5°C for all ROIs. These differences were expected due to the health condition of athletes and also because the swimming techniques performed are symmetric.

Figure 1
Skin Temperature (Tsk) evolution of Knee area in aerobic and anaerobic training before exercise (1), Immediately After Exercise (2) and each hour during the recovery period (2+n) (n=14)

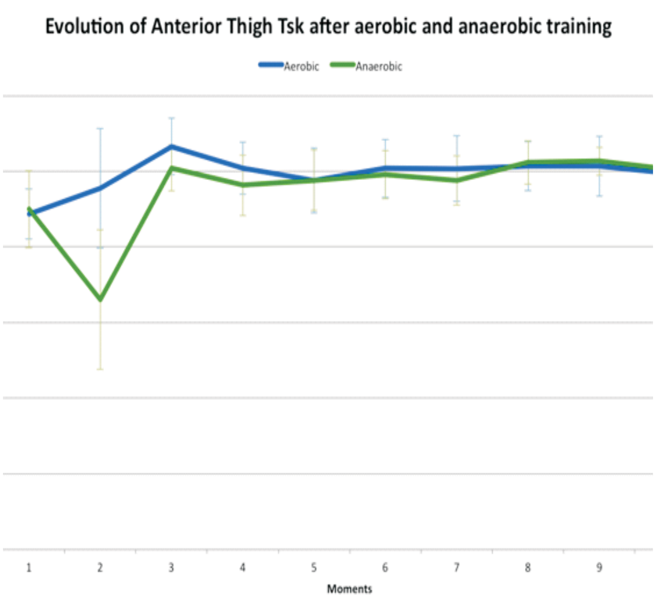

Figure 2:
Skin Temperature (Tsk) evolution of Anterior Thigh area in aerobic and anaerobic training before exercise (1), Immediately After Exercise (2) and each hour during the recovery period (2+n) (n=14)

Both techniques significantly increased skin temperature in every region of interest ($p<0.05$) but technique discrimination was not possible since no significant differences. From the analysis through the Related-Samples Wilcoxon Signed Rank Test we can observe that there is statistical evidence ($p<0.05$) for every ROI between pre and post exercise.

Differentiating swimming techniques through the ROIs and delta-T (post-pre exercise) was not possible due the absence of statistic evidence in avoiding the null hypothesis ($p>0.05$) with the Independent-Samples Kruskal-Wallis Test. No significant differences were found between the two techniques.

CONCLUSION. In this study, standardized medical thermal imaging has proven to be a useful tool to evaluate temperature differences after sports activity. A new methodology was developed and assessed. With this technique, it was possible to identify the ROIs that presented an increase in skin temperature that may be associated with muscle activity and to confirm that front crawl and backstroke when properly performed might present a symmetric pattern.

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KEYWORDS. backstroke, front crawl, medical thermal imaging, swimming, thermal symmetry.

IS IT POSSIBLE TO CREATE A THERMAL MODEL OF WARM-UP? MONITORING OF THE TRAINING PROCESS IN ATHLETIC DECATHLON

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INTRODUCTION. The decathlon consists of 10 separate track and field events completed in sequence over two consecutive days. Apart from the complexities of the organization of training and technique development, an equally important challenge for both the athlete and coach is the structure of the warm-up given the different movement patterns and energetics of each event to maximize performance [1]. Technological innovations such as thermal imaging are increasingly being used by sport scientists to enhance an athlete's performance. In order to maximize the benefit of a discipline-specific warm-up, the aim of the present study was to characterize track and field athletes' thermal imaging portrait following warm-up for the various track and field events in decathlon.

METHODS. Ten national level Polish male decathletes (19.9 ± 3.0 yr, 187.9±4.7 cm, 82.7±6.7 kg) participated in the study. Each subject was imaged using of FLIR A325 camera. Total body thermograms excluding the head were recorded in the anterior and posterior view.

Thermal imaging of each athlete was undertaken three times and analysis was carried out for following kinds of activity: rest after adaptation to ambient temperature (REST), immediately after general warm-up (GWU), and immediately after specific kinds of warm-ups: 60 m run (SPRINT), 60 m hurdles run (HURDLES), long jump (LJ), high jump (HJ), pole vault (PV), shot-put (SP).

In the recorded thermograms we analysed the average skin temperature (Tsk) in five body regions of interest (ROIs) in anterior and posterior view: calf, thigh, trunk, arm and forearms. Changes in skin temperatures between resting skin temperature, following the general warm-up, and following the specific warm-up were analysed using one-way analysis of variances (ANOVA) and post-hoc analysis undertaken by means of the Tukey's honest significant difference test. Dependences between the sports-level (the result in decathlon) of competitors and the changes of temperature were qualified by means of Pearson correlation coefficient.

RESULTS AND DISCUSSION. Highest observed individual differences referred to long jump, where the difference in the thermal reaction between the examined persons exceeded 4.5°C.

Considering the kinds of warm-up, the most homogeneous (i.e. lowest standard deviation) temperature change was obtained after the preparation for the SP. In all, but one athlete, GWU caused a decrease in Tsk. Reactions of temperature rise were however rare. Six decathletes, independently from the kind of activity, reacted with fall the in Tsk. The specific HJ warm-up proved to be the only physical activity which caused a similar reaction in all examined subjects characterised by a fall of in Tsk. The decrease in temperature after HJ and also after PV warm-up, was the largest in all performed activities, visible in both investigated body views (-1.78°C - anterior and -1.99°C posterior).

Analysing ROIs, the least variability of results (lowest SD) was noted on the trunk and thighs. Mean skin temperature computed from all ROIs changed between resting state and the following measurements. For all kinds of warm-up differences were significant and crossed one Celsius degree. Higher ranks in decathlon competition, was correlated with the greater drop in temperatures after specific warm-up ($r=0.62$; $p<0.05$).

The current finding of a large individual variation in skin temperature changes following both the GWU and specific WU, suggest the need for individual optimization of event preparation to maximize the subsequent performance and minimize the risk of injury.

CONCLUSIONS. 1. In decathlon events characterized by different specificity of the effort, some differences were observed in skin temperature changes overlying the exercised individual muscles 2. The obtained individual thermal reactions to the physical effort it could be used to adapt the warm-up on an individual basis. Further research is warranted with larger groups and among athletes of different performance levels, for the evaluation of the value of thermal imaging in monitoring athletic training.

KEYWORDS. thermography, decathlon, warm-up, thermal portrait

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SKIN TEMPERATURE DIFFERENCES BETWEEN AEROBIC AND ANAEROBIC TRAINING

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AIM. Skin temperature (Tsk) has been measured by Infrared Thermography (IRT) during and immediately after exercise [1]. Depending on the type of exercise and intensity, Tsk over muscle and joint areas changes, indicating the activation of these areas and the assimilation of workload [2].The aim of this study was to analyse differences on the Tsk response immediately after speed (anaerobic) and endurance (aerobic) training, and during 8 hours after.

METHODS: 14 physically active males (age: 21.44±2.64yrs; height: 1.78±0.04 m; weight: 73.23±7.63 kg) performed both an endurance [45' treadmill running at moderate intensity (60-75% MHR)] and a speed training [specific warm-up (Cometti, 1998) and 2 sets of 3 repetitions of 40 meters in an indoor track at a maximum speed, with 3 minutes of active recovery between repetitions, and 6 minutes of active stretching between sets (Bishop et al., 2006)]. Both training had similar duration. Tsk was recorded before the exercise, immediately after and once every hour during the 8-hour post-exercise period using an infrared camera (FLIR T335) under controlled conditions. Tsk from Thigh and Knee Region of Interest (ROI) were obtained by Termotracker® software and for tympanic temperature a ThermoScan® PRO-4000 was used. ANOVA multivariate analyses of repeated measures with training as inter-subject factor were carried out to find significant differences between both trainings.

RESULTS: ANOVA multivariate analyses revealed significant differences between anaerobic and aerobic training ($p<0.05$). Endurance training increased Tsk immediately after exercise [+1,35ºC (+4.8%) knee ($p<0.05$) and +0,2ºC (+0.6%) thigh ($p>0.05$)]. Nevertheless, Knee and Thigh ROI in speed training underwent the opposite evolution: a decrease on Tsk [-1.64ºC (-5.9%) Knee ($p<0.05$) and -1,35ºC (-4.6%) Thigh ($p<0.05$)].

CONCLUSIONS: Our results are similar to those relating the increased Tsk to constant and prolonged aerobic tasks [3] and those linking the decreased Tsk values to brief intense or maximal effort exercises [1]. In addition to the thermal differences immediately after exercise, warmer Tsk even 8 hours after exercise might be related to degree of assimilation of the exercise performed [4], and abnormal thermal responses or asymmetries could be related to overload and injury risk areas [5].Therefore, we suggest IRT as tool to monitor the assimilation of exercise workload and to prevent potential injuries by measuring Tsk after exercise and detecting abnormal Tsk patterns and asymmetries.

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KEYWORDS:Infrared Thermography, aerobic, anaerobic, speed training, endurance training, skin temperature, exercise assimilation, injury prevention

SKIN TEMPERATURE CHANGES OVER THE MEDIAL GASTROCNEMIUS AND TOTAL WORK DURING EXERCISE.

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Revised version of 12.04.2015

INTRODUCTION. Skin temperature distribution of the human body depends on the heat exchange between skin tissue, inner tissue, metabolic activity and local vasculature. Physical exercise implies the transformation of chemical energy into kinetic energy and thermal energy, generating heat that must be given away through the skin. The goal of this study was to evaluate the total work produced during an exercise of maximal exertion of the plantar flexors and relate that measurement with skin temperature changes measured by infrared imaging.

METHODS. Eight young and healthy adults volunteered to participate. The study was approved by a local University ethics committee and all participants gave their written consent to participate in the study and each participant was evaluated in a single day.

After a 15 minute acclimatization period, the exercise protocol was performed in an Isokinetic Dynamometer (Byodex System 4 Pro) and consisted of repeated movements of plantar flexion at maximal exertion (60º/s) and dorsiflexion (300º/s) until the participants performed three contractions of the plantar flexors with a torque value below 50% of the maximal voluntary contraction torque. Total work (J) values developed during the exercise were extracted from the dynamometer software.

The recommendations of previously published guidelines to capture thermal images were followed. Skin temperature measurements were performed before, during and after exercise (continuously, for 10 minutes). Thermal images were obtained using a FLIR A325 camera, calibrated, with a 320x240 resolution, 70mK sensitivity and ±2% accuracy. All images were recorded with the camera positioned below and medial to the leg being assessed, at a distance of 50 cm. Mean temperatures of the area of the medial gastrocnemius were computed.

RESULTS AND DISCUSSION. Regarding the correlation between the variables in study, skin temperature and total work produced during the exercise, the Spearman's correlation test evidenced a strong and significant correlation ($p=0.01$) between the skin temperature measured 10 minutes after the end of the exercise and the values of total work produced.

Exercise is responsible for heat production and during the recovery phase of the protocol skin temperature increased, indicating that heat was being dissipated to maintain thermal balance.

To our knowledge no study has assessed this relationship but others have found a significant correlation between skin temperature changes and energy expenditure after a 90 minute endurance exercise suggesting that skin temperature measurement could be a useful parameter to assess physical conditioning.

CONCLUSION. Skin temperature above the medial gastrocnemius 10 minutes after the exercise strongly and significantly correlates with total work produced during the protocol. Skin temperature may be a good parameter to estimate the athlete's total work produced.

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KEYWORDS. Muscle work, skin temperature, isokinetic exercise, thermal imaging.

CHANGES IN SKIN TEMPERATURE AND THERMAL SYMMETRY INDUCED BY A PHYSIOTHERAPY OCCUPATIONAL TASK.

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Revised version of 12.04.2015

INTRODUCTION. Physiotherapists perform several tasks that increase the risk of acute or cumulative "work-related musculoskeletal disorders" (WRMD) such as transfer and lifting patients, assisting patients in gait and passive mobilization. The overload induced by occupational tasks challenges thermal balance and induces skin temperature changes. Current evidence lacks research regarding the occupational demands imposed to physiotherapists using objective outcome measures. Therefore, the aim of this study is to propose a methodology of assessment and analyse the effect of a passive mobilization technique in the skin temperature of the neck and shoulder of the subject performing the mobilization.

METHODS. Four final year male students of a physiotherapy course were recruited. The study was approved by the ethics committee of the Fernando Pessoa University and all participants gave their written consent to participate in the study. Each participant was evaluated a single day in which three skin temperature measurements were performed.

Thermal images were obtained using a FLIR A325 camera, calibrated, with a 320x240 resolution, 70mK sensitivity and ±2% accuracy.

The recommendations of previously published guidelines to capture thermal images were followed. After a 15 minute acclimatization period the thermograms of the upper back were obtained before, immediately after and 5 minutes post-mobilization task performed at a rate of 20 mobilizations per minute, during 4 minutes. The frequency of mobilization technique was standardized using an electronic metronome. The region of interest selected for analysis was located in the area of both upper trapezius muscles (Figure 1).

RESULTS AND DISCUSSION. Immediately after the mobilization task, skin temperature in the dominant upper trapezius muscle area decreased in two subjects, remained the same in one subject and increased in one subject. Five minutes after the mobilization task, skin temperature had increased in all subjects for at least 0.6°C.

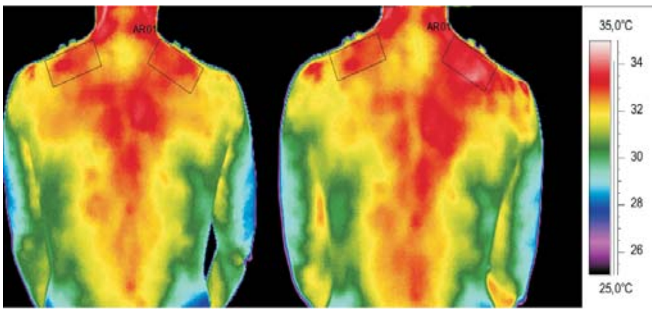

Figure 1
Regions of interest at the trapezius muscle, images have been recorded prior and past performing a mobilization task

Thermal symmetry values were affected by the mobilization task, increasing immediately after mobilization and even more 5 minutes after the task. The lowest value was 0.80°C.

