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CARDIOVASCULAR AND THERMOREGULATORY RESPONSES TO HEAT THERAPY

J. González-Alonso
Director of Centre for Human Performance, Exercise and Rehabilitation, Brunel University

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G. Machin
Head of Temperature Standards, NPL

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M. Tompsett
Formerly English Electric Valve, AT&T Bell Telephone Laboratories

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P.P. Hoekstra

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16:45 - 17:00 The Francis Ring and Kurt Ammer prizes

Congress Closes

17:00 - 18:00 General Assembly of the European Association of Thermology

Saturday 7th July 2018

09:30 Visit to Hampton Court Palace

Invited lectures

CARDIOVASCULAR AND THERMOREGULATORY RESPONSES TO HEAT THERAPY

José González-Alonso.

Centre for Human Performance, Exercise and Rehabilitation, Brunel University London, UK.

The beneficial effects of heat therapy in humans have been known for millennia. Passive heat therapy (evoked though exposure to hot water baths, hot sand immersion, sauna or use of specialised heating garments) induces a myriad of physiological responses. These include large increases in cardiac output and selective increases in skin, muscle, fat and bone blood perfusion in the extremities, head and torso, but the opposite response in the cerebral and visceral circulations. Aerobic metabolism rises in these conditions; yet the magnitude of the metabolic response is small, suggesting a predominant role of thermosensitive mechanisms in the hyperthermia-mediated cardiovascular and thermoregulatory responses. When heat therapy is repeated, significant structural and functional adaptations occur. Long-tem thermotherapy is known to

(i) increase resting blood flow and ankle-brachial pressure index,
(ii) improve vascular endothelial function, cardiac function, insulin sensitivity, blood glucose homeostasis and arterial blood pressure,
(iii) decrease pain scores,
(iv) improve walking distance, and
(v) provide symptomatic and functional benefit to a variety of patient populations.

In this talk, I will discuss the acute physiological responses and chronic adaptations to heat therapy, with particular emphasis on the effects of hyperthermia on the human cardiovascular and thermoregulatory systems. Thermometry and thermal imaging could be used in this context to further characterise and understand the physiological effects of heat therapy.

HISTORY OF UNCOOLED THERMAL-IMAGING TECHNOLOGY

Michael F. Tompsett Ph.D., FIEEE, FRPS, Member NAE

Chatham MA 02633-1708, USA

50 years ago several materials with heat sensitive physical or IR properties had been extensively studied, but there were no practical thermal imaging/thermographic systems. The first proposal for successful uncooled thermal imaging was 50 years ago, and led to the pyro-electric camera tube, which found its first application in fire-fighting, since it could see through smoke. A simultaneous proposal was to use a much smaller MOS x-y addressed pyroelectric array. This approach only became viable 20 years later, using much better integrated circuit technology. Subsequently much more sensitive thermally sensitive materials, micro-bolometer designs and integrated video analog-to-digital conversion have led to today's high-performance devices for digital thermograph.

THE KELVIN REDEFINED

G. Machin[1]

1National Physical Laboratory, Teddington, UK

In 2019 the kelvin, along with the kilogram, ampere and mole, will be redefined in terms of fixed values of fundamental constants. In addition, and at the same time, all the definitions of the SI units will be brought into a common, consistent "explicit constant" format.

This talk will describe how the international temperature community has approached the kelvin redefinition, including; the wording of the redefinition, co-ordinated effort in determining low uncertainty values for the Boltzmann constant [1] and the extensive preparations underway for the introduction of the mise en pratique for the definition of the kelvin 2019 (MeP-K-19) post the redefinition [2].

The leading contributions NPL has made to the kelvin redefinition will be highlighted including; one of the world's lowest uncertainty determinations of the Boltzmann constant, the world's lowest uncertainty values of T-T90 (for the MeP-K-19) and wider leadership through the EMPIR Implementing the new kelvin (InK-) 1 and 2 projects [3].

The talk will end with a discussion of the short, medium and long term implications of the kelvin redefinition [4].

REFERENCES

1. Fischer, J., Fellmuth, B., Gaiser, C., Zandt, T., Pitre, L., Sparasci, F., Plimmer, M., de Podesta, M., Underwood, R., Sutton, G., Machin, G., Gavioso, R., Madonna R.D., Steur, P., Qu, J., Feng, X., Zhang, J., Moldover, M., Benz, S., White, D. Gianfrani, L., Castrillo, A., Moretti, L., Darquie, B., Moufarej, E., Daussy, C., Briaudeau, S., Kozlova, O., Risegari, L., Segovia, J., Martín, M C., del Campo, D., "The Boltzmann Project", In press Metrologia 2018 https://doi.org/10.1088/1681-7575/aaa790

2. Fellmuth B, Fischer J, Machin G, Picard S, Steur P, Tamura O. White R, Yoon H. The kelvin redefinition and its mise en pratique. Phil. Trans R. Soc. A. 2016; 374: 20150037

3. Machin G, Engert J, Gavioso R, Sadli M, Woolliams E. Summary of achievements of the EMRP project implementing the new kelvin (InK). Measurement 2016; 94 149-156

4. Machin G, The Kelvin redefined. Meas. Sci. Technol. 2018. 29 022001

Session 1: Metrology, Quality Assurance and Standardisation

METROLOGY FOR QUANTITATIVE THERMOGRAPHY AT PTB

I. Müller[1], S. König[1], B. Gutschwager[1], J. Hollandt[1]

[1] Physikalisch-Technische Bundesanstalt, Berlin, Germany

Introduction

Contact-less temperature sensing and infrared radiometry sees many applications beginning with ear thermometers for the medical field, thermography of buildings, process control in industry and science, telescopes, space based remote sensing to medicine. At PTB we provide traceability for radiometric measurements in all these fields to the International System of Units by means of calculable blackbody radiation based on Planck's law. In the working group "Infrared radiation thermometry" several high-quality heat pipe cavity radiators are operated as national normal as well as plate radiators covering the temperature range from -170 °C to 962 °C [1]. Our aim is to provide and develop application-specific traceability concepts for infrared radiation thermometry, infrared radiometry, for quantitative thermography and emissivity.

Calibration Service for quantitative thermography

The instrumentation of our calibration labs is intended to meet the highest metrological demands, employing high-quality radiation sources and metrology-grade measurement equipment [2]. We provide traceability for customers in science, industry and national laboratories in many countries. In addition, we have developed an algorithm that allows for the correction of the non-uniformity of detector arrays and radiation sources. For the calibration of thermographic cameras an additional calibration facility has been established at PTB that combines high emissivity and very low uncertainty heat pipe blackbodies with plate radiators for the calibration of detector arrays. The heat pipe blackbodies are used to calibrate the central sensor field of thermography systems while the plate radiators are typically used to irradiate a larger fraction or the whole of the sensor with known temperature radiation. The radiance temperatures from -60 °C to 50 °C are provided by an ammonia heat pipe blackbody with an emissivity of 0.9994. For the use as a normal for sensor arrays a heat pipe geometry with a larger diameter at the expense of emissivity was chosen. The radiance temperatures from 50 °C to 270 °C are provided by a water heat pipe blackbody with an emissivity of 0.9994 while the highest temperature range from 500 °C to 962 °C is covered by a sodium heat pipe blackbody with an emissivity of 0.9996. The temperature gap between the water and the sodium heat pipe black- bodies is covered by a plate radiator. The plate radiator has an emitting area of 300 mm by 300 mm and can be operated in a temperature range from ambient temperature up to 600 °C. An additional plate radiator with a circular area with a diameter of 152 mm covers the temperature range from 15 °C to 120 °C. The achievable uncertainties in the central area of the sensor arrays are 30 mK for ambient temperature and 75 mK for 600 °C and are thus identical to those achievable for radiation thermometers, given that the radiation thermometer and the sensor array are sensing the same area of the radiator.

Non-uniformity correction of infrared camera systems

Infrared Focal Plane Arrays (FPAs) suffer significantly from a non-uniformity of the response of the individual detectors of the array. The data reference method (DRM) [3] - [5] of PTB is a method of non-uniformity correction (NUC) of infrared imagers and FPAs in a wide optical spectral range by reading radiance temperatures or radiance proportional signals and by applying a radiation source whose spatially radiance temperature distribution does not need to be known. The DRM enhanced NUC is based on a minimum of three successively taken images of the radiation source. A first image (primary image) is taken from the source, then a second image is taken from the source with the field of view of the imager purposely shifted in the direction represented by the rows of the FPA and, finally, a third image is taken with the field of view of the imager purposely shifted in the direction represented by the columns of the FPA in relation to the primary image. From these three images, a result matrix of the respective differences between the radiance temperature value of the detector pixels of the FPA to a chosen reference detector pixel of the FPA for a perfectly homogenous source is generated. Exemplarily the radiance temperature in Fig. 1 shows a significant non-uniformity which are caused by the non-unifor-

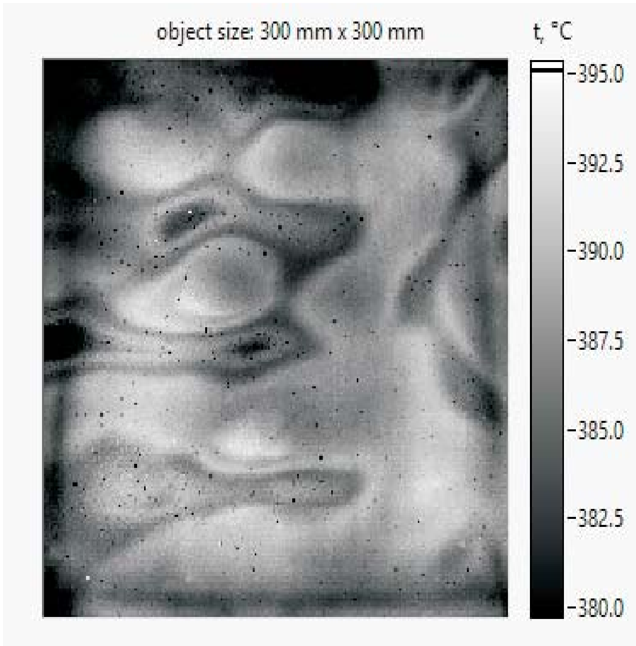

Figure 1:
Radiance temperature image of a commercial plate radiator at about 400 °C taken by an infrared imager. The observed temperature non-uniformity partly results from the true temperature distribution across the plate and partly from the pixel-to-pixel non-uniformity of the responsivity of the imager.

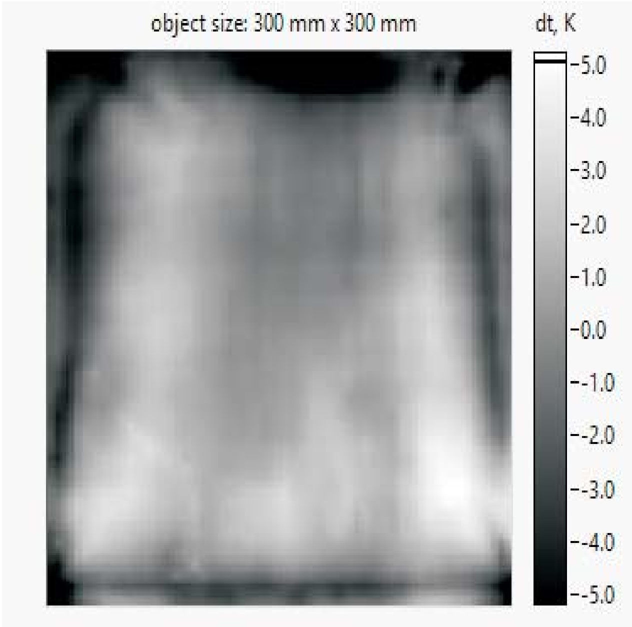

Figure 2
True radiance temperature distribution of the regulated plate radiator at 400 °C. The image is generated with the DRM method

mity of the temperature distribution of the plate radiator and the non-uniformity of the responsivity of the imager. By means of the three images, the DRM is used to correct for the deviations caused by the non-uniformity of the camera system.