Thermal imaging has been used in the occupational setting but not specifically to assess a physiotherapy task. The main findings of this study were that skin temperature changes in the dominant and in the non-dominant sides were distinct. In the dominant side, that performed the mobilization, skin temperature increased in all subjects after five minutes but not in the non-dominant side.

Thermal symmetry values reflected the increase in skin temperature observed in the dominant side as a result of the mobilization task. In our study thermal symmetry values before the mobilization were 0.23±0.19°C, which are in line with previous research, but the value increased 0.80±0.22°C and 1.03±0.26°C immediately and 5 minutes after the task, respectively. According to the literature, thermal symmetry values above the maximum found in reference samples can be used to assess musculoskeletal injuries that manifest unilaterally, affecting skin thermal patterns.

CONCLUSION. Considering the limitations of the study, the proposed methodology to assess skin temperature provided objective physiologic measurements associated with microcirculation during the chosen occupational task. The passive mobilization technique increased the skin temperature in the upper trapezius and affected thermal symmetry. Regular assessment of these professionals may contribute to early detection of exposure to overload conditions.

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KEYWORDS. Passive Mobilization, thermal symmetry, skin temperature, work-related musculoskeletal disorders.

Session 3-2 Biomedical Applications. Pain syndromes of the locomotor system

USING THERMOVIOSION IN EVALUATION THE EFFECT OF ISOMETRIC AND CLASSICAL MASSAGE ON SELECTED PHYSIOLOGICAL AND BIOMECHANICAL PARAMETERS OF LOWER LIMBS

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Revised version of 03.04.2015

INTRODUCTION. Dynamic development of physiotherapy make the necessity to look for new indicators to achieve information of effectiveness of therapy. There are a lot of methods using in supporting sports training. One of them is isometric massage - hand massage performed on tense muscles. The aim of the study was to establish a relationship between temperature of surface of front of thighs and strength, power and, bioelectric potential muscles quadriceps femoris after isometric and classical massage.

METHODS. 44 women, aged 19-23 (randomly allocated into two groups) were participants of the research. Camera Flir A325 was used for thermographic picture. Maximal torque was measured on the dynamometric Sumer UPR-02 arm-chair. Measurement of the surface electromyography was done with the utilization of the telemetric system Trigno 16ch All tests were used twice - before and after the massage (isometric - Group 1 and classical - Group 2) of muscles quadriceps femoris.

RESULTS AND DISCUSSION. After the massage temperature of skin on front of thigh significantly increased ($p<0.001$). Temperature of surface of lower limbs (unmassaged parts) also increased. There were significant differences in peak torque in Group 1 ($p<0.05$) and no differences in Group 2. There were no significant differences in bioelectric activity of examined muscles.

CONCLUSION. Isometric massage had influence on skin temperature of thigh and peak torque of muscles. Classical massage had influence on surface temperature, but it is not enough to prepare to physical activity without warm-up activity.

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KEYWORDS.
thermography, isometric massage, classical massage.

COMORBIDITIES ASSOCIATED WITH HIP PAIN: ASSESSMENT BY THERMOGRAPHY

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Revised version of 13.04.2015

INTRODUCTION. Hip pain is a common complaint that can be caused by a wide variety of problems. The precise location of hip pain can provide valuable clues about the underlying cause. Problems within the hip joint itself tend to result in pain on the inside of hip or groin. Hip pain on the outside of hip, upper thigh or outer buttock is usually caused by problems with muscles, ligaments, tendons and other soft tissues that surround hip joint. The aim of this study was identify clinical characteristics of hip pain using the combination of clinical findings associated with ultrasonography and total body thermography documentation.

METHODS. There were clinically evaluated 89 patients with hip pain, aged 45.82 ± 14.04 years. Were included only patients who had lesions confirmed by ultrasonography (US) and documented by infrared thermography, IR (FLIR T650sc, USA). Before IR e physical evaluation, all were submitted to ambient thermal equalization of 23º C, 55% R.H. for 15 minutes to take thermography images. Then was carried a capture sequence of 40 thermal images of totally naked entire body. Patients were instructed not to use drugs, alcohol, abstain from smoking or physical therapy until the day before the exams, following the Brazilian Association of Medical Thermology (ABRATERM) protocol.

RESULTS AND DISCUSSION. All patients had lesions related to hip pain that were confirmed by US and documented by thermography. In this study were identified 21 trochanteric (Figure 1), 26 iliopsoas and 31 hamstrings´s myofascial lesions and 45 of other nature (gluteal, piriformis), all confirmed by US and documented by IR imaging. Most lesions were present in males (59 cases). Considering only a significant confidence interval, subjects older than 50 years were more likely to have lesions with thermal changes in trochanter (OR = 3.39, CI 1.22 to 9.39), iliopsoas (OR = 3.70, CI 1.42 to 9.63) and hamstrings (OR = 2.18, CI 0.90 to 5,35) than younger subjects.. And women were more likely to have trochanter (OR = 2.83, CI 1.03 to 7.76) and iliopsoas injuries with thermal changes (OR = 1.69) and less than hamstrings injuries with thermal changes (OR = 0.72, CI 0.28 to 1.85) when compared to men.

CONCLUSION. This study with ultrasonography confirmation and total body thermography documentation shows that the prevalence of injuries to the hip follows a distinct pattern by age and sex. The greatest characteristic for hip pain injuries with thermal changes was most often frequency in women over 50 years, and the most prevalence in the anterolateral extent, including particularly iliopsoas and trochanteric lesions with thermal changes.

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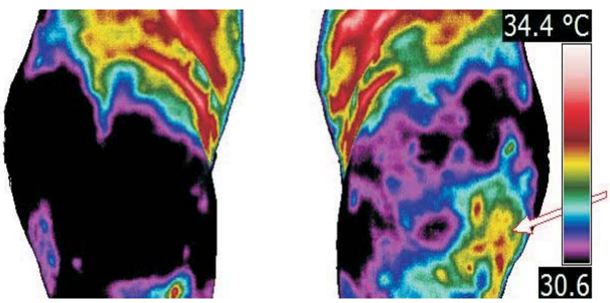
KEYWORDS. thermography, pain, hip, myofascial, injuries.



THERMOGRAPHIC EVALUATION OF LATERAL EPICONDYLITIS IN PATIENTS WITH FIBROMYALGIA SYNDROME.

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Revised version of 13.04.2015

INTRODUCTION. Lateral epicondylitis can be most distressing. A long duration of elbow complaints at baseline is an indicator of poor prognosis. Severe symptoms and concomitant neck pain at baseline, the two remaining indicators, raise the possibility that some of these patients and perhaps some of the patients with long-standing pain as well, had fibromyalgia. The aim of this study was identify risk factors associated with lateral epicondylitis in patients with and without fibromyalgia syndrome assessed by the standard clinical evaluation associated with total body thermography documentation.

METHODS. There were clinically evaluated 42 patients with lateral epicondilytis, aged 49.95 ± 11.83 years. We included only patients who had the focus of tenderness in the epicondyle, and pain at resisted extension of the hand. All the cases were documented by infrared thermography (FLIR T650sc, USA) and confirmed with ultrasonography (US). Before the physical evaluation, all were submitted to ambient thermal equalization of 23º C, 55% R.H. for 15 minutes to take thermography images first. Then was carried a capture sequence of 40 thermal images of totally naked entire body. Patients were instructed not to use drugs, alcohol and to abstain from smoking or physical therapy until the day before the exams, following the Brazilian Association of Medical Thermology (ABRATERM) protocol.

RESULTS AND DISCUSSION. All patients had lateral epicondilytis that were documented by thermography and US. The most common thermal changes associated with lateral epicondylitis were posterior cervical muscle spasm (29) and thermoreg ulatory disorders signs related to fibromyalgia (13) confirmed clinically. Among these disorders in patients with fibromyalgia were present the trunk hyper-radiation (mantle signal, Figure 1), distal hypo-radiation (vasospasm, cold hands) and periocular hyper-radiation (periocular congestion by poor quality of sleep).

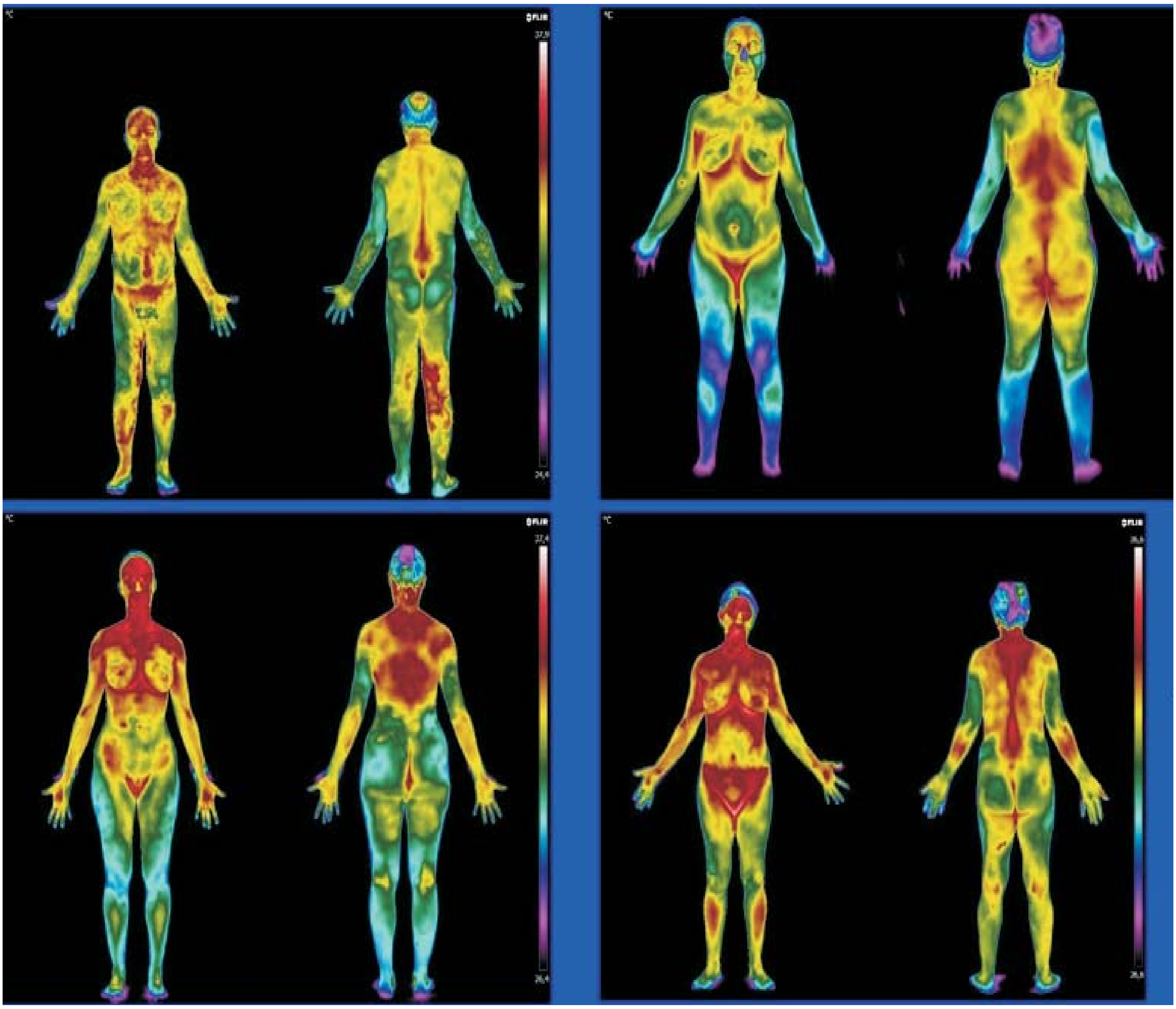

Figure 1.
Full body thermography. First line, normal pattern.
Second line, fibromyalgic patients with thermoregulatory disorders represented by the mantle signal.

The senescence appeared as a protective factor for fibromyalgia. Younger subjects with lateral epicondylitis were 4.28 times more likely to suffer from fibromyalgia than subjects older than 50 years (OR = 0.234, CI 0.06 to 0.95).

CONCLUSION. This thermographic study suggests that the prevalence of fibromyalgia syndrome associated with lateral epicondylitis is higher in young patients below 50 years, further studies are necessary to confirm this.

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KEYWORDS. thermography, pain, lateral epicondylitis, fibromyalgia, thermoregulation.

INFRARED THERMOGRAPHY AND SHOULDER PAIN IN ATHLETES AND SEDENTARY WHEELCHAIR USERS

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INTRODUCTION. Infrared thermography has been recently studied in wheelchair users (WCUs) as a new technique with which to advance in the study of this population. WCUs present a high prevalence of shoulder pain entailing functional loss and reduction in mobility that leads to negative social consequences.

The objective of this study is to relate shoulder pain to the upper body temperature.

METHODS. The "Wheelchair Users Shoulder Pain Index" (WUSPI) questionnaire was administered to a total of 29 manual WCUs. Sixteen of whom were paraplegic, 4 tetraplegic and 9 presented with other impairment or disease (amputee, sclerosis multiple, and poliomyelitis). Skin temperature (Tsk) of 22 areas of interest (ROI) of the upper body in anterior and posterior views were measured using a FLIR T335 imager and following standard protocols according to the Glamorgan protocol (T_{mean}=18.9; SD=1.8). Thermograms were taken in anatomical position with the participants sit on their own wheelchair. ROI were manually selected by a trained thermographer. Maximum and average temperatures were extracted using ThermaCam Reporter of FLIR.

Descriptive statistics were calculated (mean±SD) to organize and summarize the data. Side-to-side skin temperature differences (δTsk) were calculated for each area by subtracting the mean temperature of the right side from that of the left side. A correlation analysis between both local Tsk and δTsk with the WUSPI's results was performed.

RESULTS AND DISCUSSION. The sedentary participants presented a significantly higher WUSPI scores (W=18.8; SD=17.2) than the athletes (W=5.9;SD=6.7) ($t(27)=3.05$; $p<0.01$). The Tsk values and δTsk for Sedentary WCUs were not significantly different to the Athletes for all the considered ROI. There were not correlation between the WUSPI and the Tsk and δTsk for any ROI.

For understanding the results, it should be considered that the WUSPI does not take into account the laterality of the shoulder pain. Additionally, the WCU use both hands for propulsion, therefore there should not be any asymmetry due to their daily physical activity.

CONCLUSIONS: Tsk and δTsk results are not related with the WUSPI Test scores of WCU in any physical activity condition.

KEYWORDS. Upper extremity, athletes, disability, spinal cord injuries, rehabilitation.

Abstracts -Poster

Poster Session 1: Miscellaneous animal and biomedical applications

ASSESSMENT OF STRESS RECOVERY BY THERMOGRAPHY

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INTRODUCTION: Bravo de Lide is an autochthonous bovine breed, raised mainly in the center and south of Portugal. After three to five years living in extensive farming conditions, with minimum contact with humans, the day prior to bullfight represents a phase of different stress periods for the animals. Namely, we can highlight the transport from the farm to the bullfight ring facilities and the specific preparation for the bullfight. In Portugal, the tauromachian regulation imposes that horns are cut and coated with a leather protection, a procedure named "embolação", which serves the purpose of preventing major injuries to horses and bullfighters. In this work, our goal was to evaluate stress recovery of bulls during the regulatory resting time, after the two referred periods of stress.

METHODOLOGY: Stress recovery of thirty Bravo de Lide bulls was assessed by thermography before and 15, 30, 45, and 60 minutes after transport and "embolação",using a FLIR E60 thermographer and FLIR® (FLIR Tools™ PC software) software analysis. Skin temperature of the thoracic-lumbar region was measured with the animals in the truck, before starting the transport and at destination, and in the bullfight ring facilities, protected from sunlight exposure and air flow.

RESULTS AND DISCUSSION: Our results revealed that after transport there were individual variations concerning stress recovery. However, all the animals presented base line values of skin temperature after 30 minutes of resting (26.5ºC±0.5). Similarly, we observed individual variations concerning stress recovery after "embolação". Although most animals presented base line values of skin temperature after 30 minutes (28ºC±1.5) of resting, animals who offered greater resistance to restraint showed longer periods of stress recovery. Altogether, our results showed that the regulatory resting period imposed by the tauromachian regulation after transportation and "embolação" has the duration needed for stress recovery, respecting animal welfare, which is indispensable to the expected performance during the bullfight.

CONCLUSIONS: Thermography can be considered a reliable non-invasive method for assessing stress recovery and to confirm the animal welfare status, and it is particularly useful in situations where minimum physical interference is required as in the case of Bravo de Lide breed animals during standard management procedures prior to the bullfight.

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THE EFFECTIVENESS OF THERMOGRAPHY AS AN ASSESSMENT TOOL FOR FLAP ENGRAFTMENT IN A DOG

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INTRODUCTION: Among many various tasks veterinary nurses do, observing wounds is an important practice for veterinary nursing. As for the surgical wounds, to prevent complications such as infection or dehiscence and to promote wound healing, care according to the observation of the wounds is needed. It is important to evaluate the wound objectively and assess where the wound is in the healing process. And also, in order to discover abnormal state of the wound at the early stage, pain or discomfort patients signal are important information. However, in the process of veterinary nursing where it is difficult to get signals of symptoms from animals, early detection of abnormal states by the observation is needed.

In the field of human medicine and nursing, thermographic inspection is reportedly more efficient in the assessment of the wound healing process and the prediction for the healing process compared with macroscopic examination. Thermographic inspection is used as the method of objective evaluation in managing wounds and skin diseases in order to make abnormal skin temperature visualized by measuring surface temperature.

Now, we are considering whether we will be able to use thermography as an efficient tool for observing in the veterinary nursing. This time we monitored the flap engraftment of a dog. In this process it has been investigated whether thermography is efficient in observing the flap of a dog.

METHODS: We adopted the thermography a 8-year-old female dog with soft tissue sarcomas on her right hip. A pedicle skin flap was transferred to the hip to cover the epithelial defect area from lateral region. In this case, 3times of debridements and re-sutures were done for about 4months by the time the flap took root completely.

We observed the wound healing process by using thermography until the flap took root. During hospitalization we observed the flap when the bandage exchange after the discharge we observed the flap when the owner the dog took to the hospital in the same room. Then we recorded rectal temperature, ambient temperature and humidity of current day. After calculating the temperature difference between the flap and normal area around it, we investigated the thermograph with the wound healing process.

RESULTS: An ulcer was formed on the tip of the flap. We found that a part of the ulcer became necrotic, debridement and re-sutures were done until the ulcer was healed. We began to observe the wound by thermography 4days before the 2nd surgery. We found some granulation on the ulcer and thermography showed higher temperature on the granulation than on the surrounding area.

On the 6th day after the 2nd surgery, thermography showed lower temperature on the granulation and the sutured part than on the surrounding area. Then, thermography found the area

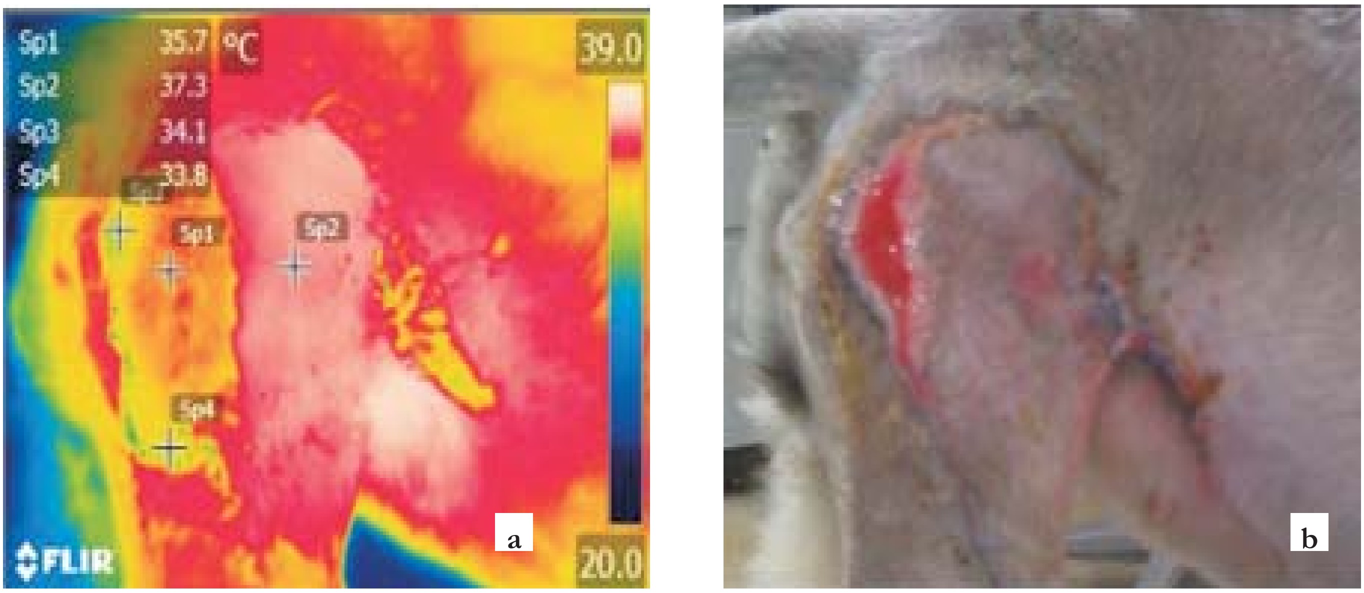

Figure.1
Thermography (a) and macroscopic examination(b)

Figure.2
Thermometric point in the flap

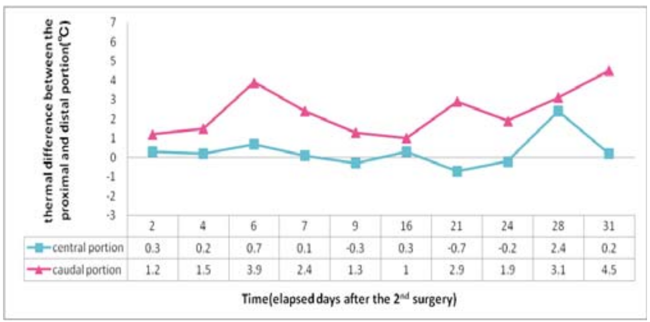

Figure 3
Thermal difference between the proximal and distal portion in the flap The diagram shows the thermal difference between the proximal and distal portion in the flap, the caudal and central portion in the distal portion during the 2nd surgery and the 3rd surgery.

with low temperature becoming smaller while the ulcer was shrinking. Thermography showed the same temperature on the flap except the ulcer as on the surrounding area.

On the 24th day after the surgery, we found the ulcer expanding and thermography showed the expansion of the low temperature area. On the 28th day after the surgery, the ulcer became a little smaller, but thermography showed low temperature on the redness except the ulcer. The ulcer was covered by the granulation tissue. We thought the wound was so large that it would take a lot of time for us to heal it by its shrinkage, so primary veterinarian planned to do debridements again.

On the 4th day after the 3rd surgery, we found some redness on the sutured part. Thermography showed low temperature on the sutured part and the surrounding area widely. On the 11th day after surgery, the redness reduced on the wound and also thermography showed the reduction of the low temperature area. Then, Thermography showed the same temperature on the sutured part as surrounding area. On the 53rd day after surgery, we found some epithelial defect area on the sutured part. Thermography showed low temperature on the sutured part clearly. We thought there was some possibility of the reappearance of sarcomas. Therefore, again we planned to do surgery.

On the 10th day after the 4th surgery, there was dehiscence on some of the sutured part. We found granulation forming and exudate fluid. Thermography showed low temperature unevenly on the sutured part and the surrounding area. On the 11st day after surgery, epithelialization ended on the wound and the treatment finished. Thermography showed

DISCUSSION: We worked out surface temperature of the wound in each process during 4 surgeries. Thermographically the distal portion of the flap, including caudal and central portion had lower temperature than the proximal portion during all processes. Before the 3rd surgery, the temperature of the caudal portion of the distal portion was 4.5? lower than that of the proximal portion (Fig.2,3). The ulcer was formed on the distal portion of the flap. Until the healing the wound was excised and sutured repeatedly and so when we notice big difference of temperature, especially low temperature, we need to think that there is possibility of the worsening condition such as defect of engraftment.

We didn't close the ulcer on the tip of the flap and treated it while it was open wound, because there was epithelial defect area widely. On the ulcer we found the good granulation formation and epithelialization by the use of external preparation and drainage material according to the disease stage. Until the 21st day after the 2nd surgery, we found the ulcer becoming smaller gradually, on the 24th day after surgery we found the wound becoming worse because of the outer stimulus. We found the ulcer expanding and infusion oozing out. On the 24th day after surgery, we found the red area around the ulcer. Interestingly, on the 24th day thermograph showed low temperature on the flap and then the part became red on the 28th day. In the field of human nursing, it is suggested that the thermographical assessment can identify delayed pressure ulcers by evaluating inflammations we can't find on inspection. The veterinarians concluded that it was difficult to heal the ulcer while it was open. Therefore, we can understand indication of delayed wound healing by thermography earlier than by ocular inspection in this case where the ulcer was excised.

CONCLUSIONS: Thermographic assessment of a flap may be efficient in a evaluating the wound healing process, which can be a useful tool to observe wound in the veterinary nursing.

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KEYWORDS: thermography, flap, veterinary nursing, wound healing

CASE REPORT-THERMOGRAPHIC EVALUATION OF A PATIENT WITH LYMPHEDEMA OF THE UPPER LIMB AFTER MASTECTOMY

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Revised version of 12.04.2015

CASE DIAGNOSIS: Lymphedema of the upper limb

Mastectomy following breast neoplasm.

CASE DESCRIPTION: This is a case of a female patient (50 years old) diagnosed with breast neoplasm in July 2014 following routine examination.

After the diagnosis the patient underwent surgical treatment with favorable clinical and functional evolution.

The patient began standard chemo-radio therapy following surgery, with relatively good tolerance.

Four months later, she developed lymphedema of the upper limb. The patient was referred to the rehabilitation clinic for functional assessment and specific therapy.

Clinical examination revealed increased volume of the limb, edema, and change in peripheral temperature, pain and limited range of motion.

METHOD: After evaluation the patient received a rehabilitation program for 2 weeks, 1 time per day. The rehabilitation interventions included lymphatic drainage massage and mobilization of the limb.

Thermographic evaluation was performed at the beginning and at the end of the treatment, and at 5 days, using Glamorgan protocol. For the caption of images we used thermographic camera Flir 4.

RESULTS: We compared the measurements at the beginning and at the end of treatment, using area temperature of arm and forearm. We compared temperatures both in the affected and healthy limb, and also we assessed anterior and posterior side, arm and forearm.

		Before treatment		**After treatment**	
		impaired	healthy	impaired	healthy
anterior	arm	34.4°C	34.2°C	34.0°C	33.9°C
	forearm	34.1°C	34.1°C	34.2°C	33.9°C
posterior	arm	33.2°C	32.8°C	32.6°C	32.5°C
	forearm	33.9°C	32.6°	32.5°C	32.°&

CONCLUSIONS: After 5 days of treatment the volume of the limb has decreased, improvement in range of motion and peripheral temperature assessed with thermografic evaluation.

We observed an improvement in the affected limb of -0,4 degrees(anterior side);-0,6 degrees(posterior side) as shown in the table above.

DISCUSSION: This type of pathology limits finding the best therapeutic option, and having in mind the increased incidence of breast cancer in Romania, we are twice motivated to have better results in our approach.

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ABSENCE OF ALTERATIONS IN CUTANEOUS TEMPERATURE DURING THE PHASES OF MENSTRUAL CYCLE.

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INTRODUCTION. Female reproductive hormones can affect the body's thermoregulation mechanism1. This study aims at verifying if there are significant changes in the cutaneous temperature of the lower abdomen, navel, lumbar region, and buttocks during the various phases of menstrual cycle in young women.