Figure 2 shows the corrected radiance temperature distribution of the plate radiator normalized to the reference pixel of the camera (at center). For typical camera systems, a significant contribution of the temperature non-uniformity, as observed in Figure 1, results from the non-uniformity of the imager. With the DRM method, the non-uniformity can be corrected limited by the noise of the imager, the temporal stability of the camera system, and the temporal stability of the radiation source only. However, the temporal stability of thermal imagers is, especially for demanding applications, an issue. With the DRM method, the camera non-uniformity can be corrected in-situ when observing temporal stable and uniform images or by means of a dedicated "target" which can be a plate radiator or, for instance, a wall. The DRM measurements take typically 1 minute or less and the correction can be implemented to directly correct the live images of the camera. This renders possible frequent re-measurements of the camera non-uniformity and minimizes uncertainties associated with the temporal stability of the camera systems.

References

1. Hollandt, J, Friedrich R, Gutschwager B, et al. High-accuracy radiation thermometry at the national metrology institute of Germany, the PTB., High temperatures, high pressures: 2004; 35/36: 379 - 415 .

2. Gutschwager B, Taubert R D, Hollandt J, Analysis of reference sources for the characterization and calibration of infrared cameras, International Journal of Thermophysics 2015; 36 (2-3) 303 - 314

3. Gutschwager B, Hollandt J. Nonuniformity correction of imaging systems with a spatially nonhomogeneous radiation source," Appl. Opt. 2015; 54: 10599-10605

4. Holst GC. Testing and Evaluation of Infrared Imaging Systems. 3rd ed., co-published by JCD Publishing, 2008

5. Ferrero A, Lopez M, Campos J, Sperling A. Spatial characterization of cameras for low-uncertainty radiometric measurements. Metrologia 2014, 51, 316-325

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SIZE OF SOURCE EFFECT IN THERMAL IMAGERS

I. Pušnik[1], J. Drnovšek[1]

[1] University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality

Introduction

The Size-of Source Effect (SSE) is well described and measured phenomenon in radiation thermometers. Basically, it is the effect that decreases or in some cases increases the measured radiation from the target therefore being an important influential parameter that contributes to the measurement uncertainty. It could importantly corrupt the accuracy of a measurement result, if not properly considered. It is determined by either the indirect or the direct method. The direct method is mainly used to determine the SSE of commercial radiation thermometers, which have direct reading of temperature. On the other hand, the SSE in thermal imagers is not agreed commonly. Thermal imagers have detectors, which consist of array of small detectors. Thermal resolution of a thermal imager varies from 80x60 to 640x480 pixels or more. Each pixel is one thermal detector and has its own so called instantaneous field of view (iFOV). This is the smallest area within the field of view (FOV) of a thermal imager that can be detected at a certain distance. FOV is the largest area that a thermal imager could see at a certain distance. FOV is determined degrees (horizontal by vertical) and forms a rectangle image. To describe the SSE of a thermal imager with the approach similar to that in radiation thermometers is not very useful. In this respect we developed a special system for measurement of the SSE of thermal imagers.

Methods

The rationale behind the proposed method is to control the incident radiation to the thermal imager selectively in vertical and horizontal direction. The developed system for measuring the SSE consists of 33 aluminium plates with different number of rectangular or quadratic openings and different distances between the openings. There are 10 plates with 1 rectangular opening of different widths from 1 mm to 40 mm, and plates with 3, 5, and 10 rectangular openings of different widths (1 mm, 2 mm, 3 mm, or 5 mm) and different widths between the openings (1 mm, 2 mm, or 3 mm). Plates were coated three times with the high emissivity paint and dried in an oven for one day at 100 °C. Rectangular plates (10 cm by 8 cm) were set to the copper holder, which temperature could be maintained at room temperature. The copper holder was placed in front of the blackbody aperture. For a thermal imager we should first calculate the iFOV at the minimum focus distance or larger distance, which is used for measurement of the SSE. Ideally, we should set a thermal imager at such a distance, that a particular opening in the plate is covered by the integer number of pixels. In this way we could determine the influence of a particular line of pixels exposed to the room temperature on the neighbouring line of pixels exposed to the target temperature. The experiment was performed at different distances of a thermal imager from the plates (20 cm, 40 cm, 60 cm, 80 cm, 100 cm) and different temperatures of the blackbodies (50 °C, 250 °C, 500 °C, 750 °C, 1000 °C, 1250 °C, 1400 °C).

For measurements a high-end thermal imager Flir T650sc was used with the resolution 640x480 pixels, operating wavelength 7,5 µm to 13 µm, 45° field of view (FOV) lens, automatic focus and noise equivalent temperature difference (NETD) of 20 mK. The thermal imager was calibrated with the special blackbody (large aperture of 26 cm diameter). Its expanded measurement uncertainty in the range from 10 °C to 70 °C was 0.3 °C.

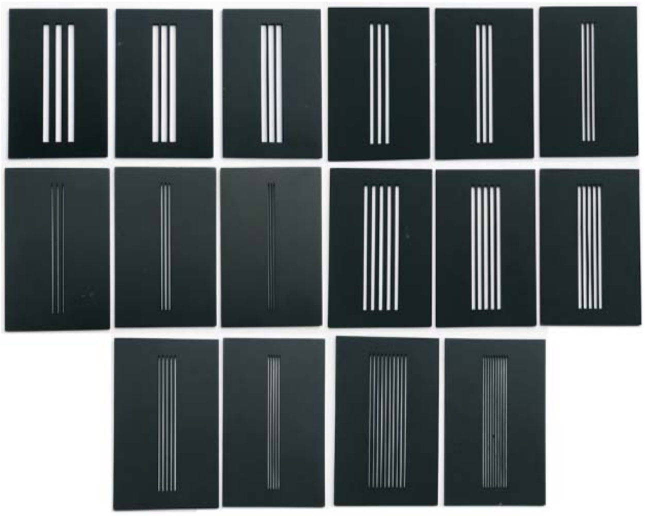

Figure 1.A
Tiles with rectangular openings

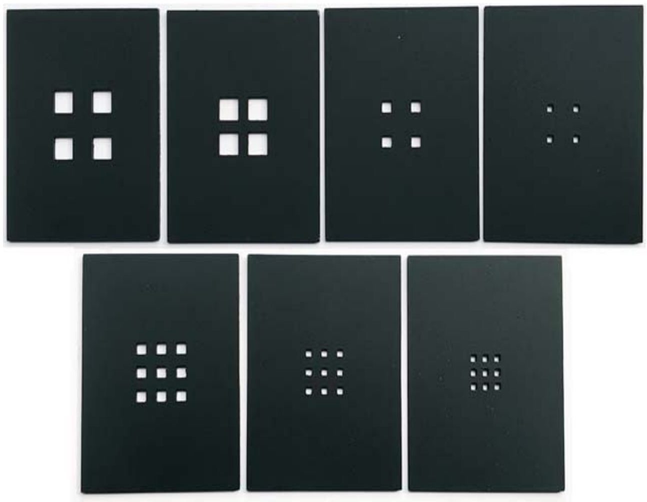

Figure 1.B

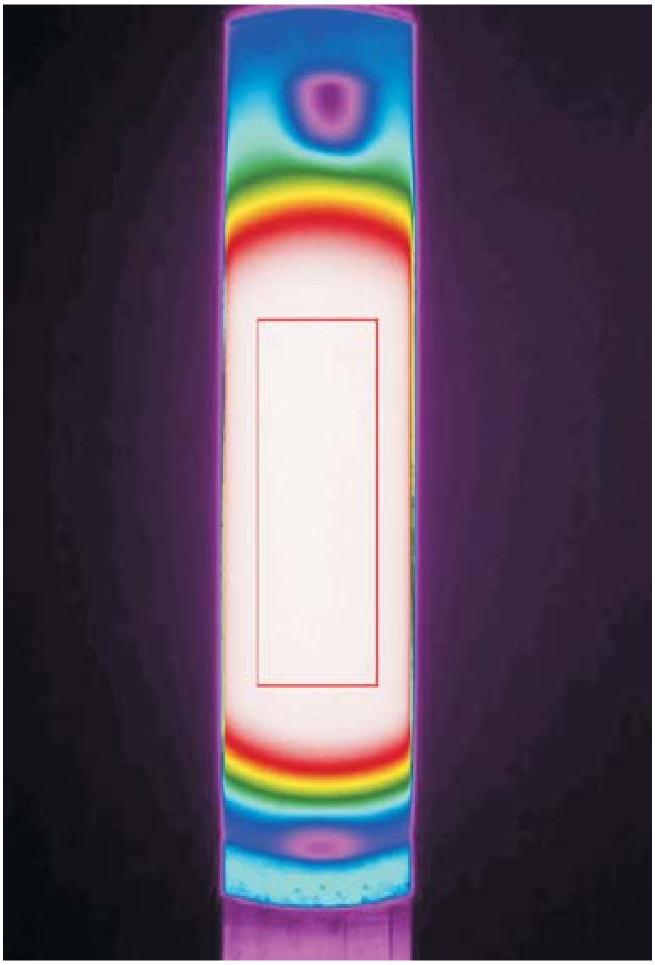

Figure 2.A
ROI examples at 1 rectangular aperture

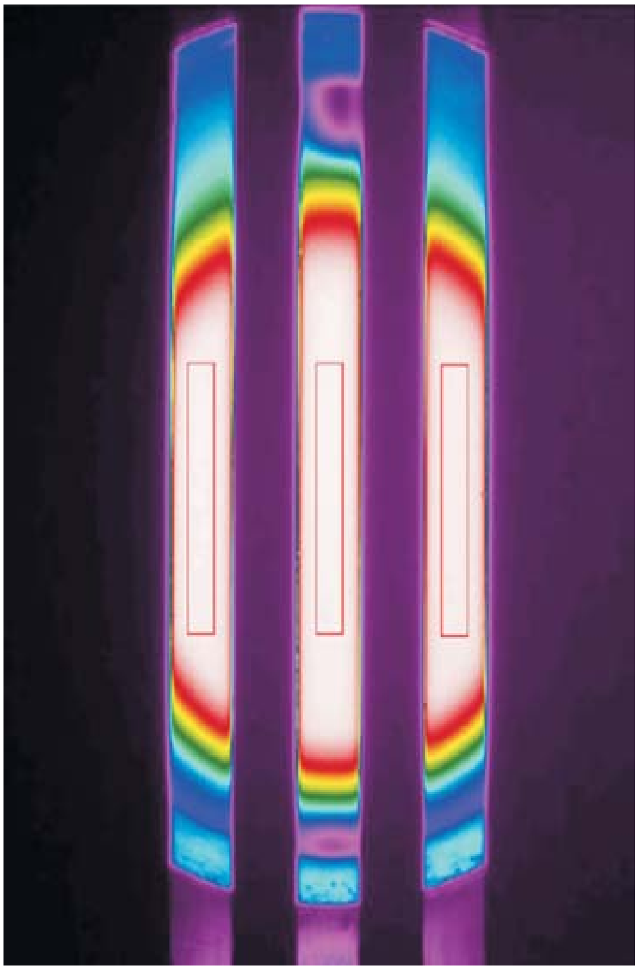

Figure 2.B
ROI examples at 3 rectangular apertures

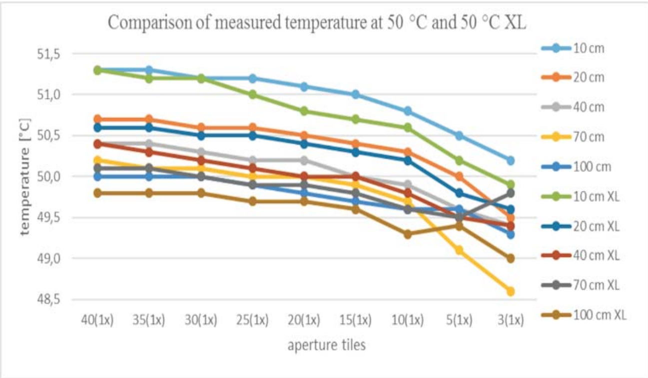

Figure 3.
SSE at different apertures and distances at 50 °C

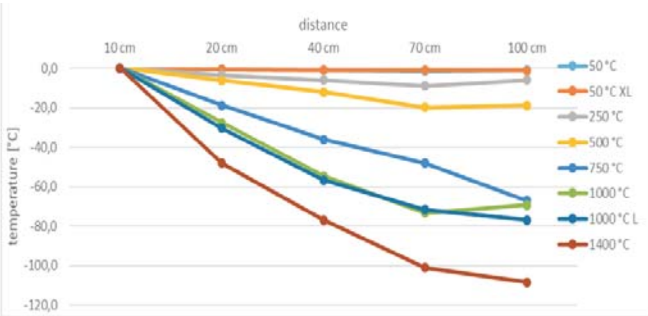

Figure 4.
Temperature deviation comparison from maximum measured temperature at tile 5(3x)5

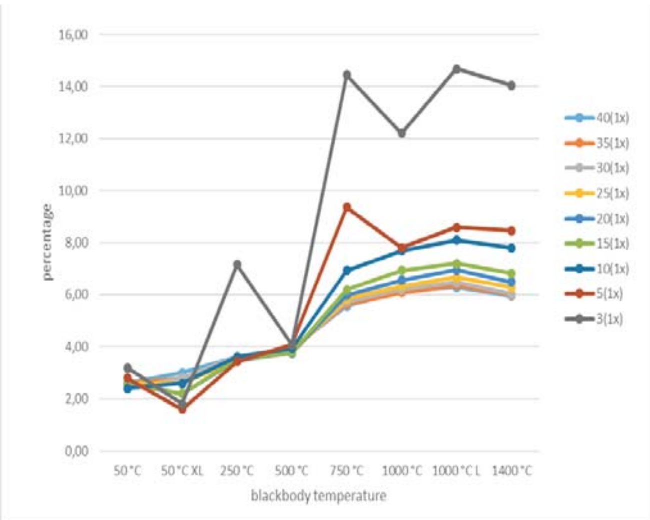

Figure 5.
Differences between maximum and minimum measured temperature presented as percentage of blackbody temperature

Results

Temperature measurements were performed for tiles with one rectangular slot of different dimensions, for tiles with more rectangular slots of different dimensions and different distances between the slots, and for tiles with quadratic slots of different dimensions and different distances between the slots. For every temperature, tile and distance the ROI (region of interest) was determined in the software for analysis of thermograms. The number of pixels in the ROI was calculated based on the distance and iFOV.

Depending on the distance of the thermal imager from the blackbody and its temperature the deviation of measured temperature was between 1 % and 2 % in some case even more. At higher temperatures (above 750 °C) the deviations increased almost to 10 %. Differences between maximum and minimum measured temperature presented as percentage of a blackbody temperature are presented in Figure 5.

With decreased width of rectangular apertures lower temperature was measured under the same conditions. Lower temperature was measured with the same tile when the distance between the imager and aperture tile increased (applies for all used blackbody temperatures). The largest uncertainty was observed when using the smallest aperture tiles at large distances. Increased temperature was measured when the distance between rectangular apertures on the tile was smaller. SSE causes lower measured temperature with square aperture tiles compared to rectangular ones under the same conditions. With the increasing distance between the imager and aperture tiles, measured temperature of the individual pixels at the aperture edge showed decreasing number of pixels, which could be used for accurate temperature measurement.

Conclusions

The most important finding is that suggested minimum number of pixels for measurements 3x3 is far from sufficient for accurate temperature measurement. Based on the measurements along the line through the quadratic slots at least 7 pixels are required to cover the measured target and 7 more must be present between the ROI and the edge of the target to obtain the results of accuracy around 2 %. Based on the results the SSE in thermal imagers is much worse than the SSE in radiation thermometers. The method how to determine the SSE in thermal imagers is not widely agreed in the measurement community. In this case the used thermal imager was one of the best in the market so the question is how bad is the SSE in thermal imagers of lower quality.

References:

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. A large aperture blackbody bath for calibration of thermal imagers. Measurement Science & Technology, 2013; 2 (24), 1-8

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. Calibration of thermal imagers by evaluation of the entire field-of-view. International Journal of Thermophysics 2011; 32 (11-12) 2600-2609

Grgic G, Pušnik I. Analysis of thermal imagers. International journal of thermophysics, 2011; 32 (1-2) 237-247

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CONTEMPORARY MEDICAL THERMOMETRY

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Since the advent of reliable mercury-in-glass thermometers at the turn of the last century the practice of clinical thermometry was thought to be a solved issue. However with advances in technology there has, in recent decades, been a proliferation of temperature measurement methods applied to medical science.

The first part of this paper will give an overview of the fundamentals of temperature measurement, especially outlining the often neglected issues of calibration and traceability (to known temperature references). These two aspects form the basis of all sound measurement on which reliable trustworthy research of enduring value is founded.

The second part of the paper will focus on some of the more modern approaches to thermometry that NPL has been investigating some of which are in use in a clinical setting; these will be:

a) Performance evaluation of clinical thermometers; tympanic and skin thermometers (case studies to show the importance of calibration and traceability) [1, 2]

b) Intra-cranial thermometry performance evaluation [3, 4]

c) Standardisation of MRI thermometry (MR spectroscopy) [5, 6]

d) Clinical Thermal imaging [7, 8. 9, 10]

Where appropriate these will be illustrated with examples of clinical use.

References

1. Ishii, J., Fukuzaki, T., McEvoy, H.C., Simpson, R., Machin, G., Hartmann, J., Gutschwager, B. & Hollandt, J., "A comparison of the blackbody cavities for infrared ear thermometers of NMIJ, NPL and PTB", In: Tempmeko 04, The 9th International Symposium on Temperature and Thermal Measurements in Industry and Science, Zagreb, Croatia, Davor Zvizdic, ed, LPM/FSB 200, pp. 1093-1098

2. Fletcher T, Whittam A, Simpson R, Machin G. Comparison of non-contact infrared skin thermometers. J. Med. Eng. & Technol. 2018 (submitted)

3. Childs C, Machin G. Reliability issues in human brain temperature measurement. Critical Care 2009, 13: R106

4. Machin G, Childs C. A systematic performance evaluation of brain and body temperature sensors using ultra-stable temperature references. J. Med. Eng. & Tech.2010, 34: 192-199

5. Vescovo E, Levick AP, Childs C, Machin G, Zhao S, Williams SR. High Precision Calibration of MRS Thermometry using Validated Temperature Standards: Effects of Ionic Strength and Protein Content on the Calibration. NMR in Biomedicine.2013, 26(2) 213-223

6. Babourina-Brooks B, Simpson R, Arvanitis TN, Machin G, Peet AC, Davies NP. MRS thermometry calibration at 3T: Effects of protein, Ionic concentration and magnetic field strength. NMR in Bio- medicine 2015, 28(7) 792-800

7. Machin G, Chu B. High quality blackbody sources for infra-red thermometry and thermography between -40°C and 1000 °C. Imaging Science 2000, 48: 15-22

8. Simpson R, McEvoy HC, Machin G, Howell K, Naeem M, Plassmann P, Ring F, Campbell P, Song C, Tavener J, Ridley I. In field-of-view thermal image calibration system for medical thermography applications. Int. J. Thermophys 2008; 29, 1123-1130

9. Petrova N, MacDonald A, Ainarkar S, Plassmann P, Ring F, Simpson R, Bevans J, Allen J, Machin G, Edmonds M. Infrared thermometry reveals no differences of the skin temperatures at the plantar, dorsal, medial and lateral sites between the right foot and left foot in healthy volunteers. Diabetic Medicine 2016; 33 (Suppl. 1), 35-196, ()

10. Machin G, Whittam A, Ainarkar S, Allen J, Bevans J, Edmonds M, Kluwe B, MacDonald A, Petrova N, Plassmann P, Ring F, Simpson R. A thermal imaging system for the prevention of diabetic foot ulceration. Physiol. Meas. 2017; 38 420-430

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THE LACK OF TERMINOLOGY AGREEMENT IN DESCRIBING INFRARED CAMERAS AT SCIENTIFIC WRITING

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Introduction

Every time an infrared thermal imaging research paper is written for any biomedical application, it is common to find at the "materials and methods" or "methodology" section the description of the infrared cameras used in the experiment. However, the names of the characteristics provided differ and are inaccurate, it also happens in the full equipment specifications provided by the manufacturers. This deserves attention not only for education proposes but also for the increase of research quality.

Methods

Searching in the main medical literature database "PubMed", using the search terms: "(thermography OR infrared imaging OR thermal imaging) AND infrared camera" there are until 31st December 2017, a total of 1028 papers, from which only 5 addressed correctly the camera specifications description.

Results

Most of the specifications provided are the brand, model, image resolution, thermal sensitivity and accuracy. The same is easily found at most of the infrared cameras manufacturers provided cameras specifications (figure 1).

Imaging Specifications

Detector	FLIR A325sc
Detector Type	Uncooled Microbolometer
Spectral Range	7.5 – 13.0 µm
Resolution	320 x 240
Detector Pitch	25 µm
NETD	<50 mK
Electronics / Imaging	
Time Constant	<12 ms
Frame Rate	60 Hz
Dynamic Range	14-bit
Digital Data Streaming	Gigabit Ethernet (60 Hz)
Command & Control	Gigabit Ethernet
Measurement	
Standard Temperature Range	-20°C to 120°C (-4°F to 248°F) 0°C to 350°C (32°F to 662°F)
Optional Temperature Range	Up to 2,000°C (3,632°F)
Accuracy	±2°C or ±2% of Reading

Figure 1
The technical specifications for the infrared camera FLIR A325sc provided by the manufacturer.

Discussion

The guidelines for specifying a thermal camera for medical applications suggested that it should be described in terms of: detector type, thermal accuracy, thermal sensitivity, optics, array size and resolution.

It is important to note that in infrared thermal imaging the quality of the images is not given by the image resolution, but by the sensors focal plane array size and these two parameters may not be the same misleading users, some cameras use interpolation, which creates pixels from others and the common correspondence between infrared sensor and pixel is lost, being the values different for the both parameters.

Noise Equivalent Temperature Differential (NETD) - is a signal-to-noise ratio that represents the temperature difference which would produce a signal equal to the camera's temporal noise, being approximately the minimum temperature difference which the camera can resolve. This parameter is calculated by dividing the temporal noise by the response per degree (responsivity) and is usually expressed in millikelvin (mK), being the value a function of the camera's f/number, its integration time, and the temperature at which the measurement is made. Although this parameter does not consider the target size, characteristics of the display and the subjective interpretation of the operator. To measure this parameter a blackbody is required and a good quality area source of it.

Thermal Resolution can be expressed as the Slit Response Function (SRF) in terms of a subtended angle or the number of resolvable elements in a longitudinal line. An assessment is described in ASTM E-1213 - 92, Standard Test Method for Minimum Resolvable Temperature Difference (MRTD) for Thermal Imaging Systems. If the temperature measurement is not as critical as imaging, then the MRTD may be more useful. This parameter is usually expressed by camera manufacturers as NETD, but this is impractical due to the NETD degrades over time, the measurement requires specialised equipment, the measurement is not standardised, and manufacturers can improve it through higher object-background temperatures. Thermal Sensitivity specifies the minimum change in signal due to variation in incident radiation which a sensor can detect (the smallest temperature variation that the imager can see). The sensor can, however, detect temperature variations in things that are too small for it to measure. It is important to mention that each sensor in the array will have a different response curve to infrared radiation and therefore result in image non-uniformity. The value often found with these three terms is the manufacturer provided NETD.

Since accuracy is a qualitative concept of closeness of the agreement between the result of a measurement and a true value of the measurand. The temperature measurement accuracy, simple the expected error of an Infrared Thermal System or Thermal accuracy can be expressed in ± degrees of percentage of the overall operational temperature range. Since the definition of accuracy may mislead the readers, the most adequate term of the international vocabulary of metrology is measurement uncertainty or simply uncertainty. Being uncertainty expressed as the doubt about the validity of the result of a measurement or its standard deviation.

Attention is required to harmonize these aspects and improve the quality of further research. Perhaps a working group could be established to propose such a standard to IEC or ISO.

References:

AZOM materials, Thermal Analysis - Precision, Trueness, Accuracy and Errors. Last accessed on 15.01.2018 at https://www.azom.com/article.aspx?ArticleID=5744

BIPM I, IFCC I, IUPAC I, ISO O. The international vocabulary of metrology-basic and general concepts and associated terms (VIM), 3rd edn. JCGM 200: 2012. JCGM (Joint Committee for Guides in Metrology), 2008.