METHODS. Thermographic images of the lower abdomen, navel, lumbar region, and buttocks of 8 women (24.7±5.8 years, 52.6±6.1 kg, 158.2 ±2.10cm) were recorded during 4 weeks in order to measure the temperature at all phases of menstrual cycle.The images were captured at the same hour in a specific laboratory, at ambient temperature of 23° and ±40% of relative humidity of the air, and monitored by a digital thermo-hygrometer (model ITHT-2250, Instrutemp®, Brazil).All women underwent a 15-minute period of acclimatization in standing position, dressed in a bikini. To capture the images we used a thermal imager (model T-360, FLIR®, USA) positioned in parallel to the floor, at a 90 ° angle and 1 m away from the regions of interest. The participants remained in standing position at the time of image capture. We registered one image in front view, containing the regions of navel and lower abdomen, and one image in posterior view, containing lumbar region and buttocks.The mean temperatures of the regions analyzed in this study were obtained by using the FLIRQuickReport software and then analyzed using the SPSS 20.0 program. Data normality tests (Shapiro-Wilk) were performed, followed by a repeated measures ANOVA.

RESULTS AND DISCUSSION. There was no significant difference in mean cutaneous temperature of the lower abdomen, navel, lumbar area, and buttocks. The isolated analysis of the buttocks showed a significant difference ($P = 0.05$) of 0.86° only in the left buttock between the luteal (29.37 ± 0.31 °) and ovulatory (28.51 ± 0.29 °) phases.

Thermography has been widely used in aesthetic physical therapy to detect the microcirculatory changes that occur in some aesthetic disorders, such as gynoid lipodystrophy. Knowing the cutaneous thermal changes occurring in women during the menstrual cycle is important to avoid misdiagnosis due to hormonal changes. Some studies1,2 have argued that estradiol, follicle-stimulating hormone (FSH), luteinizing hormone, and progesterone, the four hormones that characterize the woman's menstrual cycle, have a significant effect on body temperature. According to Rao and Sha2, estradiol induces increased vascularization in the breasts during the preovulatory period, causing a corresponding variation in skin temperature. However, these changes were not observed in the areas analyzed in this study, except for the left buttock. We believethat this is due to the small sample size and the lackof monitoring regardingthe participants' contraceptive intake.

CONCLUSION. In this sample, there was no significant difference in the cutaneous temperature of the lower abdomen, navel, lumbar area, and buttocks. For future studies, we suggest monitoring changes in core temperature and comparison with skin temperature of other body regions, then correlating the results with blood hormone levels in order to obtain more conclusive results.

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KEYWORDS. Thermography, menstrual cycle, reproductive hormones

ASSESSMENT OF FEVER FOR INFECTION CONTROL USING THERMOGRAPHY ?FACIAL THERMOGRAPHY IN PATIENTS WITH FEVER

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INTRODUCTION. To control infections such as Ebola haemorrhagic fever, thermography can be used to monitor patients with fever resulting from infection. However, evidence-based cut-off levels for the thermographic index to reasonably discriminate patients with fever from healthy individuals have yet to be established. We therefore compared facial temperatures between patients with fever and healthy volunteers, as measured using the diagnostic standards advocated by the Japanese Society of Thermology, and reconsidered assessment for infectious control using thermography.

METHODS. Thermographic examination was performed in 50 healthy volunteers (23 males, 27 females; mean age, 25 years), 48 patients (28 males, 20 females; mean age, 40 years) with influenza A, 13 patients (9 male, 4 female; mean age, 35 years) with influenza B and 65 patients (43 male, 22 female; mean age, 29years) with the other pyrogenetic disease. Subjects were acclimatized for 20 min in an environment with a room temperature of 25.0-26.0°C and 40-50% humidity. Areas of the forehead, nose, right and left cheeks, and chin were measured by thermography, and mean temperature of these areas was regarded as the facial surface temperature. Axillary temperature was measured using a clinical thermometer. This study was performed with the approval of the Ethics Committee of Tenri Health Care University and Hyogo University of Health Sciences, and all human samples were collected after obtaining written informed consent.

RESULTS AND DISCUSSION. Facial temperatures of healthy volunteers were as follows: forehead, 34.7 ± 0.4°C; right cheek, 34.1 ± 0.6°C; left cheek, 34.1 ± 0.6°C; nose, 34.5 ± 1.0°C; and chin, 34.2 ± 0.6°C. In contrast, facial temperatures of patients with fever were as follows: forehead, 36.2 ± 1.4°C; right cheek, 36.0 ± 1.6°C; left cheek, 36.0± 1.7°C; nose, 36.2 ± 1.6°C; and chin, 36.5 ± 1.8°C. Facial temperatures were significantly higher for patients with fever than for healthy volunteers ($P<0.05$, Welch's t-test).

Secondly, we compared facial thermography with axillary temperature measured by a clinical thermometer in patients with fever. Significant correlations with axillary temperature were observed for the forehead ($R=0.27$), right cheek ($R=0.27$), left cheek ($R=0.26$), nose ($R=0.24$) and chin ($R=0.30$) ($P<0.01$, Spearman's correlation coefficient by rank test).

Facial temperatures of patients with fever were higher than those of healthy volunteers. However, some patients showed lower temperatures than some healthy volunteers. Furthermore, the correlations are not sufficiently strong to clearly detect patients with fever.

CONCLUSION. In our efforts to develop a universally accepted method for infection control, it would seem that thermography offers one of the more promising techniques. A new evidenced based standard of thermography for detection of patients with fever is necessary to avoid spreading pyrogenetic disease.

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KEYWORDS. Thermography, infection control, assessment of fever, patients with fever, Ebola haemorrhagic fever.

POSSIBLE APPLICATION OF TELETHERMOGRAPHY IN THE NON-INVASIVE STUDY OF THE "CANCERIZATION FIELD"

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INTRODUCTION: Introduction. The concept of Cancerization Field proposed by Slaughter for oral mucosa (1953) (1) can be applied to the dermatologic field. In fact, individuals chronically exposed to the sun could run, after the appearance of a tumor in some critical areas (e.g. temporal, fronto-parietal), the risk of a second tumor in the same site. Indeed, in these areas, many authors have demonstrated, significant preneoplastic alterations, respectively, at histological, immunohistochemical and biomolecular level (e.g. altered nuclei, p53 mutation, high number of CPD), without any clinical correspondence. Until now, it has been impossible to know when and where the second tumor will be clinically evident.

METHODS: Methods. The study included 30 patients chronically sun-exposed admitted to our Institute with a clinical diagnosis of actinic keratosis (AK). All the lesions were examined both clinically and by TTG, before their excision and histologic examination

RESULTS AND DISCUSSION: We found that most lesions (AK) showed a hyperthermic gradient (24/30 cases, 80%) whose values varied from 0.5°C to 2°C (mean 1.0°C). The remaining 6 cases of AK (16.7%) appeared as "cold" for the presence of squamous or crusts on their surface. However, in all 30 cases (100%), we noted a hyperthermic peri-lesional area recalling an image of a "halo", whose mean gradient was lower compared with that of the AK lesions (mean 0.76°C), and an extension that varied from a few mm to some cm (mean 2.46 cm2). In 5/30 patients we performed in parallel a second biopsy within the halo, and a third one outside it. The histologic pattern showed no keratinocyte alterations; only at dermal level, actinic elastosis. The immunohistochemistry showed a significant p53 and p17 overexpression in the area of the "halo" field, much less evident in the samples from outside it.

CONCLUSION: Our data seem to indicate the possibility that TTG could show an anomalous perilesional area around the AK, appearing as a hyperthermic halo. This pattern could be equivalent to Slaughter's CF, so indicating a pre- neoplastic condition. These initial observations have to be confirmed through a study involving more patients, including histological, immune- histochemical and bio-molecular studies (e.g. TP-53, procollagen-I, MMP-1 and Tn-C). If confirmed, TTG could be a very useful, non-invasive and easy to perform method for both epidemiological studies and the follow-up of operated subjects.

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EVALUATION OF THE EFFICACY OF INFRARED THERMOGRAPHY IN ASSESSING PERIPHERAL NERVE REGENERATION IN A RAT MODEL

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INTRODUCTION: The role of thermography in the realm of peripheral nerve injury is still a matter of intense debate. In acute lesions it is well known that peripheral nerve lesions cause peripheral vasodilation and thus increased skin temperature. However, the impact of chronic nerve lesions on skin temperature has led to conflicting findings by different authors and is still a matter of intense debate. This is unfortunate, since most people seek medical attention for chronic nerve lesions. In the present work we compared IR Thermography of the skin surface supplied by a given peripheral nerve of the rat forelimb with well-established techniques of the nerve regeneration assessment over a 3 month period, simulating a chronic nerve lesion.

METHODS: Twenty three rats were randomly assigned to one of the following groups: sham surgery (Group I), excision of 1 cm length of the right median nerve at the arm level (Group II), and the referred excision followed by nerve gap bridging with an autologous nerve segment (Group III). The rats were subsequently followed for 90 days, and evaluated every 15 days, using the following functional tests: walking track analysis, running velocity, pain sensitivity (von Frey filaments) and grasping test. At day 90, the rats were anesthetized with a mixture of ketamine and diazepam, and submitted to IR thermography of both forepaws and of both median nerves. The rats were placed on their back at the study room for 10 minutes before the thermographic acquisitions, at constant environmental temperature (in an interval of 19-24º C) and humidity between 50 and 60%. The temperature of the forepaw surface was measured using a FLIR® E6 camera with thermal sensitivity <0.06°C placed at an angle of approximately 90° and a 25 cm distance from the skin surface. Three thermographies were taken of each nerve and forepaw. Spot temperatures of the forepaw region were obtained,

Then, electroneuromyography was performed on both sides. Next, maximal wrist flexion strength was evaluated under tetanic stimulation bilaterally. At the end, rats were euthanized, the weight of both flexor carpi radialis muscles was determined, and nerve, muscle and brain tissue were removed for histological analysis (conventional, immunohystochemistry, and fluorescence microscopy).

RESULTS AND DISCUSSION: The results showed a significant difference in IR thermographic images for the 3 groups of rats, as it is represented in the images below. The mean temperature difference between the operated and non-operated paws was up to 9,0 ± 0,1 ?C, depending on technique used for nerve regeneration, while in the control group the same difference was 0,8 ± 0,5 ?C. The thermographic evaluations obtained in the 3 groups showed a good correlation with the results of the conventional techniques of peripheral nerve regeneration assessment.

CONCLUSION: IR thermography seems to be a suitable method for peripheral nerve injury evaluation in a rodent model of chronic median nerve lesion. As far as we could determine, this is the first study of the kind reported in the literature. The obtained results are very promising but lack validation by further experiments and other research groups.

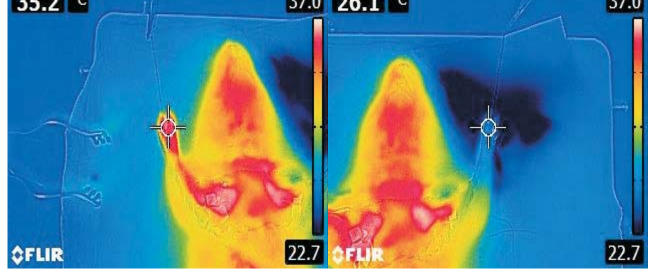

Figure 1
Representative thermographies of the skin surface of both forepaws of a rat from Group 2 (Excision of 1 cm length of the right median nerve)

STUDY OF THE FACIAL SURFACE SKIN THERMAL DISTRIBUTION BY INFRARED THERMOGRAPHY: FACIAL THERMOANATOMY

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Revised version of 13. 04. 2015

INTRODUCTION. Assignment of anatomical reference is a key step in diagnosis of facial diseases. Although thermography can assess physiological and functional aspects of the face such as microcirculation and autonomous nervous system function. It may determine a fixed hot landmark as the inner canthus of the eyes, which are related to the site of superficial supra-orbital vessels projections. The aim of this study was to identify, map and quantify facial thermo-anatomical points in a healthy adult population that can be used as a reference landmark for thermography studies.

METHODS. The volunteers were recruited at the clinic of Dentistry Faculty, University of São Paulo, Brazil. A hundred sixty-one volunteers of both gender and mean age of 63 ±15 years were included. The temperature at the facial area surface of over the thermal gradients was assessed by medical thermography, using regional frontal and lateral views. The volunteers were acclimatized in a room with a mean temperature of 23°C and a relative humidity of 60% for 15 minutes. Thermographic images were obtained following standard protocols of Brazilian Association of Thermology (ABRATERM). The thermo-anatomical points corresponded to the main heat sources of the face (Figures 1 and 2). The size points were represented by a defined circle with 6 mm diameter adjusted for each thermo-anatomical point of the facial thermogram.

RESULTS AND DISCUSSION. Twenty eight thermo-anatomical reference points have been identified in this study. The mean temperature threshold of the points ranged from 33.3°C to 35.6°C and the thermo-anatomical point location correspond of 94.6% in the sample ($p<0.05$). There was no statistically significant difference between the mean and maximum temperature of the thermo-anatomical points in these healthy individuals related to ages and sides of each point, except when compared by gender and racial groups ($p<0.05$).

CONCLUSION. The face has trusted and fixed thermo-anatomical points, which can be assessed as reference for thermography analysis. There was a difference between gender and racial groups when compared them to the thermo-anatomical point temperatures.

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KEYWORDS. Thermography, Anatomy, Face, Dentistry.