FLIR. FLIR infrared camera A325sc technical specifications. Last accessed on 09.01.2018 at http://www.flirmedia.com/MMC/THG/Brochures/RND_010/RND_010_US.pdf

Hockings C. Infrared System Specifications-What does it all mean? 2013. Last accessed on 09.01.2018 at http://www.ndt.net/article/apcndt01/papers/867/867.htm

Howell KJ, Smith RE. Guidelines for specifying and testing a thermal camera for medical applications. Thermology international, 2009, 19(1), 5-14.

JCGM/WG 1 2008 Working Group. (2008). Evaluation of measurement data-guide to the expression of uncertainty in measurement. In Tech Rep JCGM 100: 2008 (BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML.

Redjimi A, Kneževic D, Savic K, Jovanovi? N, Simovic M, Vasiljevic D. Noise equivalent temperature difference model for thermal imagers, calculation and analysis. Scientific Technical Review, 2014, 64(2): 42-49.

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Session 2: Fever and Body temperature

TECHNICAL AND CLINICAL ACCURACY OF BODY TEMPERATURE MEASUREMENT IN CLINICAL PRACTICE: AN UPDATE OF ISO STANDARD 2-56

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Introduction

In clinical practice, assessment and evaluation of body temperature, has great impact on decisions in nursing care as well as medical diagnosis, treatment and the laboratory test ordered. Procedures for quality assurance of technical accuracy is well established in ISO standards (1-3). Technical accuracy indicates proximity of the devices' measurement results to a true value and precision of the measurement. However, when assessing body temperature in clinical practice, we use the device on the individual patient. Therefore, we also have to consider errors due to differences between individuals as well as within individuals when evaluating and interpreting the reading (4-6). This raises the question about clinical accuracy in measurement of body temperature (7, 8). What factors might influence the reading and how can we handle those errors to assure clinical accuracy? What accuracy can we expect, and what accuracy is acceptable in clinical practice?

Methods

In 2017, the ISO standard "Medical electrical equipment -- Part 2-56: Particular requirements for basic safety and essential performance of clinical thermometers for body temperature measurement" was revised and updated (9). However, due to questions raised in the committee, the JWG 8 committee in Linköping in Sweden in December 2017 continued the revision of the standard.

Discussion

Current research regarding definitions of body temperature in health and disease and the influence of errors, influencing body temperature measurement, initiated a further revision of the standard by the committee. The issues addressed were

- The concept of a different reference and measurement site
- Subject populations when testing clinical accuracy
- The clarification of key definitions, such as adjusted mode, clinical accuracy, measurement site
- Clinical testing for reliability, repeatability, accuracy/bias, validity/sensitivity for temperature changes.

The presentation at the EAT conference in London will give an update of the committee's conclusion and discuss how these issues influence current technical quality assurance and clinical practice.

References

1.ISO. Clinical thermometers - Part 5: Performance of infra-red ear thermometers (With maximum device). Brissels: CEN; 2003.

2.ISO. Medical electrical equipment_ Part 2-56: Particular requirements för basic safety and essential performance of clinical thermometers for body temperature measurement. Switzerland2009.

3.ISO/IECI. General Requirements for the competence of testing and calibration laboratories. Geneva, Switzerland: International Organization for Standardization; 1999.

4.Sund Levander M, Grodzinsky E. Variation in normal ear temperature. American Journal of the Medical Sciences. 2017;Available online 25 May 2017.

5.Sund-Levander M, Grodzinsky E. Time for a change to assess and evaluate body temperature in clinical practice. International Journal of Nursing Practice. 2009;15:241-9.

6.Sund-Levander M, Grodzinsky E, Loyd D, Wahren LK. Error in body temperature assessment related to individual variation, measuring technique and equipment. International Journal of Nursing Practice. 2004; 10:216-23.

7.Grodzinsky E, Sund Levander M, editors. Assessment of fever. Physiology, immunology, measurement in clinical practice. Malmö: Gleerups; 2015.

8.Sund-Levander M, Grodzinsky. Accuracy when assessing and evaluating body temperature in clinical practice: Time for a change Thermology International. 2012;22(Appendix 1 Number 3):25-32.

9.ISO. Medical electrical equipment_ Part 2-56: Particular requirements för basic safety and essential performance of clinical thermometers for body temperature measurement. Switzerland: ISO/TC 121/SC 3 Lung ventilators and related equipment; 2017.

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BILATERAL DIFFERENCES IN ASSESSING BODY CORE TEMPERATURE WITH NON/OR MINIMAL CONTACT METHODS IN YOUNG ADULTS

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Introduction

There are several sites in which the human body core temperature can be remotely and minimally invasively assessed, which could be used to identify febrile states in a threat of pandemic situations at high populational traffic places (e.g. airports, ports, universities, schools, public buildings). In those locations, a fast method is required for temperature screening the masses. However, attention is needed for its implementation (1). Standards (2,3) have been released indicating how to act in that situation. The usual non/or minimal invasive sites used to assess core body temperature are the axilla, the tympanic membrane and the inner canthi of the eye. Thus, these sites are bilateral and can be measured in only one side, there is an absence of data in comparing bilateral measurements, however it is expected that they present some variation. The aim of this research is to compare the bilateral differences at human body sites (axilla, inner-canthi and tympanic membrane) when using the available remote and minimally invasive methods.

Methods

198 healthy volunteers (97 males and 101 females) with mean age 23±9 years old, BMI of 22.5±2.9, underwent temperature screening through axillar and tympanic thermometer and frontal facial thermal imaging using internationally accepted capture protocol (4,5) and screening guidelines (2,3) in an environmental controlled examination room. For the axilla temperature assessment, a Beurer thermometer FT 09/1 (measurement accuracy of ±0.1°C and operational range from 35.5 to 42°C) was used. The tympanic membrane measurements were obtained with a Hartmann Thermoval duo scan thermometer (measurement accuracy of ±0.1°C and operational range from 35 to 42°C). The thermal images were obtained using a thermal camera FLIR E60 (Focal Plane Array sensor size of 320x240, NETD of 50mK at 30º C and a traceability of ±2% of the overall reading). Mean temperature values were obtained from the different methods. Every time that a bilateral difference higher than 1ºC was found in the thermometer methods, the measurement was repeated, and the smaller difference was taken out of three assessments. The IR measurements were assessed by three different operators using the FLIR ThermaCAM Researcher Pro 2.10 software package. The agreement between the 3 operators was assessed calculating the intraclass correlation coefficient (ICC) and using the Bland-Altman method, assessing agreement and limits of agreement (average ± 2 standard deviation of differences). Differences between the three measurement methods were assessed with the Friedman's two-way analysis of variance by ranks test with factors methods vs. site. A repeated measures ANOVA was used to compare the mean differences between the right and left side in the inner canthi, axillar and tympanic measurement site separately. All statistics were calculated using the IBM SPSS v24 software package.

Results

The table 1 presents the average temperature (± standard deviation) values, and maximum and standard deviation of bilateral differences per measurement site. The consistency of data at the inner canthi of the eye was 0.960 and 0.959 per the left and right respectively. Among the three evaluators the ICC was 0.922 and 0.918 for the left and right inner canthi respectively. The agreement between the site measurements of the right and left sides of the body was excellent in the inner canthi (ICC = 0.990), good for the axillar temperature (ICC = 0.844) and moderate for the tympanic temperature (ICC = 0.695).

In terms of bilateral differences between assessment methods, the ICC was 0.99 ($p<0.05$), 0.844 ($p<0.01$) and 0.695 per inner canthi of the eyes thermal imaging, axilla thermometer and tympanic membrane thermometer methods correspondingly. The repeated measures ANOVA detected significant differences in the differences between the right and left sides of the body ($F=7.920$; $p=0.002$). The agreement between the three methods was poor. In the pairwise analysis, the agreement between the different temperature assessment methods was 0.089 for the inner canthi and axilla, -0.009 for inner canthi and tympanic membrane and 0.225 for axilla and tympanic membrane. Significant differences were found in the temperature measurements for all sites pairs (p?0.001).

Discussion

The three studied methods were able to estimate the core body temperature in afebrile participants. The bilateral higher variations were found at the tympanic membrane assessment method and the smaller at the inner canthus thermal imaging approach. The thermal imaging method proved that at the studied areas of interest there was good data consistency and small inter operators' variability. There was statistical difference between left and right sites at the inner canthi and axilla measurements, being higher for the axilla. The bias analysis demonstrated that the smaller bias was found in the inner canthi of the eye measurement.

Table 1
Mean temperature values, and maximum, mean (± standard deviation) and limits of agreement of bilateral differences per measurement site.

site	Mean Temperatures		Bilateral differences		
	Right	Left	Maximum	Mean (± s.d.)	Limits of agreement
Inner canthi	36.0 ± 0.5	36.0 ± 0.5	0.3	0.07 (± 0.09)	0.26
Axilla	36.3 ± 0.4	36.2 ± 0.5	1.1	0.26 (± 0.32)	0.91
Tympanic membrane	36.4 ± 0.6	36.4 ± 0.6	2.0	0.32 (± 0.56)	1.36

Conclusion

All methods were able to estimate the body core temperature. However, the major bilateral agreement was found at the inner canthi of the eye thermal imaging method. Further research is needed to understand the higher bilateral variability in using the traditional thermometer axilla and tympanic membrane assessments, since these are the methods currently used within a clinical setup.

Acknowledgment

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References

1. Mercer JB, Ring EFJ. Fever screening and infrared thermal imaging: concerns and guidelines. Thermology International 2009; 19(3); p. 67-69.

2. Ring EFJ, Ammer K. The technique of infrared imaging in medicine, Thermology international 2000; 10(1); p. 7-14.

3. Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body, Thermology international 2008, 18(4); p. 125-144.

4. ISO TC121/SC3-IEC SC62D, Particular requirements for the basic safety and essential performance of screening thermographs for human febrile temperature screening, 2008.

5. ISO/TR 13154:2009 ISO/TR 8-600, Medical Electrical Equipment-Deployment, implementation and operational guidelines for identifying febrile humans using a screening thermograph, 2009.

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THE REVISED ISO STANDARD FOR SCREENING THERMOGRAPHS FOR HUMAN FEBRILE TEMPERATURE SCREENING

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Introduction

Following the outbreak of the highly infectious SARS in the Far East in 2000 and further pandemic influenza outbreaks around the world, there was an international response to consider fever screening particularly among the international travelling public. This screening was based on the premise that most pandemic diseases are accompanied by an elevated core temperature. The International Standards Organisation called a group of experts together for a series of meetings to create new standard recommendations for the use of infrared imaging to detect passengers with raised body temperature. The initial methodology had been published by the Singapore Standards Authority using facial thermograms. It was recommended that under controlled conditions febrile passengers could be detected by remote sensing. After 5 years the ISO committee was reconvened to update this document.

Areas for revision: The committee was able to draw on experience from the fact that certain areas of the recommendations were not clear enough. There was further need for extending the range of potential pandemic infections where this technology could be usefully deployed. Finally, more studies had become available from which the reference list could be updated.

Definitions

These were expanded. A more precise description of the region of the inner canthus of the eyes was described. Experimental studies confirmed that with strict protocols this site was the optimal area of the face to indicate fever. The use of the colour display was clarified e.g. The SCREENING THERMOGRAPH shall be provided with at least one colour mapping mode where the colours follow the order of the visible spectrum (e.g., rainbow scale) such that blue is cooler and red is hotter. Many examples of the industrial colour scale were found which is far less sensitive to the narrow temperature band in a human face thermogram. The definition of the required correct positioning of the camera and the subject's face was also expanded. Clarifications such as the use of the calibration source were also expanded. The EXTERNAL TEMPERATURE REFERENCE SOURCE should be set at a value near the THRESHOLD TEMPERATURE. The minimum temperature range of the EXTERNAL TEMPERATURE REFERENCE SOURCE was chosen to be slightly broader than the minimum temperature range of the THRESHOLD TEMPERATURE. The CALIBRATION SOURCE is required to be sufficiently large so that the SCREENING THERMOGRAPH's measurement is not affected by its small size and to allow a clear identification of the display colour within the WORKABLE TARGET PLANE. The CALIBRATION SOURCE should not be larger than 10 % of the FACE, so as to not adversely affect the infrared camera assessment. The target area for measurement has also been expanded: the current evidence indicates that the region medially adjacent to the inner canthi is the preferred site for fever screening due to the stability of that measurement site. This is due to this region being directly over the internal carotid artery.