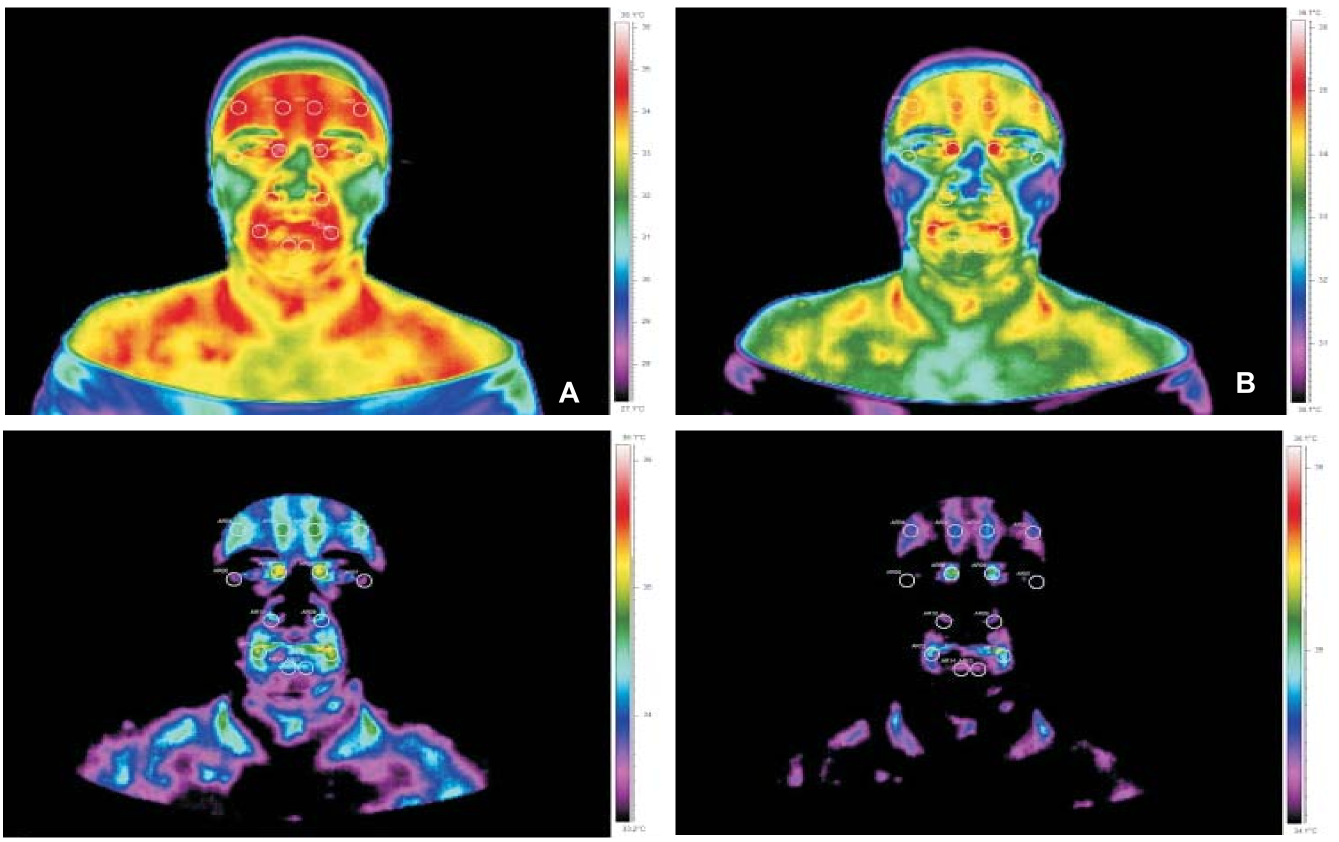

Figure 1
Thermograms sequence for the identification of thermo-anatomical points (front view).

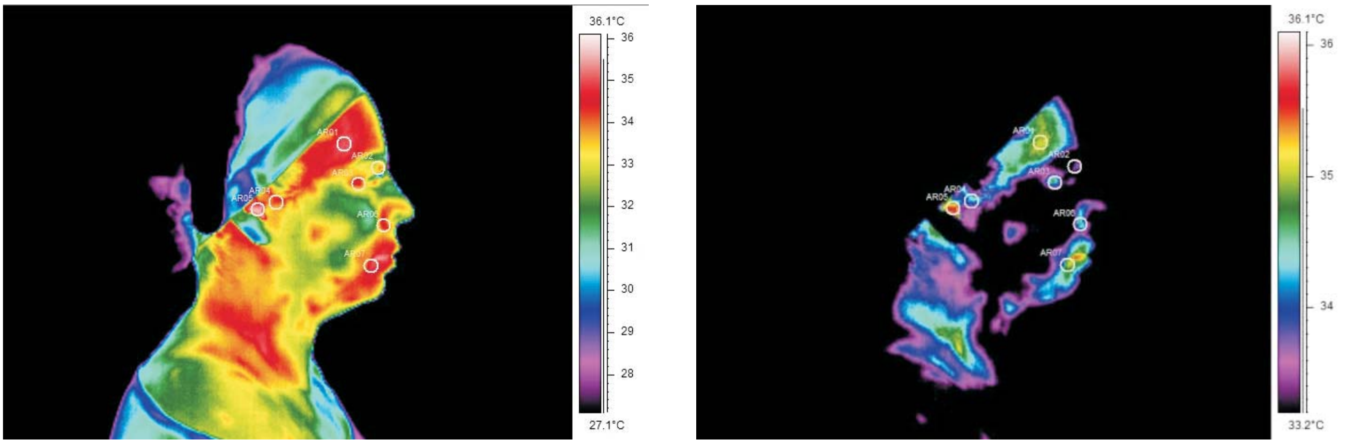

Figure 2
Thermograms sequence for the identification of thermo-anatomical points (lateral view).

EXPERIMENTALLY INDUCED PAIN ELICITS AUTONOMIC AROUSAL IN HEALTHY SUBJECTS.

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Revised version of 12.04.2015

INTRODUCTION: Pain is a hard to study, unpleasant and subjective experience. Experimentally inducing noxious stimuli has been referred as one of the most accurate and safe way to study pain mechanisms. Cold pressor pain, induced by the submergence of the hand in cold water, is said to mimic the effect of chronic conditions very effectively because of the unpleasant feeling reported by the subjects. The aim of this study was to investigate facial skin temperature responses induced by a cold pressor test.

METHODOLOGY Nine healthy subjects were recruited from the local community and were evaluated by thermal imaging before and after a cold pressor test. The study was approved by the ethics committee of a local University and all participants gave their written consent to participate in the study. Each participant was evaluated a single day in which two skin temperature measurements were performed.

Thermal images were obtained using a FLIR A325 camera, calibrated, with a 320x240 resolution, 70mK sensitivity and ±2% accuracy.

The recommendations of previously published guidelines to capture thermal images were followed. After a 15 minute acclimatization period the thermograms were obtained from the anterior view of the face before and after the cold pressor test. Mean temperature values were computed for the nose, the mandible and maxilla. The intensity of pain induced by submerging the non-dominant hand in cold water (4ºC) for 1 minute was evaluated by a numeric rating scale.

RESULTS/DISCUSSION Thermal imprints were change-sensitive to the cold pressor test. Skin temperature increased in most of the analyzed regions of interest and the increase was significant in the non-dominant maxilla and mandible and in the dominant mandible ($p<0.05$). Skin temperature correlated strongly and significantly ($p<0.05$) with pain reported by the subjects.

Skin temperature changes might have happened as a result of autonomic arousal induced by the cold pressor test.

CONCLUSION: CPT induced facial skin temperature changes. A negative, strong and significant correlation was found between skin temperature in the mandible (before and after the cold pressor test) and pain reported. Thermal imaging of the face proved useful in pain research, allowing to estimate autonomic activity.

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KEYWORDS Thermal imaging, facial skin temperature, cold pressor test, pain, autonomic system.

CASE REPORT: THERMAL ANATOMIC ASPECTS IN FACIAL PALSY, AND USE OF THERMOGRAPHY AS A HEALING EVALUATION METHOD

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INTRODUCTION. Infrared (IR) thermography has been used in different diagnosis in Medicine. As it studies microcirculation, it can help any pathology that affects itself. The authors related a case report of IR study of idiopathic facial palsy (Bell's Palsy), that is a dysfunction of the cranial nerve VII (the facial nerve), and causes inability to control facial muscles on the affected side, with aesthetic and functional problems, like blinking and closing the eyes, smiling, frowning, lacrimation, salivation, flaring nostrils and raising eyebrows. It also carries taste sensations from the anterior two-thirds of the tongue, via the chorda tympani nerve (a branch of the facial nerve). Because of this, people with Bell's palsy may present with loss of taste sensation in the anterior 2/3 of the tongue on the affected side.

The causes are not completely understood, but are mostly related with wild range of temperature. The diagnosis is generally made by exclusion and there is difficulty to follow the improvement after treatment.

METHODS. PPM, female, 43 years old, and 3 days after the start of the symptoms. No other pathologies related. Performed to examination with infrared sensor ThermaCAM T335 (FLIR), 320x240 resolution (76,800 pixels) in the spectral range of infrared (7.5 to 13 microns) for dynamic study (30 Hz), sensitivity 0.05

INFRARED THERMOGRAPHY AS A TOOL FOR MONITORING OF RADIOFREQUENCY TISSUE ABLATION INSIDE OF METAL STENT.

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Revised version of 01.04.2015

INTRODUCTION: Biliary stents are used to treat obstructions that occur in the bile ducts. The stents can be blocked by new tissue within a few months after implantation. This complication can be solved by using radiofrequency ablation (RF). However, this procedure is accompanied by a large amount of thermal energy that may, in some cases, cause serious complications. This heating process can be observed by using contactless thermography as show in this research report were we monitored the dynamics of the heating process, the temperature difference between monopole or dipole heating and temperature distribution in tissue or in stent material in ex-vivo experiments.

METHOD: Measurements were made ex vivo. As a model of tissue fresh bovine liver were used at room temperature. The metallic EGIS Biliary stents 10 mm x 80 mm, double bare, were used in the experiments (Egis, S&G Biotech, Seoul, Korea). For the radiofrequency ablation an EndoHPB 8F, 180 cm long catheter connected to the generator 1500X RF working on a frequency 460 kHz ± 5% (AngioDynamics, NY, USA) was used. All thermograms were recorded with a FLIR B200 infrared camera (Flir Systems, Danderyd, Sweden).

The experiment was performed in mode of monopole and bipole heating with different position of indifferent electrode and with different output intensity. Temperature of tissue around stent was monitored. Temperature of alone stent was measured in the case of tight contact of the active electrode and of the metal material of stent. The resultant temperature changes using various settings were monitored.

The images were processed by using FLIR QuickReport 1.2 (Flir Systems, Danderyd, Sweden) and by using ImageJ 1.45s software. Images in grayscale were standardized to the same temperature range and temperature histograms (obtained from a spot measurement) or mean temperature value of selected areas were obtained and further evaluated.

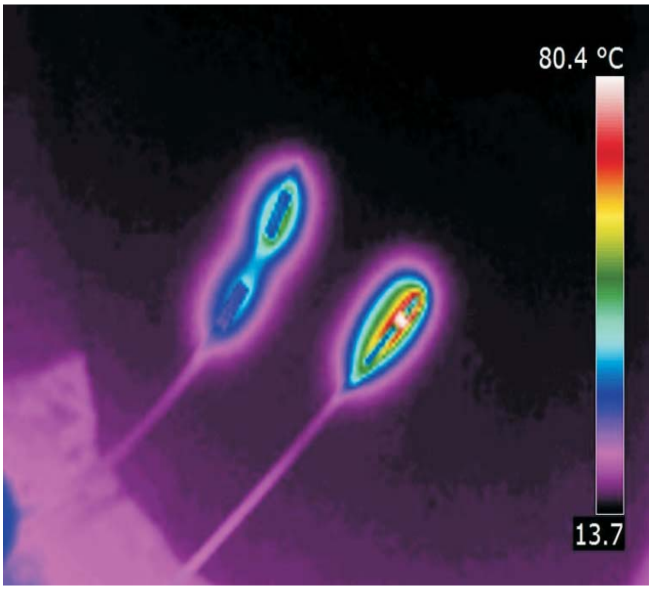
RESULTS& DISCUSSION: The results showed that infrared thermography seems to be an appropriate method for observing the distribution and changes in temperature during ex vivo radiofrequency ablation.

The results show an increase in temperature of the stent's material during thermoablation process. It is believed that the metal stent becomes an active electrode in case of contact with the electrode. The results show an increase in temperature of the stent and the surrounding tissue during the treatment. Temperature distribution measured on the stent was affected by power applied and was non-homogeneous. The maximum temperature values were observed at the ends of the stent. The temperature value of the stent during thermoablation depended also on the position of the second (inactive) surface electrode. Thus, there seem to be several factors that affect the final temperature or process of tissue ablation both inside the and around the stent.

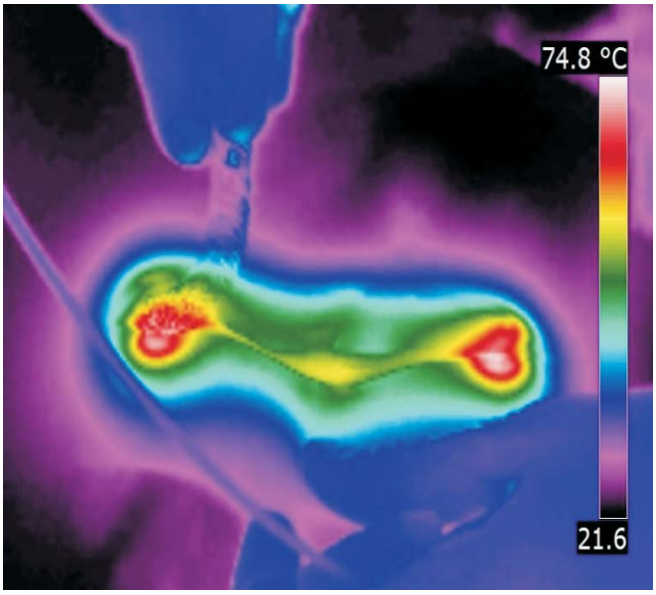
CONCLUSION: In this study we have shown that thermography can be used for understanding the process of thermal tissue destruction and for increase the efficiency and safety of radiofrequency ablation.

KEYWORDS: Infrared camera; infrared thermography; radiofrequency ablation; stent; temperature

The project is supported by grant NT/14586-3



The temperature measurement of monopole and bipole radiofrequency tissue heating.



Temperature distribution in tissue after radiofrequency ablation of metal stent.

THERMAL IMAGING TO ASSESS CHANGES OF FOOT SKIN TEMPERATURE IN PATIENTS TREATED WITH PERCUTANEOUS TRANSLUMINAL ANGIOPLASTY

Erik Staffa[1], Vladan Bernard[1], Luboš Kubícek[2], Vašek Zižlavský[2], Robert Vlachovský[2], Daniel Vlk[1], Vojtech Mornstein[1], Robert Staffa[2]

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INTRODUCTION: Lower extremity peripheral arterial disease (PAD) most frequently presents with pain during ambulation,

°C and thermal stabilization for 15 minutes in thermally controlled room (23 ° C), with minimum convection air (0.2 m / s) and relative humidity below 60%. The images were taken in four different moments: before treatment (Figure 1) and after 2 injections of medicinal CO2 gas (Figures 2, 3) and 3 weeks after (Figure 4). Comparison between the images and correlation with symptoms have been done.

RESULTS AND DISCUSSION. The infrared images have demonstrated a very useful method to show the thermal asymmetry of the face (Figure 1). As Bell's palsy often has a thermal injury involving big thermic alteration in its pathogen, thermal images can be very useful to quantify the lesion and also observe the recovery (Figures 2, 3, 4). After two weeks of treatment the patient experienced a great improvement in movement and sensibility. After three weeks, she had recovered almost completely from the symptoms. This improvement was coincident with the thermal symmetry observed after the injections. The vasa nervum microcirculation has been showed cold before injections and hot immediately after that, with a maintained recovery of the temperature (Figure 3). The CO2 gas injection has the property of increase blood flow through direct vasodilatation effect. It could explain the faster recovery observed at this patient and showed with the infrared images.

Generally, at literature, most patients (71%) have complete regression of the symptoms only one year after. Despite of being a case report, this showed an interesting result, with an objective way of measurement of improvement.

CONCLUSION. Thermography made possible to observe a difficult physic phenomenon often described along Bell's Palsy: the cooler nerve image. It also allows observing the heating process with the reopening of blood supply in the affected region after injection of CO2 gas.

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KEYWORDS. Facial Palsy, Thermography, Carboxytherapy.

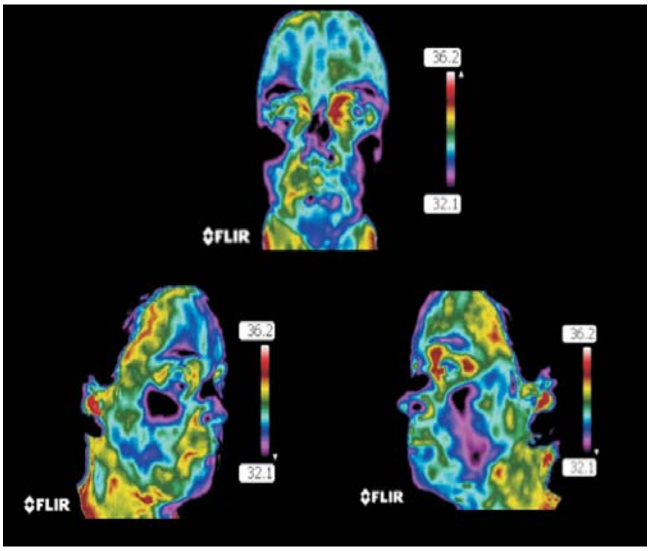
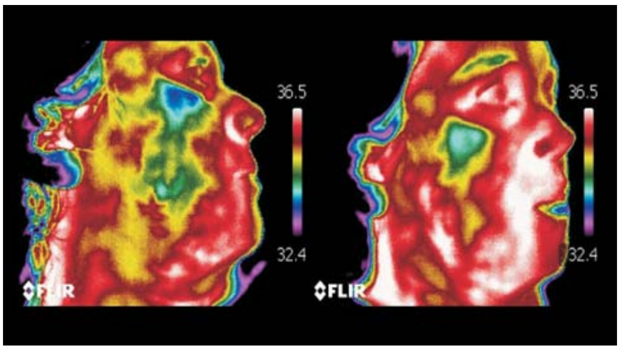


Figure 1.⥣
Infrared images before treatment, showing thermal asymmetry between hemi face (DT= -0,6ºC at ophthalmic territory). Region of law heat radiation of the facial nerve on the right side of the face (blue



.Figure 3. ⥣
Infrared images after ten minutes of the first injection of CO2

Figure ⇒.
Infrared images after 3 weeks, with isothermy (DT=0 ºC) and total recovery of the symptoms, without low temperature at the facial territory.

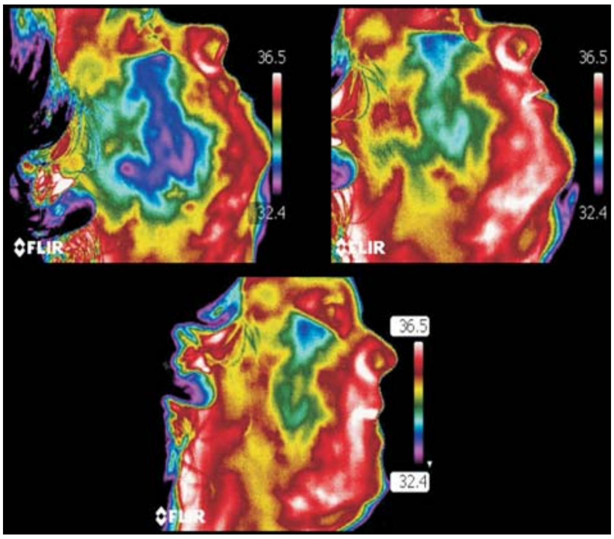
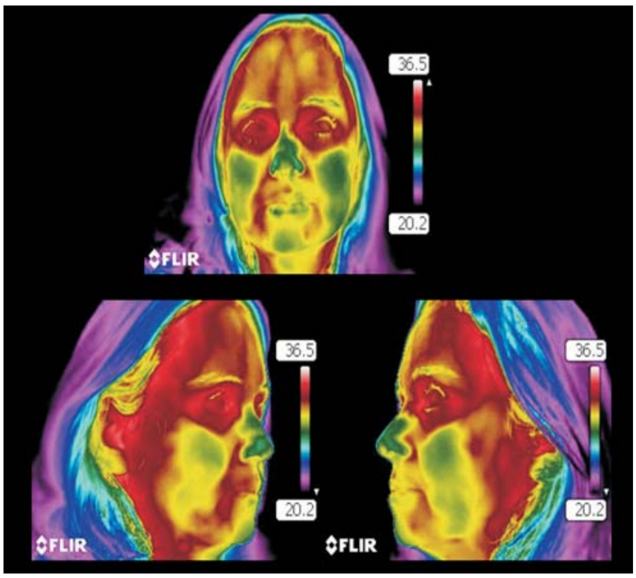


Figure 2. ⥣
Infrared images showing the patient after first injection: 5 seconds, 30 seconds and 3 minutes of CO2 gas injection in the face. Note the hot spots start growing and increasing with time.



which is known as claudication. Treatment for claudication that is due to PAD often relies on revascularization with percutaneous transluminal angioplasty (PTA). Aim of our study was to evaluate the correlation between PTA and thermal changes in the skin of patients measured using an infrared camera. We compared thermal changes in the skin of patients before and after revascularization by PTA and we tried to find a correlation between ankle brachial index (ABI) value and foot skin temperature. We present benefits of infrared thermographic systems for the monitoring of foot temperature as a means of early detection of foot ischemic disorders.

METHODS: The study included 21 patients (7 female and 14 male), mean age was 49.5 years. Patients were with symptomatic peripheral arterial disease but without visible defects and ulceration on lower limb. Patients were classified according to Fontaine classification (Fontaine stages I-III). Recruited patients were without amputations on lower limb and without non-compressible arteries (severe mediacalcinosis). The status of the blood supply of lower limb was identified by CT angiography. Thermal images and the measurement of the ankle brachial index values were obtained before revascularization and the second day after revascularization.

RESULTS & DISCUSSION: The results showed the change of skin temperature of limb after revascularization. It is evident, that the temperature of revascularized limb increased in average for the whole monitored group of patients. Temperature change value per one person in the limb treated with PTA was 0.4°C, for non-treated limb was -0.5°C. In the case of ABI in the treated limb, the mean value of ABI before PTA was 0.75 and it increased up to 0.15 after the procedure. The mean value of ABI in the case of non-treated limb decreased up to -0.02 from 0.98.

CONCLUSIONS: The foot skin temperature in patients with PAD obtained by the infrared camera corresponds with development of ABI values during our study. It is evident, that the increase of ABI index correlated with increase of skin temperature in the case of limb treated with PTA.

KEYWORDS: peripheral arterial disease, infrared thermography, thermal imaging, percutaneous transluminal angioplasty.

Research was supported by grant MUNI/A/1449/2014

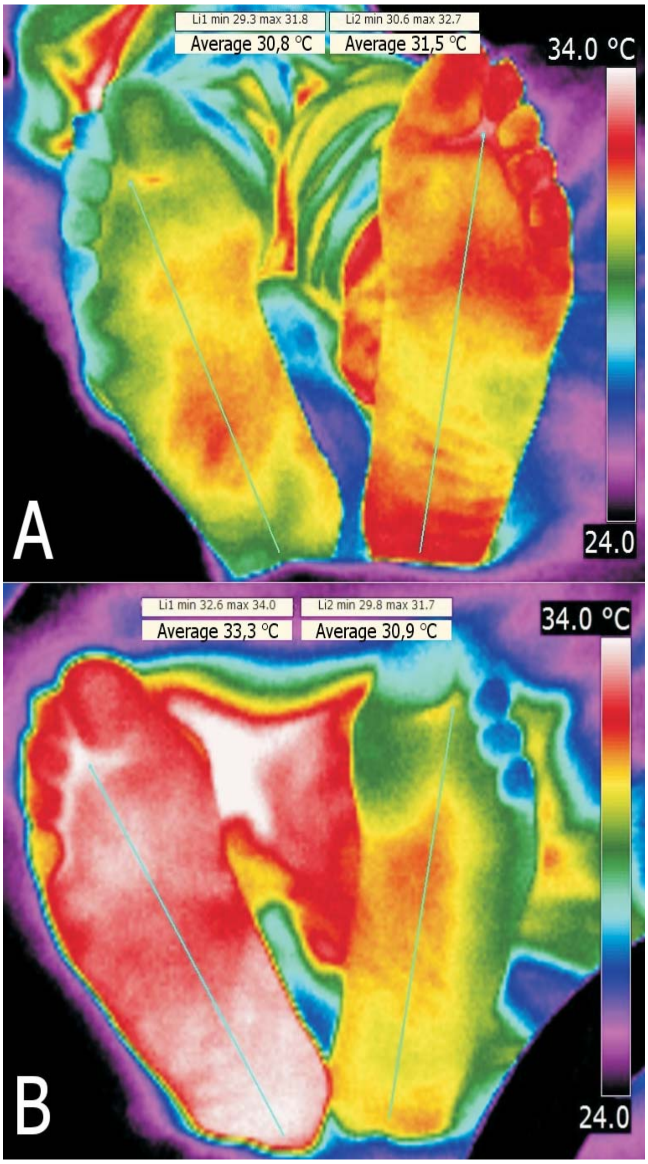


Figure: Thermal images of the plantar feet of a patient before (A) and after (B) revascularization with PTA .

THERMOGRAPHIC ANALYSIS OF THE ANAEROBIC EXERCISE POST-RECOVERY BY COLD WATER IMMERSION

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Revised version of 26.05.2015

INTRODUCTION. Cold water immersion has been widely used in sports practice for enhancing post-exercise recovery. The objective of this study was to analyse the thermographic pattern after anaerobic exercise and evaluate the effect of the cold immersion in the acute and delayed recovery.

METHODS. The study included 22 volunteers of both sexes, physically active, aged from 18 to 30 year old who were distributed into 3 different groups. Group A (GA) held anaerobic exercise (jumping, n = 6), group B (GB) anaerobic exercise + cold water immersion (n = 8), in which after anaerobic exercise the volunteers were submitted to cold water immersion in water at 10 ° C for 15 minutes, and group C (GC) (control, n = 8), which remains at rest during the entire time. The subjects were submitted to pain (algometry) and thermographic evaluation (T-360, FLIR). The algometry was assessed by a pressure exerted in anterior thigh by a dynamometer (DD-300, Instruthem®, Brazil), until level 5 in a visual analogue scale (VAS). The thermographic images were captured at rest (T0), after exercise (T1), 10, 20 and 30 minutes (T2, T3 and T4), 24 and 48 hours after exercise (T5 and T6). IN GB T2 evaluation was performed 10 min after cold water immersion. Statistical analysis was performed using ANOVA with repeated measures for evaluation of the dependent variables, adopting the significance level as $\alpha = 0.1$ in IBM SPSS statistical package, version 20.

RESULTS AND DISCUSSION. The results showed that the GA and GB groups presents decreased temperature at T1, while GC showed no changes during the experiment. In GA, the temperature recovered the initial level at T2 and remained at this level until T7. In GB the temperature was further decreased at T3 with partial recovery at T5, but the complete recovery occurred only at T6. In contrast, Bandeira et al.[1] found, after 24 hours, a significant increase in temperature of the thigh muscles in subjects undergoing exhaustive exercise. However, this author used soccer players while in the present study the subjects were irregularly active. On the other hand, this study provides evidence that the cold immersion was effective to maintain the decreasing temperature of the thigh after exercise. In the evaluation of pain was observed that the pressure levels for EVA grade 5 decreased significantly in GA and GB groups, immediately after exercise and remained in the GC. These levels were maintained until 24 hours after, but only in the GB the pressure increased significantly after 48 hours. These results show that cold water immersion was effective in reducing delayed onset muscle soreness (DOMS) in agreement with the studies of Ingram et al. [2] that also observed a significant reduction of DOMS in a group of subjects underwent to cold immersion after exhaustive exercise.

CONCLUSION. This study points to evidence that the cold water immersion performed after exercise changes the post-exercise thermographic pattern and presents benefits in the recovery of delayed onset muscle soreness when compared to the isolated exercise.

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KEYWORDS. Thermography, Cryotherapy, Sports, Physiotherapy.