Relevant Infections:Since the more recent serious problem in Africa caused by the EBOLA outbreak, a list of potential infections that can be usefully screened by thermal imaging and those that do not manifest with an increase in temperature (fever) have been added.

Conclusion

Significant improvements and expansion of the original ISO standard for fever screening with infrared thermal imaging for fever detection have now been achieved and internationally accepted. Evidence that the original recommendations work when properly applied as described has been published. Equally there is evidence that not using the methodology correctly fails to provide the necessary discrimination for separating febrile from non febrile persons. To correctly apply this standard requires investment in both trained personnel and appropriate calibrated technology. The Ebola crisis demonstrated that this is an economic challenge for a number of countries, where local hygiene may be at levels where risk of infection and delays in bringing full medical care when urgently needed.

References

IEC/FDIS 80601-2-59, Medical electrical equipment - Part 2-59 Particular requirements for the basic safety and essential performance of screening thermographs for human febrile temperature screening.

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THE CORRELATION BETWEEN TYMPANIC MEMBRANCE TEMPERATURE AND SPECIFIC REGION OF FACE TEMPERATURE WITH STATISTICAL CORRECTION

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Introduction

Many travelers travel through airports or ports as they progress toward an international society. At the same time, there is a growing possibility that many infectious diseases will travel between countries. In the case of the outbreaks of infection disease such as SARS in 2002/2003, a large number of pyrogenesis detectors were placed in order to prevent the spread of a fever in international airports and ports, which led to early screening of high-temperature patients. According to ISO reports, the inner canthus temperature is the most suitabl

Material and Methods

1) Participants: Data were collected from National Health Insurance Service (NHIS) Ilsan Hospital from August 2016 to November 2017. In total, 2155 patients were included in this study. The patients were informed about the procedures for all stages of the investigation and signed informed consent forms prior to enrolment in the study.

2) Experimental design: Patients who were not able to sit or open their eyes were excluded. Facial temperature was measured by the following methods. First, the beds were block light and heat from the outside. Second, place the temperature and hygrometer next to the bed, and position the IR camera at a distance of 1.5 meters from the patient, and then taken. Finally, left and right tympanic temperature was measured

3) Thermal image processing: In order to estimate the patient's temperature status from the thermal image, position the six regions of interest (ROI) of eyes (medial canthus, cornea, sclera between medial canthus and cornea, both eyes) and the ROI of the inter-brow and calculate the ROI average and standard deviation temperature for each 4x4 pixel size. Patient information included in the study were gender, age, presence of lens wear, height, weight, blood pressure and diagnosis, room temperature, humidity and time of measurement. For the identification of high-fever patients, we divided the ear temperature into 37.5 degrees and compared the existing statistical methods with support vector machine (SVM) in classification accuracy. In the support vector machine, a total of 70% were selected randomly for learning (training set), and the remaining 30% were classified to verify the efficiency of the model (validation set). The infrared camera received a calibration certificate from the institution, certified by the specification and KOLAS. The hygrometer and tympanic thermometer also received a calibration certificate. Data were calculated using calibrated measurements.

4) Statistical analysis: The numerical and categorical characteristics of the study population were expressed as mean±standard deviation and percentages, respectively. To quantitatively assess the performance of the seven spots correlation with core temperature, we calculated interclass correlation (ICC), root mean squared error (RMSE) and quantile root mean squared error (QRMSE). The closer the ICC value is to 1, the better the result, but the closer the RMSE and QRMSE are to 0, the better. In addition, we checked visual quality using by Bland-Altman plot and Taylor diagram. The scatter plots was analyzed to determine the linear relationship and the distributional identity between tympanic membrane and thermographic temperature. When the eardrum temperature exceeded 37.5 degrees, we observed monotone increase in facial temperature. Based on these results, we defined the patients with high fever and compared the logistic regression method and the SVM to distinguish high fever patients. All of graphics were created using R software for Windows version 3.0.2. All of statistical measurements were performed in SAS version 9.4.

Results

Baseline characteristics of the study population (total 656 patients) are listed in Table 1. The mean age at the time of thermography was 48.58 years-old. When age was categorized by below 10 years-old, there were 77 (11.74 %), 60 teenagers (9.15 %), 33 twenties (5.03 %), 35 thirties (5.34 %), 62 forties (9.45 %), 95 fifties (14.48 %), 136 seventies (20.73 %), 65 eighties or more (9.91 %), respectively. Within the population, 53.20 % of participants were male. Mean room temperature and humidity were 26.06°C and 42.61 %, respectively. The left side ear and facial temperature were measured by increasing the room temperature by 0.5°C and the humidity by 10%. Since the results on the left and right do not differ greatly, only the results on the left side are summarized in Table 1.

The average temperature of the medial canthus was similar to that of the ear among the various parts of the face temperature. Despite changes in room temperature, the ear temperature was

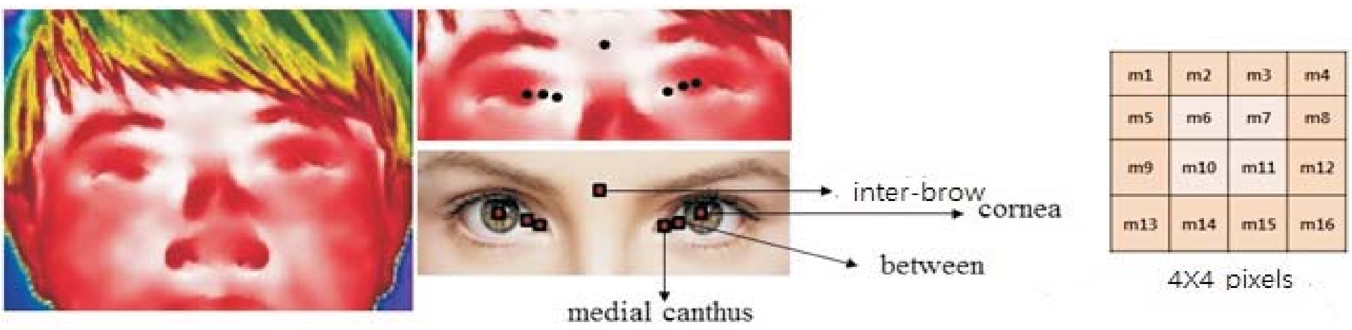


Figure 1
Seven ROIs of temperature measurement of the eye and face. The size of each ROI was 4X4 pixels.

maintained at 37.2°C. To quantitatively assess the performance of the temperature of seven ROIs, we calculated RMSE and QRMSE. The ICC, RMSE and QRMSE are defined as follows

$$ICC = \frac{1}{Ns^2}\sum_{n=1}^{N}(y_{pred} - \bar{y})(y_{true} - \bar{y})$$

$$RMSE = \sqrt{\sum \frac{(y_{pred} - y_{true})^2}{n}}$$

$$QRMSE = \sqrt{\sum \frac{(Rank_{(y_{pred})} - Rank_{(y_{true})})^2}{n}}$$

Where y_{pred} denote the mean temperature of 4 by 4 temperature pixels of each ROIs, and y_{true} denote eardrum temperature for each person, respectively. The $\bar{y}$ and s denote the common average and variance of y_{pred} and y_{true} respectively. Rank( ) denote the quantile of data. Table 2 shows the results of ICC, RMSE and QRMSE. As can be seen, the medial canthus produces better per-

Table 1
Baseline characteristics of the study population, and left side membrane and face temperature for each room conditions.

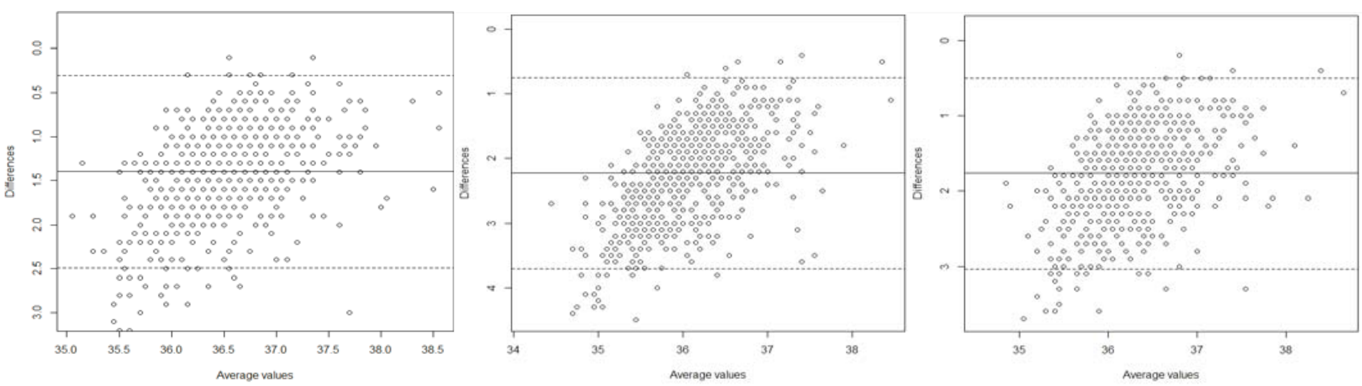
Sex	N(%)	Room Temperature (°C)	Ear	MC	Cornea	Between	Inter Brow
Male	1208(56%)	= 25	37.2 ± 0.5	35.7 ± 0.8	34.7 ±0.9	35.2 ±0.8	34.7 ± 0.9
Female	947(44%)	25.1~25.5	37.1 ± 0.4	35.7 ± 0.6	34.9 ± 0.8	35.4 ± 0.7	34.7 ± 0.7
Age (y)		25.6~26.0	37.2 ± 0.4	35.8 ± 0.7	35.0 ± 0.8	35.5 ± 0.7	34.9 ± 0.8
=9	244(11.3%)	26.1~26.5	37.2 ± 0.5	35.8 ± 0.7	35.0 ± 0.9	35.4 ± 0.8	34.9 ±0.8
10~19	184(8.5%)	26.6~27.0	37.2 ± 0.5	35.8 ± 0.8	35.1 ± 0.8	35.5 ± 0.8	35.0 ±0.7
20~29	92(4.3%)	27.1~27.5	37.2 ± 0.4	36.0 ± 0.5	35.3 ± 0.7	35.7 ± 0.6	35.2 ±0.7
30~39	82(3.8%)	> 27.5	37.3 ± 0.5	36.0 ± 0.7	35.1 ± 0.8	35.6 ± 0.8	35.1 ±0.7
40~49	204(9.5%)	Humidity (%)					
50~59	351(16.3%)	= 10.0	37.1±0.4	35.7 ± 0.6	34.7 ± 0.9	35.2 ± 0.7	34.9 ± 0.6
60~69	343(15.9%)	10.1~20.0	37.3±0.4	35.9 ± 0.8	35.0 ±0.9	35.5 ± 0.9	35.0 ± 0.5
70~79	460(21.4%)	20.1~30.0	37.1±0.5	35.7 ± 0.8	34.9 ± 0.9	35.4 ± 0.8	34.9 ± 0.8
0= 80	195(9.0%)	30.1~40.0	37.2±0.5	35.9 ± 0.6	34.9 ± 0.8	35.4 ±0.7	35.0 ± 0.7
		> 40.0	37.2±0.5	35.8 ± 0.7	35.1 ± 0.8	35.5 ±0.8	34.9 ±0.8

MC: Medial canthus
Ear: tympanic membrane
Between: ROI between medial cantus and cornea

Table 2 RMSE and QRMSE result of seven points for each tympanic temperature

		Total(N=2155)		
		ICC	RMSE	QRMSE
Left	Medial Canthus	0.3850	1.5047	1.4224
	Cornea	0.2567	2.3508	2.2675
	Between	0.3114	1.8837	1.7998
	Inter Brow	0.2685	2.3835	2.3134
Right	Medial Canthus	0.3496	1.5201	1.4371
	Cornea	0.2452	2.3532	2.2752
	Between	0.3033	1.8698	1.7915
	Inter Brow	0.2739	2.4005	2.3327

ICC : Interclass correlation
RMSE : root mean squared error
QRMSE : quantile root mean squared error



Medial canthus Cornea Between

Figure. 2 Bland-Altman plot for thermographic temperature of left eye with left ear temperature

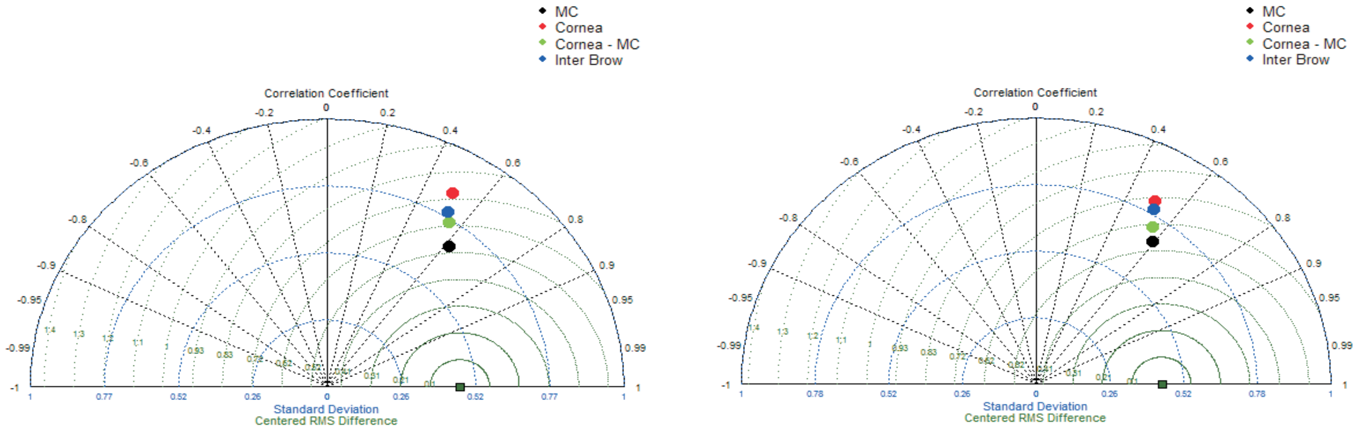
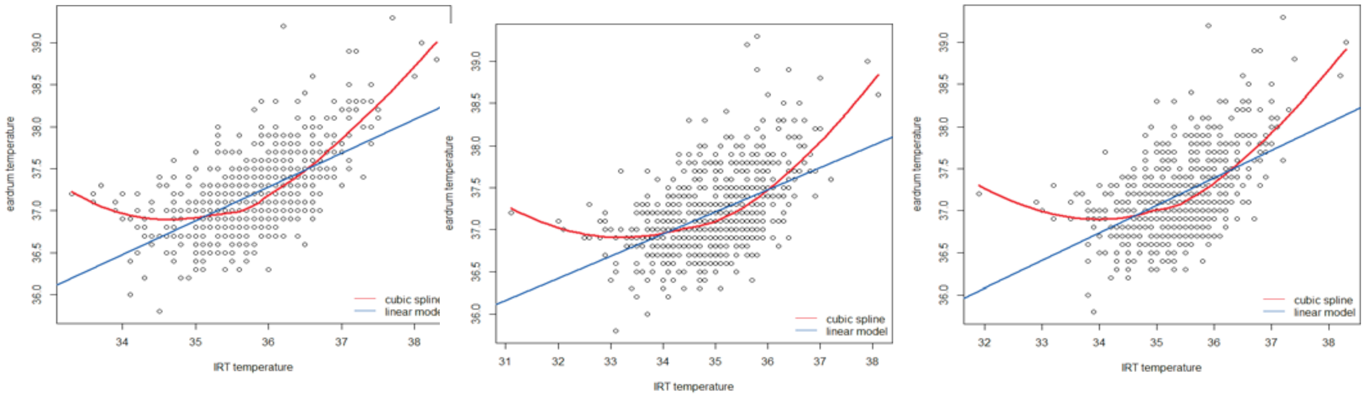


Figure 3 The Taylor diagram compare thermography observations and ear temperature for each side.



Medial canthus Cornea Between

Figure 4 Scatter plot with linear regression and cubic spline for thermographic temperature of left eye with left ear temperature (x-axis : IRT temperature, y-axis : eardrum temperature)

Table 3 Accuracy, sensitivity, specificity, PPV and NPV of the SVM result in comparison with logistic regression

	Logistic	SVM		
	Training set	Validation set	Training set	Validation set
Accuracy(95%CI)	85.22(83.23-87.21)	81.11(78.55-83.67)	93.10(91.68-94.53)	85.00(82.67-87.33)
Sensitivity(95%CI)	75.26(69.13-81.40)	64.23(56.21-72.26)	62.10(55.21-69.00)	32.85(24.98-40.71)
Specificity(95%CI)	87.06(85.01-89.11)	84.14(81.55-86.73)	98.83(98.17-99.49)	94.36(92.72-96.00)
PPV(95%CI)	51.81(45.92-57.71)	42.11(35.41-48.80)	90.77(85.79-95.75)	51.14(40.69-61.58)
NPV(95%CI)	95.01(93.62-96.40)	92.91(90.99-94.82)	93.38(91.91-94.86)	88.67(86.49-90.85)

PPV : positive predictive values
NPV : negative predictive values
SVM : support vector machine

formance than cornea, between medial canthus and cornea and inter-brow in each side. Figure 3 and 4 show the similarity between temperature of IRT image and tympanic membrane for seven spots. The medial cantus performed well on left and right, high correlation and low RMS difference.

Scatter plot shows that rapid temperature change occurs at the eardrum temperature of 37.5°C. Among the statistical classification methods, the comparison of the classification probabilities by the support vector machine using the machine learning method and the classical method, logistic regression, showed that the results of the machine learning method showed high agreement with the accuracy.

Logistic regression analysis showed accuracy of 81% and machine learning result to be about 85% in validation set. In machine learning, sensitivity and specificity were 33% and 94%, respectively, and positive predictive values (PPV) and negative predictive values (NPV) were 51% and 88%, respectively.

Discussion

We measured seven ROIs of the facial IRT and estimated the similarity to the temperature of the eardrum. The results showed that the medial canthus of the eye was the closest to the tympanic membrane temperature with the same result as ISO. The inter-brow of the face was most different from the tympanic temperature. However, for travelers with eye disabilities or acute illness of the eye, it may be better to use inter-brow as an alternative ROI.

However, the tympanic temperature and the medial canthus temperature differed by more than about 2°, and the accuracy was problematic because the dispersion was relatively large. Therefore, it is difficult to use the facial temperature instead of the tympanic temperature. To solve all these problems, a study was conducted to isolate high-fever patients based on 37.5 degrees, to screen for the transmission of diseases in high-fever patients, and to improve the classification accuracy through machine learning. Because of the analysis, the accuracy increased slightly compared with the existing statistical model, but the sensitivity was relatively poor. Sufficient learning of data is needed to further enhance consistency and pre-processing of data is required. Therefore, we plan to use the medial canthus in future to formulate an estimation formula to estimate the tympanic temperature in addition to the formula that accurately classifies patients with high fever over 37.5 degrees.

Conclusion

The facial temperature was measured for patients admitted to the hospital for two years, and the relationship between the temperature and the tympanic membrane temperature was analyzed. We plan to apply a variety of machine learning methods to get a more accurate result, and we will recruit more data to improve results.

Acknowledgment:

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References:

ISO/IEC. International vocabulary of metrology - Basic and general concepts and associated terms (VIM). 3rd eds, ISO/IEC GUIDE 99, 2007.

ISO/IEC. Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) in Uncertainty of measurement; ISO/IEC Guide 98-3, 2008.

Chandler C. The use of thermography inelevated bosy temperature screenig, Pan Am J Med Thermol.2015, 2: 58-62

Piani C, Haerter JO, Coppola E. Statistical bias correction for daily precipitating in regional climate models over Europe Theor Appl Climatol, 2010; 99(1-2), 187-192

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Session 3: Animal thermography

INFRARED THERMAL IMAGING IN HORSES - A LITERATURE OVERVIEW

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Infrared thermography (IRT) was introduced to equine veterinary medicine in the mid-1960s and early 1970s (Delahanty & Georgi 1965; Strömberg 1971). Since that time IRT has been confirmed as a non-invasive diagnostic method for measuring physiological or pathological changes in surface temperature (Soroko and Howell 2018). In recent publications thermography has been applied in equestrian studies as a complementary diagnostic tool, and as a technique in the evaluation of welfare, thermoregulation and athletic performance (Soroko &Davies - Morel 2016). The aim of the review is to present application of thermography in equine sport and medicine.

Thermography in veterinary medicine plays a role as a complementary diagnostic method for diagnosis of inflammatory conditions, vascular and neurological disorders (Ciutacu et al. 2006). Most commonly, IRT is used for indicating orthopaedic injuries mainly associated with the forelimbs and back area which are very common injury sites. Numerous publications have proved IRT has advantages in diagnosing subclinical signs of inflammation of the musculoskeletal system in performance horses (Turner 1991; Eddy et al. 2001). IRT is used in the diagnosis of a variety of limb injuries including tendinopathy, bucked shins, laminitis, and inflammation of the carpal and tarsal joints (Soroko et al. 2013; Soroko et al. 2018). In the case of back abnormalities, IRT has been applied in neuromuscular disease of the thoracolumbar region, and muscular and spinous process inflammation of the thoracic vertebrae (Fonseca et al. 2006).

IRT can be used to document the change in body surface temperature resulting from exercise, and thus evaluate the function of individual parts of the body in performance horses (Soroko et al. 2014). Jodkowska (2005) developed a model of horse body surface temperature before and after exercise and concluded that body surface temperature patterns were correlated with exercise performance. Therefore, body surface temperature examination of the distal limbs and back is helpful in assessing the quality of exercise and the preparation of the horse for training. Other studies have indicated the most important body regions to be monitored for the effects of training (Soroko et al. 2014; Soroko et al. 2017a). Simon et al. (2006) and Soroko et al. (2017b) studied changes of body surface temperature in response to treadmill exercise to evaluate the physiological effect on the equine musculoskeletal system. Assessment of body surface temperature can also indicate inflamed areas that could account for a reduction in athletic performance (Soroko et al. 2014). In performance sport and racing horses, IRT offers an easy and efficient evaluation of saddle fit. IRT examination indicates the temperature distribution created between the saddle and the surface of the back (Arruda et al. 2011).

Normal thermographic patterns for the horse have been described, with a high degree of symmetry between left and right sides of the body (Soroko et al. 2017c). Several studies have attempted to establish the temperature distribution of the symmetrical parts of the body of a horse at rest under a variety of environmental conditions. Tunley and Henson (2004) indicated reproducibility of the thermal patterns over the horse back over hourly, daily and weekly intervals at the confidence limit of 90%. Purohit and McCoy (1980) demonstrated some consistent general characteristics of thermal patterns in the limbs, but the horses in their study presented with a wide range of absolute limb surface temperatures.

Recently, there has been considerable interest in the measurement with IRT of equine eye temperature, for the detection of fever (Johnson et al. 2011), inflammation (Rushton et al. 2015) and as an indicator of physiological stress (Valera et al. 2012; Soroko et al. 2016).

Looking to future uses, periodic routine thermographic evaluation of performance horses could assist in the design of training programmes and aid injury prevention, but larger controlled studies are now required to demonstrate utility.

References

Arruda TZ, Brass KE. De La Corte FD. Thermographic assessment of saddles used on jumping horses. Journal of Equine Veterinary Science 2011;31; 625-629.

Ciutacu O, Tanase A, Miclaus I. Digital infrared thermography in assessing soft tissue injuries on sport equines. The Bulletin of University of Agricultural Sciences and Veterinary Medicin 2006;63; 228-233.

Delahanty DD, Georgi JR. Thermography in equine medicine. Journal of the American Veterinary Medical Association 1965; 147; 235-238.

Eddy AL, Van Hoogmoed LM, Snyder JR. The role of thermography in the management of equine lameness. Veterinary Journal 2001; 162; 172-181.

Fonseca BPA, Alves ALG, Nicoletti JLM, Thomassian A, Hussini CA. Mikaik S. Thermography and ultrasonography in back pain diagnosis of equine athletes. Journal of Equine Veterinary Science 2006;26:507-16.

Jodkowska E. Temperatura powierzchni ciala jako kryterium predyspozycji wysilkowych konia. Zeszyty Naukowe AR we Wroclawiu 2005; 511.