SKIN TEMPERATURE IS CORRELATED WITH SYMPTOMS IN PATIENTS WITH PATELLAR TENDINOPATHY

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Revised version of 14.04.2015

INTRODUCTION: Tendon injuries are very common in the athletic and working populations. Patellar tendinopathy is responsible for significant morbidity in athletic and non-athletic population. The prevalence of this condition may reach 50% in male indoor volleyball players. Temperature has been used as an outcome measure in tendon conditions and several studies point to a relationship between musculoskeletal disorders and changes in blood flow. The aim of this study was to assess a possible relationship between disability and skin temperature changes in athletes with patellar tendinopathy.

METHODOLOGY: Twenty volleyball players were recruited for this study. 8 had no history of patellar tendinopathy, 5 had history patellar tendinopathy but were asymptomatic and 7 had symptomatic tendinopathy. The study was approved by the ethics committee of a local University and all participants gave their written consent to participate in the study.

The skin temperature was evaluated using a FLIR A325 camera, calibrated, with a 320x240 resolution, 70mK sensitivity and ±2% accuracy.

The recommendations of previously published guidelines to capture thermal images were followed. After a 15 minute acclimatization period the thermograms were obtained from the anterior view of the knee in a room at 22ºC and relative humidity below 50%. The VISA-P scale was used to evaluate the severity of the symptoms.

RESULTS/DISCUSSION: Significant differences were found between the skin temperature in the anterior view of the knee of athletes with symptomatic tendinopathy and athletes with no history of tendinopathy (30.8ºC and 29.7ºC; $p \leq 0.05$) but not on thermal symmetry (0.3ºC and 0.2ºC: $p > 0.05$).

The VISA-P score was significantly different between athletes with symptomatic tendinopathy and athletes with no history of tendinopathy (p≤≤0.05).

Even mild tendinopathy can affect the skin temperature of the affected knee when compared to controls with no history of tendon pathology. Lower VISA-P scores were related to increased skin temperature.

CONCLUSION: Skin temperature values related with valid clinical measures of symptoms in patients with patellar tendinopathy. The assessment of skin temperature may be an objective outcome measure in patients with patellar tendinopathy.

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KEYWORDS: Thermal imaging, patellar tendinopathy, VISA-P score, volleyball.

THERMOGRAPHIC CHANGES IN WORKERS WITH SHOULDER DISORDERS

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Revised version of 10.04.2015

INTRODUCTION. Work-related musculoskeletal disorders (WMSDs) of the shoulder is a frequent cause of absence from work, however it diagnosis is difficult and limited. This study aims to correlate thermography and clinical diagnosis and the function of patients, trying to achieve a more reliable and affordable diagnosis.

METHODS. The sample contained 20 subjects, aged between 42.45 ± 9.8, 10 assigned to a group with shoulder WMSDs, 60 % bilateral (G1, n = 16 affected shoulders), and 10 for a healthy group (G2, n = 16 healthy shoulders), matched for age, sex and BMI. The subjects performed thermographic (T -360, FLIR), dynamometric, range of motion (ROM) and pain assessments in the shoulders. The room temperature was maintained between 22 and 24 ° C. Were captured images in anterior, posterior, right and left profile (Figure). The images were analyzed by FLIR QuickReport 1.2 SP2 software. the average temperature of five regions of interest (ROI) was recorded. Data were tested for normality and homogeneity of variance and applied the independent Student test or Mann Whitney test for comparison of the dependent variables of the groups. We also applied the Pearson correlation analysis between the variables temperature, ROM, strength and pain. significance level was 5%.

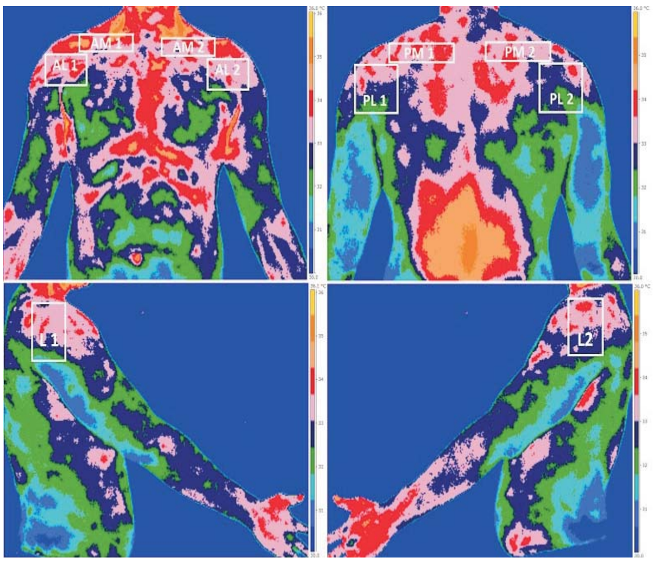

Figure:
Five regions of interest around the shoulder have been investigated: anteromedial (AM); anterolateral (AL); posteromedial (PM); posterolateral (PL); lateral (LAT).

RESULTS AND DISCUSSION. In the experimental group, pain intensity as measured by VAS, showed a mean of 7.2 ± 1.4. The average temperature of the ROIs AM and AL of G1 showed a significant decrease compared to the G2 (ΔT AM = -1.01ºC; ?T AL = -1.01ºC). The G1 showed a significant decreased ROM for all movements assessed compared to G2 (?ROM forward elevation = -36.8º; ΔROM abduction= -44º; ?ROM external rotation= -16.1º; ΔROM internal rotation= -10.8º). The strength deficit was present in all muscle groups of G1 compared with G2 (?st = flexion -3.2kg; ?st = -3.3kg abduction , external rotation ?st= -3.1kg ; ?st internal rotation= -3.8kg) . These changes stem from the fact that the shoulder dysfunction leads to muscle atrophy and impaired functional amplitudes. The external rotation ROMs had moderate negative correlation with the temperature of the ROIs AM, AL, PL and L (r Pearson = 0.53 to 0.55). The internal rotation of WMDs showed a moderate negative correlation with the temperatures of the five ROIs (r Pearson = 0.53 to 0.68), indicating that the decrease of the rotation of WMDs is associated with increased temperature around the shoulder. The pain had moderate positive correlation (r Pearson = 0.51 to 0.54) with the temperature of the ROIs AL, PM, PL and L, showing that the temperature increase may be due to local inflammation. There were no significant correlations between muscle strength and average temperatures of the ROIs.

CONCLUSION. In this study, the presence of pain, ROM deficit and muscle strength were features present in individuals with WMSDs. Thermography shown to correlate with clinical and functional conditions of the shoulders of individuals with WMSDs, being a complementary exam to aid in the diagnosis and for grading impairment presented by the subjects.

KEYWORDS. thermography, diagnosis, work diseases, shoulders dysfunctions.

THERMOGRAPHIC PROFILE OF THE HAMSTRING MUSCLES DURING STATIC STRETCHING

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Revised version of 17.04.2015

INTRODUCTION. The hamstring muscles are very susceptible to the adaptive shortening and, in consequence of that, they are more prone to distensions in sports practice. This study aimed to characterize the thermographic profile of these muscles during static stretching, with the purpose of identifying the skin temperature (Tsk) changes that may indicate a critical zone for myotendinous rupture.

METHODS. We evaluated 15 young volunteers of both gender, with flexibility deficit ? 20º in relation to the knee extension angle with the hip at 90° of flexion. After 15 minutes of acclimatization with ambient temperature, the subjects were positioned supine with the hip set at 90 ° of flexion. The stretching was performed by means of traction by an adjustable strap attached to the ankle and moving the limb toward knee extension. The tension was adjusted every 30 sec over 3 min or until the painful threshold of the subject. Thus, thermographic images were recorded in 7 moments: at rest and at 30, 60, 90, 120, 150 and 180 s (T1 to T7 times). The thermographer used was T-360 camera (FLIR Systems). The image analysis was performed using the FLIR QuikReport 1.2 SP2 software. ANOVA with repeated measures and the Pearson correlation coefficient were used, to compare the means of the dependent variable (Tsk in °C and Tension in kg) and to test the linear correlation between variables, respectively. For this analysis we used the IBM SPSS Statistics 20.

RESULTS AND DISCUSSION. In the temperature analysis during the static stretching there were no statistically significant changes. However, a trend by increasing temperature between T1 and T4 moments was verified, after which detected a decrease of the temperature by the end of the stretching (T7). The instant T4 was also the time when it was identified a decrease in tension recorded on the dynamometer, although at this point there was no adjustment for reduction of the tension. According McArdle [1] peripheral receptors, such as GTO, act in the regulation of muscle tension state, inhibiting the contraction of agonist muscles leading to relaxation. We hypothesized that the temperature variation may occur in the acute response to tension adjustments, however when this setting ceases, the heat dissipation can be reduced due to muscular relaxation. Research made by Kutin et al. (2011) and Kathirvel et al. (2012) evaluating changes in temperature using the maximum tensile load in the deformation, of a sample of non-biological compounds, have observed that the temperature increase occurred only when the material started changing its original structure and reached the breaking point. However, for ethical reasons, this study with human stretching, the tension was adjusted respecting the subject and the nociceptive thresholds and the critical zone of rupture could not be achieved.

CONCLUSION. This study showed no evidence that static stretching with submaximal force induces subtle changes in temperature that may indicate a critical zone to rupture. However, the maintenance of anti-gravity position during stretching can be masked results. The inclusion of a control group can correct this limitation in the future.

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KEYWORDS. Thermography, Stretching, Injury, Physical Therapy, Sports.

THERMOGRAPHIC ANALYSIS OF THE EFFECT OF DIFFERENT MODALITIES OF EXERCISE: AEROBIC AND ECCENTRIC EXERCISE

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Revised version of 11.04.2015

INTRODUCTION. In the aerobic exercise an anti-inflammatory response can occur by the increase of interleukin-6 as a result of muscle contraction, while the eccentric exercise has pro-inflammatory response due to muscular injury. This study aims to assess the inflammatory exercise response by thermography pattern analysis and pain evaluation.

METHODS. The sample consisted of 20 subjects, aged from 18 to 30 years old. The subjects were allocated into three groups: Group A (GA) that performed aerobic exercise on a treadmill (n = 6), Group B (GB) vertical jump (n = 6) and Group C (GC) control (n = 8), without exercise. For thermographic record subjects remained to rest for 15 minutes in the examination room, with temperature between 22 and 24 ° C and relative humidity <60. One camera T-360 (FLIR) with thermal sensitivity of 0.05 ° C and 320 x 240 pixels of resolution was used, to capture two images (whole body and face) at time T0 to T6 at rest, after exercise, 10, 20, 30 min, 24 and 48 hours post exercise, respectively. The temperature was measured in the upper/lower limbs and trunk and expressed as the mean body temperature. For the evaluation of pain, VAS was used in the same time from T0 to T6, by a pressure measured with a dynamometer DD-300 (Instruthem®, Brasil). ANOVA with repeated measure (temperature) and Friedman (VAS) with 5% of significance level was used for statistics analysis, in IBM SPSS statistical package, version 20.

RESULTS AND DISCUSSION. The results showed that there was a significant decrease in temperature ($\Delta T = -2.15$ and $\Delta T = -1.7$) between the time T0 and T1, and a partial recovery between T1 and T2 ($\Delta T = 1.45$ and $\Delta T = 1.3$) for groups GA and GB respectively, while the temperature was kept stable in GC. The GB result is in agreement with the studies made by Ferreira et al. (2008) that demonstrated a decrease in temperature immediately after resistance exercise, with gradual recovery after the exercise. However, at end of recovery period, the temperature had a different variation when compared to initial temperature (T0). For the GA was a decrease of 1.7°C, while GB returned to baseline levels after 48 hours.

In the evaluation of post-exercise pain levels was stable in GA and GC groups, while there was a significant decrease in the pressure capable of generating pain in the GB group (4.1 to 2.8 kgf), between T0 and T7. This result shows that the eccentric exercise caused delayed onset muscle soreness (DOMS) which peaked 48 hours after exercise. These results confirms the study of Nosaka et al. [2002] who demonstrated that the greatest increase DOMS has expressed between 24 and 48 hours after the first stimulus of the maximum eccentric action.

CONCLUSION. The aerobic exercise protocol used in the present study resulted in a temperature decrease which was maintained until 48 hours after exercise. The DOMS in the group that performed the eccentric exercise showed that this type of exercise has the most tissue damage that is accompanied by a painful process that persists for at least two days.

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KEYWORDS. Delayed, onset, soreness, pain, inflammation.

HOW THERMOGRAPHY CAN ASSIST CLINICAL EXAMINATION IN VARIOUS STAGES FOLLOWING TRAUMA

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INTRODUCTION. The authors report case studies, demonstrating how thermography can help in diagnosis and evaluation of pain syndromes. All the images only have significance if compared with accurate medical examination.

Trauma has different stages that can be checked and understand with thermal images. After the acute phase it is possible to detect signs suspicious for complex regional pain syndrome (CRPS) This is a clinical syndrome of variable course, and unknown cause characterized by pain, swelling, and vasomotor dysfunction of an extremity, often as a result of trauma or surgery. Limb immobility may also lead to CRPS; in a hemiplegic upper limb after stroke is often termed shoulder-hand syndrome. CRPS may also develop in the absence of an identifiable precipitating event.

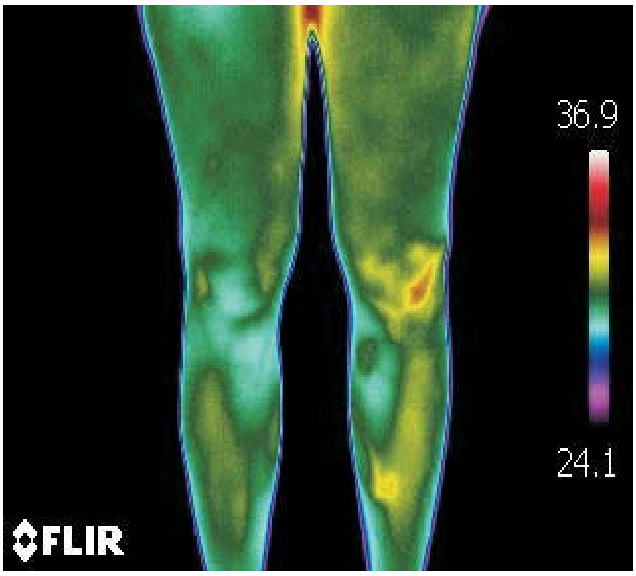
The course of temperature of the affected limb is often related with changes of other diagnostic signs of CRPS and temperature measurements based on thermography can be used as outcome measure of CRPS. That kind of approach provides a more detailed insight into pain syndromes for patients, physicians and Insurance Companies

METHODS. The authors studied 15 cases referred by Insurance Company. The initial goal was the detection of possible faked consequences of injuries.