Johnson SR, Rao S, Hussey SB, Morley PS. Traub - Dargatz JL. Thermographic eye temperature as an index to body temperature in ponies. Journal of Equine Veterinary Science 2011; 31; 63-66.

Purohit RC, McCoy MD. Thermography in the diagnosis of inflammatory processes in the horse. American Journal of Veterinary Research 1980; 41; 1167-1174.

Rushton JO, Tichy A, Nell B. Introduction of the use of thermography and thermometry in the diagnosis of uveitis in horses: a pilot project. Veterinary Record Open 2015; 27; 2.

Simon EL, Gaughan EM, Epp T, Spire, M. Influence of exercise on thermographically determined surface temperatures of thoracic and pelvic limbs in horses. Journal of the American Veterinary Medical Association 2006; 229; 1940-1944.

Soroko M, Davies-Morel MCG. Equine Thermography in Practice; CABI Publisher, United Kingdom, 2016.

Soroko M, Dudek K, Howell K, Jodkowska E, Henklewski R. Thermographic evaluation of racehorse performance. Journal of Equine Veterinary Science 2014; 34; 1076-1083.

Soroko M, Howell. K. Infrared thermography: current applications in equine medicine. Journal of Equine Veterinary Science 2018; 60; 90-96.

Soroko M, Howell K, Dudek K, Henklewski R, Zielinska P. The influence of breed, age, gender, training level and ambient temperature on forelimb and back temperature in racehorses. Animal Science Journal 2017a; 88; 347-355.

Soroko M, Howell K, Dudek K, Wilk I. Janczarek I. Physiological changes of the horse musculoskeletal system during physiological effort measured by infrared thermography. Tavares JMRS, Natal Jorge RM. (eds.), European Congress on Computational Methods in Applied Sciences and Engineering, Springer International Publishing AG 2017b; 2011-2014.

Soroko M, Howell K, Dudek K. The effect of ambient temperature on infrared thermographic images of joints in the distal forelimbs of healthy racehorses. Journal of Thermal Biology 2017c; 66; 63-67.

Soroko M, Howell K, Zwyrzykowska A, Dudek K, Zieli?ska P, Kupczy?ski R. Maximum eye temperature in the assessment of training in racehorses: correlations with salivary cortisol concentration, rectal temperature and heart rate. Journal of Equine Veterinary Science 2016; 45; 39-45.

Soroko M, Henklewski R, Filipowski H, Jodkowska E. The effectiveness of thermographic analysis in equine orthopedics. Journal of Equine Veterinary Science 2013; 33; 760-762.

Strömberg B. The normal and diseased superficial flexor tendon in racehorses. a morphologic and physiologic investigation. Acta Radio- logica Supplementum 1971; 305; 1-94

Tunley BV, Henson FM. Reliability and repeatability of thermographic examination and the normal thermographic image of the thoracolumbar region in the horse. Equine Veterinary Journal 2004; 36; 306-312.

Turner TA. Thermography as an aid to the clinical lameness evaluation. Veterinary Clinics of North America Equine Practice 1991; 7; 311-338.

Valera M, Bartolomé E, Sánchez MJ, Molina A, Cook NJ. Schaefer AL. Changes in eye temperature and stress assessment in horses during show jumping competitions. Journal of Equine Veterinary Science 2012; 32; 827-830.

Von Schweinitz DG. Thermographic diagnosis in equine back pain. Veterinary Clinics of North America Equine Practice 1999; 15; 161-177.

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USE OF THERMAL IMAGING FOR DIAGNOSTIC OF MMA OR PDS IN SOWS

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Introduction

Mastitis, metritis and agalactia syndrome, commonly referred to as MMA, is a complex syndrome seen in sows shortly (12 hours to three days) after farrowing. More recently it has been called postpartum dysgalactia syndrome (PDS). However, MMA syndrome may be considered the emerging part of an iceberg represented by PDS, which is the more important and underestimated part and therefore the least obvious and most dangerous. Mastitis is a bacterial infection of the udder. In many cases only one or two mammary glands are affected. Metritis is an infection of the uterus, presented as vulval discharges. Agalactia is a reduction or total loss of milk production by the sow. It is often not detected until the nursing litter show signs of hunger and/or weight loss. MMA leads to increased piglet mortality and reduced weaning weights. Clinical signs include constipation, fever (+1,0 °C to 1,5 °C) and anorexia (one to two days). Inappetence is often the first sign noticed, along with restlessness during suckling and a loss of condition in the litter. A few cases of MMA show all signs together and signs tend to be farm-specific. In majority of cases low milk production and depressed daily live weight gain of piglets are the only indications of the problem. Diagnosis is based on clinical signs, particularly inappetence and fever in the sow and a reduction in the condition of the litter. Treatment usually includes the use of antibiotics and medicines to reduce inflammation and injecting products to stimulate milk production. Small doses of oxytocin can help, although they should not be necessary, if piglets are suckling regularly. If used early on, oxytocin may reduce the need for veterinary input. Treatment should be given as soon as MMA is diagnosed or if sow body temperature rises above at least 39,3 °C (rectal measurement), 12 to 18 hours post farrowing. In some pig farms the MMA represents a very serious problem, therefore expensive veterinary treatment is required. A combination of appropriate criteria is essential to achieve a proper diagnosis and to minimize use of antibiotics and prevent antibiotic resistance. Based on the stated facts the most important are preventive measures in order to avoid either formation of MMA or to treat the sows as soon as possible to prevent the loss of milk or even piglets. The aim of the experiment is to determine, if the use of thermal imaging compared to rectal temperature could be considered as a reliable and effective preventive action for early detection of MMA and to provide an effective veterinary treatment on time. At the same time, we would like to determine, if the temperature of the mammary gland exists, which could be considered as the reference temperature based on which the decision for veterinary treatment could be taken.

Methods

Thermal imaging of mammary gland was compared to rectal temperature measurements in pregnant sows at the farm with 52 breeding sows and 28 gilts. Both types of temperature measurements were performed in a group of breeding sows in the farrowing unit (5 sows, 6 sows, 10 sows) from up to 9 days before the farrowing and then every day up to 9 days after farrowing. Rectal measurements were performed with a calibrated veterinary liquid-in-glass thermometer with the expanded measurement uncertainty of 0,2 °C. Thermal imaging was performed with two substantially different thermal imagers to compare their performance and suitability of temperature analysis. One is a high-end thermal imager Flir T650sc with the resolution 640x480 pixels, operating wavelength 7,5 μm to 13 μm, 45° field of view (FOV) lens, automatic focus and noise equivalent temperature difference (NETD) of 20 mK. Another thermal imager is a relatively simple and less sophisticated Fluke TiS45 with the resolution 160x120 pixels, operating wavelength 7,5 μm to 14 μm, FOV 35,7° by 26,8°, manual focus and NETD of 90 mK. Both thermal imagers were calibrated with the special blackbody (large aperture of 26 cm diameter) in the range from 10 °C to 70 °C the expanded measurement uncertainty of 0,4 °C (Flir) and 2 °C (Fluke). In the experiment the thermal imagers were used at the distance of 0,5 meters (Flir) to 1 meter (Fluke), depending on the field of view. Thermal imagers were switched on for 30 minutes before thermography was performed. In the analysis of thermograms the emissivity of mammary glands was set to 0,97. For each sow the rectal temperature was measured first. Thermal imaging was performed from the right side (R) (front part, rear part, and complete mammary gland) and the left side (L) except during the farrowing, when thermal images were taken only from the side, which was available because a sow was lying. Example of a typical thermogram is presented in Figure 1A (Flir) and 1B (Fluke). Air temperature of all spaces (free range space, pre-far-

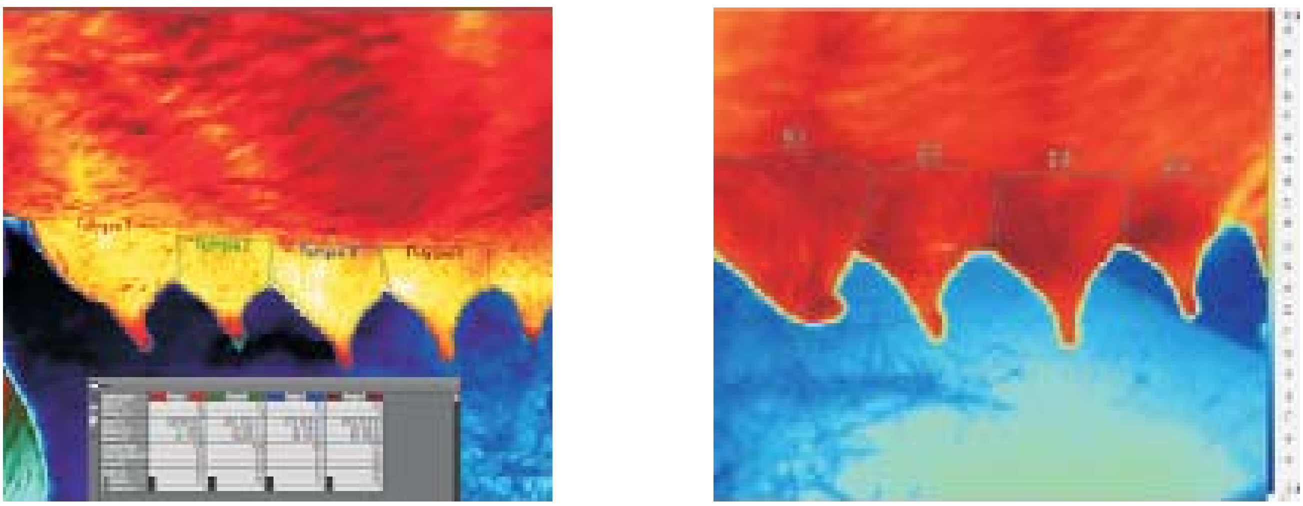

Figure 1 Thermogram of mammary gland with Flir (A) and Fluke (B).

rowing space, dedicated space after farrowing) were measured with thermometers which logged the temperature every 5 minutes.

Results

Measurements in three groups of breeding sows were performed and analyzed. Each mammary gland on the left and the right side was analyzed and its maximum temperature was determined. The results showed that temperature of a mammary gland and rectal temperature increased on the day of farrowing, which is physiological phenomenon. Temperature differences measured with both thermal imagers were smaller after farrowing and were mainly lower than 2 °C. Before farrowing, the temperature differences measured with both thermal imagers were larger and were mainly in order of 3 °C (Figure 2). Due to increased temperature of the mammary gland when approaching to farrowing the difference between the rectal temperature and the temperature of the mammary gland was decreasing (Figure 3). The most important question is which value of rectal temperature or temperature of a mammary gland could be set as a limit at which the veterinary treatment of MMA should be introduced. Unfortunately, the farm was not willing to take a risk not to treat the sows for MMA after farrowing. Therefore, we were not able to measure the temperature of a mammary gland of a febrile sow. The question is also, which thermal imager is suitable for such purpose, if any.