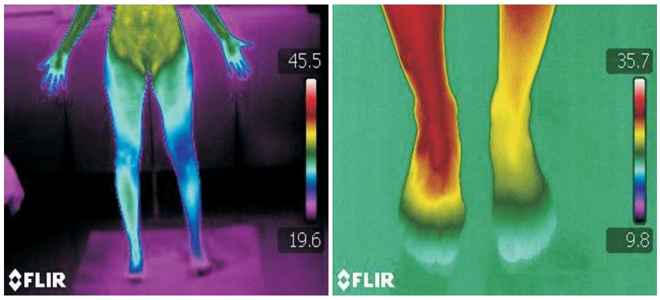
The collected images were standardized at room humidity, and temperature. Each patient had full body study to understand the related problem, comparing to others medical symptoms and studies and/or areas without diseases. Camera set adjustment of temperature had to be individualized for each patient, but the objective was to measure ASYMMETRY of temperature distribution in each individual. Other studies were always negative or inconclusive, but thermographic findings did support the clinical diagnosis.

RESULTS AND DISCUSSION. In all cases, IR helped to understand skin temperature alterations, its intensity and time course, as shown in the three examples below.

Case 1: The acute stage is observed one month of trauma. Pain, often burning in nature, is one of the first symptoms that initially limits function. Swelling, redness with vasomotor instability. The hot spot on the left knee might have been caused by a lesion of anterior cruciate ligament (an anatomic lesion was shown with magnetic resonance imaging), with small but significant difference in temperature (DT= 1,9 °C). No changes on the contralateral side.



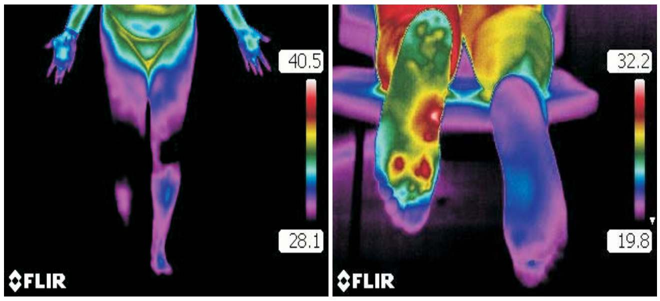
Case 1



Case 2

Cases 2: Subacute stage. If the process is not arrested or reversed in the acute phase, the condition may progress to the subacute stage, which can last for up to 9 months, as shown in this patient. Persistent and severe pain appears, cold symptoms, and cyanosis start also.

Significant difference in temperature between the two limbs (DT=2,0°C to 4,0°C.) 10 months left ankle torsion. Pain grade 8, moderate claudication, no findings in other studies.



Case 3

Case 3: Chronic stage. If the process continues, the chronic phase may develop approximately 1 year after disease onset. This stage may last for many years or can be permanent

Right leg was folded back during a fall to the floor, 11 months before. Knee arthroscopy 5 months after the injury. Right knee pain was grade 6, severe claudication. No findings in other studies. Noticeable temperature difference between the lower limbs (DT= 4,4°C).

CONCLUSION. All findings were relevant for Insurance Medical Experts and some have changed the initial diagnosis, with objective support by Standardized Thermal Images, and specialized medical reports. Combined with clinical examination, thermal image appears as a great method to help in differentiation of complex pain syndromes.

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KEYWORDS. Reflex Sympathetic Dystrophy, Thermography, Insurance Companies.

REGIONAL DIFFERENCES IN SKIN TEMPERATURE BETWEEN TWO INTENSITIES OF CYCLING

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INTRODUCTION. In cycling, exercise workload resulting in an increased core temperature [1], muscle activation [2], power output [3] and effective forces in the pedals [4]. However, it is unclear how it affects skin temperature. The aim of the study was to determine the influence of cycling workload on the skin temperature of the different body regions.

METHODS. Fourteen cyclists performed two 45-minutes cycling tests at 50% and 35% of peak power output (POmax) on different days. Local skin temperature was recorded by infrared thermography camera (FLIR E-60, Flir Systems Inc., Oregon, USA) before the cycling test and after 15 minutes of thermal adaptation to room temperature, immediately after and 10 minutes after finishing the cycling test. The camera was positioned 1 m away from the participant and the thermal images were taken perpendicular to the body regions of interest (ROIs). Seventeen ROIs (deltoid, chest, abdomen, upper back, lower back, vastus lateralis, rectus femoris, abductor, vastus medialis, biceps femoris, semitendinosus, knee, popliteal, tibialis anterior, gastrocnemius, ankle anterior, and achilles) were defined on 12 thermal images recorded in each measurement time. Each ROI was selected with the same area for all participants. Differences in absolute and variation of the skin temperature due to different cycling workload were analyzed.

RESULTS. No differences in absolute values of skin temperature between workloads ($p>0.05$) at any ROI were observed. However, higher reductions in the skin temperature due to exercise were observed at 50% rather than 35% POmax at the abdomen, tibialis anterior, ankle anterior and Achilles, and knee presented a lower increase ($p<0.05$).

DISCUSSION AND CONCLUSION. Cycling workload did not have any effect in variation of the skin temperature in the most ROIs probably due to higher sweat rate. Only the ROIs with lower metabolic heat production and blood perfusion were affected with higher reductions and lower increases of the skin temperature at higher workload. These results suggest that these regions are affected by a temperature decrease due to a slightly higher overall sweat rate according to a higher intensity [5] rather than temperature increases through rising workloads. In conclusion, cycling workload did not have any effect in the skin temperature in the most ROIs due to the higher heat loss of the thermoregulatory system, and only ROIs that are mostly constituted by connective, bone and fat tissues were affected. Our findings highlight the difficulty of linking skin temperature with cycling workload.

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Baron Professor Leopold de Thibault de Boesinghe MD

sadly passed away in 2015 aged 72 years. He was born in Belgium during the Second World War to a family related to the Belgian Royal family. He became a senior radiologist in The University Hospital of Gent, working in cancer and nuclear medicine. He authored several papers on breast cancer and its treatment in the 1970's .

One of the first people in his country to use infrared thermography in his practice, he became involved with the European Association of Thermology for many years. As Professor at the University of Gent, he became interested in industrial medicine, and took part in health policy development in Belgium.

He married in Madrid, to a lady also related to the Spanish Royal family, and they had two children. As an honoured guest and friend I was able to attend the wonderful wedding ceremony in Madrid, which I will never forget.

Leopold was proud of his Belgian heritage and lived in a historic house in the centre of Gent for many years. At the Graz EAT conference in 1986 he supported the international proposal to set up an International College that would link Thermology Societies in Asia, Europe and the USA. He became President of the College in 1989, and was also President of the European Association of Thermology. A memorable occasion was the EAT Conference of Medical Thermology in 1992 held in Gent at the University Conference Centre, a former Monastery in the city centre. Other specialist committee meetings were also held in Belgium arranged by Leopold.

A selection from Leopold`s publication list demonstrate both his multilingulism (he spoke English, French, Spanish, German, Flemish) and his broad interest in medicine and medical research.

He travelled and attended many conferences, and always enjoyed meeting colleagues from other countries. The last photograph I received from Leopold was of him holding a grandchild, I believe taken in Madrid where his children and their family live. After retirement from the University Leopold continued to be involved in some clinical duties and with the Belgian Medical Society.

His enthusiasm and interest in medical thermology remained, and he will be missed by all who knew him.

Francis J Ring; July 2015

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2015

26th -27th September 2015

Annual Scientific Session of the American Academy of Thermology in Greenville, South Carolina

AAT welcomes you to our 2015 Medical Thermal Imaging Scientific Session in beautiful downtown Greenville, South Carolina!. Annual Meeting proceedings and the Physicians Member Certification Course will be held on the Bon Secours St. Francis Hospital campus at the Bernadine Center.

Please use
http://aathermology.org/events-calendar/annual-session-program/hotel-travel/

for details on how to get to Greenville, recommended hotels and block rates, and directions to the Bon Secours St. Francis Hospital Bernadine Center.

Pre-Meeting Physician Member Certification Course: Friday, September 25th, 2015.

Take the next step toward AAT Membership status elevation! Take an AAT Member Certification Course.

2015 Program and Events

General Sessions: Saturday, September 26th, 2015

08:00am – Registration

08:30am – Welcoming Remarks - Jeffrey Lefko, Greenville, SC, Executive Director, American Academy of Thermology

8:35-9:30am

Keynote Address: Overview of New Technology Advances in Biosciences and Translational Applications of New Technology - Davood Tashayyod, Coulter Project Director, Drexel University

9:15am – 10:45am SESSION 1: CLINICAL CONDITIONS, AAT GUIDELINES & INDICATIONS

9:15-9:45am Presentations of 2015 Revisions of Neuromusculoskeletal Thermography Guidelines and Breast Thermography Guidelines -Dr. Robert Schwartz, MD, Greenville, SC, President of American Academy of Thermology

9:45- Presentation of New 2015 Oral Systemic Guidelines - Dr. Robert Schwartz, MD, Greenville, SC

10:15–10:45 am Clinical Applications in Animal Physiology- Dr. Tracy Turner, DVM, Elk River, MN, Board Member, American Academy of Thermology

Q&A/ Discussion

10:45am – Break

11:15am – SESSION 2: PANEL DISCUSSION: ADVANCEMENTS IN THERMOGRAPHIC CAMERAS, EQUIPMENT, AND IMPROVING THERMOGRAPHIC STUDIES

11:15-11:40am Physics Review of Medical Thermal Imaging - Mr. Gary Lux, Cold Mountain Infrared, Black Mountain, NC, LLC

11:40-12:30am HOW I DO IT- IMPROVING THERMOGRAPHIC STUDIES- ORAL/POSTER PRESENTATIONS

Jay Mead, MD, Clackamas, OR, **Laboratory Correlates for Estrogen Imbalances with Thermal Imaging**

James Campbell, MD, Clemmons, NC, **Thermographic Findings in Autoimmune Diseases**

Q&A/ Discussion

12:30pm – Lunch (provided)

1:30pm –SESSION 3: PANEL DISCUSSION: HOT TOPICS IN THERMAL IMAGING, RESEARCH ISSUES AND CHALLENGES

1:30-1:35pm Thermal Imaging Controversies- Lymphatic Congestion and Angiogenesis
Moderator: Dr. Robert Schwartz, MD, Greenville, SC, President of American Academy of Thermology

1:35-2:45pm Lymphatic Congestion and Angiogenesis: What am I Looking At?
Jan Crawford, RN, Member, AAT Board of Directors
Philip Getson, DO, Vice President, AAT Board of Directors
R.A. Bhaskaran, MD, AAT Certified Physician Member

Q&A/ Discussion

3:00pm – Break

3:30pm – SESSION 4: PANEL DISCUSSION: EMERGING ROLE OF THERMAL IMAGING, RESEARCH ISSUES AND CHALLENGES

3:30-3:45pm New or Emerging Technology Uses–AAT Member Atlas of Thermography - James Campbell, MD, Clemmons, NC, Chair of Member's Only Website Thermorgraphy Atlas project

3:45-4:00pm Sports Medicine Thermal Imaging - Robert G. Schwartz, MD, President, American Academy of Thermology

4:00-4:30pm Recent International Developments in Thermography, Integration of Thermography into PMR, Educational Components of Medical Residency Programs - - Dr. Bryan O'Young, MD, New York, NY, Secretary, AAT Board of Directors,

4:30-5:00pm Issues and Challenges for Research and Education in Medical Thermography - James Melton, MHA, Cary, North Carolina, Member, AAT Board of Directors

Q&A/ Discussion

5:00pm – ANNUAL SCIENTIFIC SESSION WRAP UP AND REMARKS

5:30pm – Session Ends

Shuttle back to Crowne Plaza Hotel

6:30- 7:30pm – Meet and Mingle Reception with the Leadership at the Crowne Plaza Hotel

PRESENTATION OF AAT 2015 ACHIEVEMENT AWARD

Committee Meetings: Sunday September 27th, 2015

07:30am – Shuttle from Crowne Plaza Hotel

08:00am – Committee Meetings
(Committee members and other attendees**):**

- ·Membership Committee including:
  - Sub Committee on Complimentary Alternative Medicine (CAM) and Allied Health
  - Sub Committee on Technicians/Technologists.
- Devices and Equipment Committee
- Journal/Newsletter
- Website Committee
- Education Committee
- Advocacy Committee

09:15am – General Session (all in attendance)

10:15am – General Session Ends

10:30am – Shuttle returns to Crowne Plaza Hotel

10:15am – Board of Directors Meeting (board members only)

1pm – Board of Directors Meeting Ends

29th September-2nd October 2015

AITA 2015-Advanced Infrared Technology and Applications in Pisa, Italy

Scope & Topics
After the 12th International Workshop held in Turin (Italy) in September 2013, it has been decided to organize the 13th AITA 2015 in Pisa (Italy) with the main objectives to assess the state of the art of the technology in the Infrared bands and to present its most interesting applications. In the 13th AITA edition, special emphasis will be given to the following topics:

- ·Advanced technology and materials
- ·Smart and fiber-optic sensors
- ·Thermo-fluid dynamics
- ·Biomedical applications
- ·Environmental monitoring
- ·Aerospace and industrial applications
- ·Nanophotonics and Nanotechnologies
- ·Astronomy and Earth observation
- ·Non-destructive tests and evaluation
- ·Systems and applications for the cultural heritage
- ·Image processing and data analysis
- Near-, mid-, and far infrared system

Further information:

http://ronchi.isti.cnr.it/AITA2015/