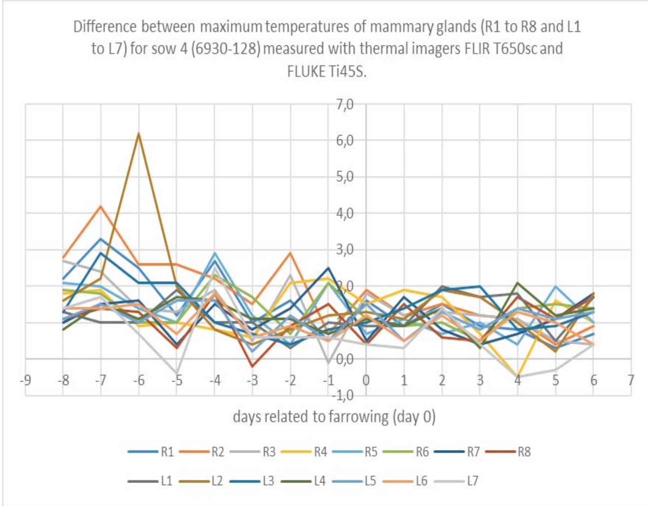

Figure 2

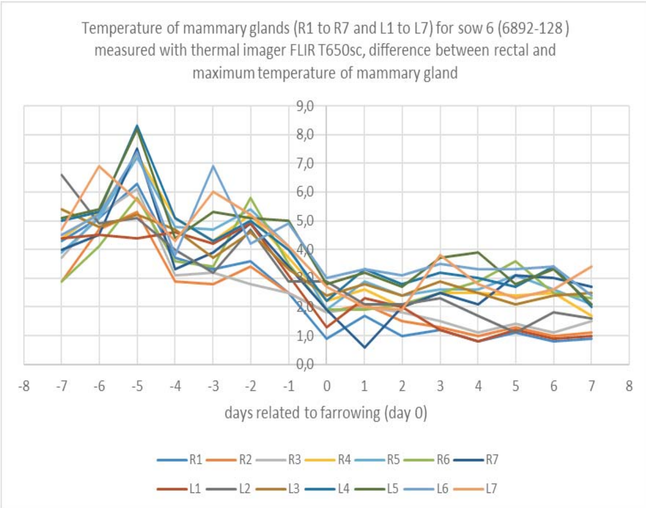

Figure 3

Conclusions

Thermal imaging technique could be useful in veterinary for various applications. In the case of sows, we would like to confirm the level of applicability of thermal imaging depending on the quality of applied thermal imager compared to the contact measurement of rectal temperature. Analysis of results shows that a correlation exists between rectal temperature measurements and temperature measurements of mammary glands with a thermal imager. Results show also relatively good correlation of results between both thermal imagers (high quality and moderate quality performance) although absolute measured temperatures are different (corrections determined during calibration were applied in both thermal imagers). Therefore, a less sophisticated and much cheaper thermal imager is not suitable for acceptable temperature analysis and it could not be applied on a daily basis in small farms probably because they could not afford themselves a much more expensive and accurate thermal imager. However, specialized veterinary stations could offer such an analysis, if they would know how to conduct it and if its benefit (earlier detection compared to measurement of rectal temperature) could be proved. Extensive measurements are still under investigation therefore results of a complete study will be presented at the congress. In any case, a further study should be conducted to investigate the correlation of temperatures (rectal and mammary gland) in febrile and healthy sows. The economic analysis of preventive measurements with a thermal imager should be performed later taking into account the price of a suitable thermal imager, time spent for analysis of measured results and the price of veterinary treatment in a case where thermal imaging is performed or not.

References

Gerjets I, Kemper N. Coliform mastitis in sows: A review. J Swine Health Prod. 2009; 17(2):97-105

Martineau GP, Le Treut Y, Guillou D, et al. Postpartum dysgalactia syndrome: A simple change in homeorhesis? J Swine Health Prod. 2013; 21 (2), 85-93

Soerensen DD, Pedersen LJ. Infrared skin temperature measurements for monitoring health in pigs: a review. Acta Vet Scand. 2015; 57(1): 5.

Schmidt M, Lahrmann KH, Ammon C, et al. Assessment of body temperature in sows by two infrared thermography methods at various body surface locations. J Swine Health Prod. 2013; 21(4):203-209

Loughmiller JA, Spire MF, Dritz SS, Fenwick BW, Hosni MH, Hogge SB. Relationship between mean body surface temperature measured by use of infrared thermography and ambient temperature in clinically normal pigs and pigs inoculated with Actinobacillus pleuropneumoniae. Am J Vet Res. 2001; 62, 676-681.

Warriss PD, Pope SJ, Brown SN, Wilkins LJ, Knowles TG. Estimating the body temperature of groups of pigs by thermal imaging. Vet Rec. 2006; 158, 331-334.

Brown-Brandla T. M., R. A. Eigenberg, J. L. Purswell. Using thermal imaging as a method of investigating thermal thresholds in finishing pigs. Biosystems Engineering 2013; 114 (3), 327-333

M. Hovinen et al. Detection of Clinical Mastitis with the Help of a Thermal Camera. J. Dairy Sci. 91:4592-4598

Schmidt M et al. Application of infrared thermography on lactating sows. Landtechnik 2013, 68(4):228-231

Loughmiller JA, Spire MF, Dritz SS, Fenwick BW, Hosni MH, Hogge SB. Relationship between mean body surface temperature measured by use of infrared thermography and ambient temperature in clinically normal pigs and pigs inoculated with Actinobacillus pleuropneumoniae. Am J Vet Res. 2001;62:676-81.

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. A large aperture blackbody bath for calibration of thermal imagers. Measurement science & technology, 2013; 2 (24), 1-8

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. Calibration of thermal imagers by evaluation of the entire field-of-view. International journal of thermophysics, 2011; 32 (11/12), 2600-2609

Grgic G, Pušnik I. Analysis of thermal imagers. International Journal of Thermophysics, 2011; 32 (1/2) 237-247

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DETECTION OF PATHOLOGY OF HORSE EXTREMITIES WITH THE USE OF THERMOGRAPHY

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Introduction

Thermography, despite its practicability and easy handling and preparation is not used as frequently as it could be. It detects the variations of temperature of the skin, which changes depending on the grade of vascularization of the area. This means that we can detect if there is a physiological alteration as soon as it starts to change the physiology of the animal, even before that the clinical signs show up [1].

Thermography allows us to measure the temperature distribution of the body and, by studying different changes of this surface's temperature, we can associate those with clinical signs and pathologies [2]. This technique, compared with surface palpation, is 10 times more sensitive to temperature change [3].

With this said, thermography is and adjuvant technique. All diagnostic methods should be used to achieve a complete diagnostic, as all of them provide different information that can lead us to the ultimate diagnostic.

Material and methods

12 apparently healthy horses randomly selected from the same stable were studied with the intention to evaluate if, even though they were free of any clinical sign of any illness, we could find thermographic evidence of early pathology.

In order to take part of the study, the animals should be free of clinical signs of any illness, as well as not having any diagnosed chronic pathology or a current disease. Age ranging [5-13] yr, mean 7 yr. The animals were used for different purposes, racing horses, jumping, dressage and school horses. Weight was estimated using the method described by Ellis and Hollands [4] resulting in a median weight of 489 Kg [386-579].

Images were acquired using a Flir I7 camera, a portable low-resolution camera (140x140 pixel), with a Thermal Sensitivity - <0.15°C at 25°C and ± 2% Accuracy - reliable temperature measurement with thermal sensitivity of 0.1°C.

First of all, all the horses went through a complete veterinarian examination. A general physical examination was performed, including lameness exam of the four extremities.

Horses were prepared for the inspection with the following method: Full body brushed with all dirt removed; All soles were completely brush cleaned; Removing bandages or boots at least 2 hours before the inspection; Removing blankets and rugs; No liniment / heat rubs / cold hosing were used on the day of the inspection; Two hours before the thermal study, physical activity was forbidden.

Thermographic examination was performed indoor, avoiding direct sun and therefore false measurements. The measurements taken during this study were taken indoor following the standards stablished in equine veterinary practice [5]

One of our horses (number 16), had a clinical history of lameness for one week due to a hematoma on the sole. It was treated and didn't show further clinical signs one month prior to the thermal study.

Results

It has been described that the difference of 1ºC between the symmetrical part of the body is abnormal and indicates pathology [6][3]. In this study, the images were evaluated by comparing their temperature distribution, but also considering that the difference should be greater than 1ºC to be considered pathological.

Qualitative study of the thermal images was performed, comparing the obtained images with the standard thermal distribution of a healthy animal, to identify thermal changes that indicate subclinical physiological changes. Three animals within the studied horses, showed a different thermal pattern that the standard.

An increase of temperature of the sole of the front right extremity was found on the specimen number 16 (Figure 1), which is correlated with inflammation of that surface. Inflammation can

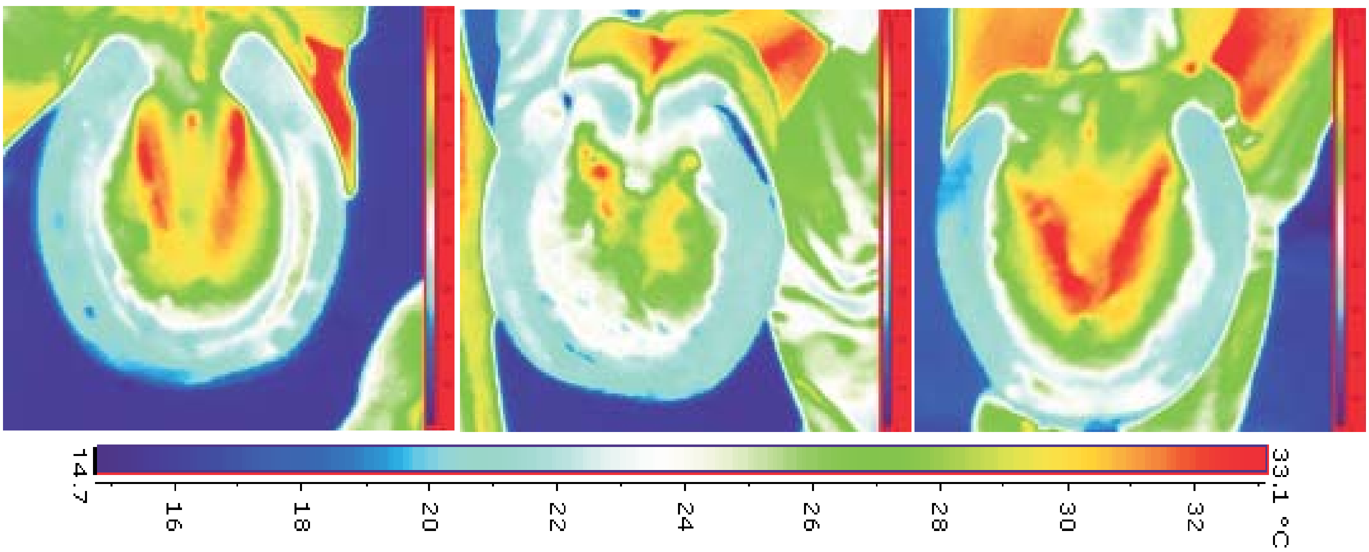

Figure 1:
Comparison between three different animals. a) healthy animal with no problem whatsoever,
b) specimen number 25, that wasn't properly cleaned for the examination –thus showing the importance of proper horse preparation prior to the examination- and c) specimen number 16, with inflammation that wasn't diagnosed yet by other diagnostic methods.

go unperceived if the animal is not showing clinical signs and can't be detected by any other diagnostic tool but thermography.

Concerning specimen number 25 (Figure 1), a decrease of the sole was found, but we confirmed that the sole of this individual was not properly cleaned, which causes the apparent temperature decrease, thus showing the importance of a proper preparation of the animal.

Specimen number 12 showed an approximately 2ºC decreased temperature of all the hoof and sole, even though having no apparent clinical signs. These images were taken again the next day to confirm the thermal result. This animal started showing symptoms of lameness a few days later. X-rays were performed, and it didn't have any radiological changes.

To determine pathology, we can either notice an increasing or decreasing temperature on different anatomical structures that will make more accurate our list of differential diagnosis.

Conclusion:

Thermography, contrary to ultrasonography and x-rays, allows us to get physiological information of the tissue, and can detect changes of the vascularization before the clinical symptoms even show up, which gives us a better approach to the treatment and the prognosis of the patient [7]. This technique should be complementary to other diagnostic tools, as it doesn't provide all the information needed to confirm illness.

With thermography, we were able to detect the physiological effect of the nerve deterioration of our specimen number 12 before the bone structure started to fail. Lameness treatment was administrated before the radiological signs appeared which improved the prognosis of the illness.

This technique can be used to detect subclinical inflammation, which is interesting to avoid relapses of illnesses, like in the case of plantar hematoma. The main limitations of this technique are that it requires a good preparation of the patient, and that it only captures the temperature distribution of the surface of the body.

To conclude, it is a clinically relevant, reliable, useful and easy method to diagnose animals. Also, provides information that no other diagnostic tool provides.

Acknowledgment:

The authors would like to thank the owners and riders of the equestrian center Mas Ferrat (Valencia) for their help with the study. According to the Spanish law RD 53/2013, no animals were harmed and all of them were studied under veterinarian supervision. The authors declare no conflicts of interest.

References

1.J De Moura D, et al. Uso da termografia infravermelha na análise da termorregulaçao de cavalo em treinamento. Eng. Agric. Jaboticabal Jan/fev 2011; V31; p.23-32.,

2.Soroko M, et al. The use of thermography to evaluate Back musculoskeletal responses of young racehorses to training. Proc. Appendix 1 of thermology international 2012; 22/3; p.152-156

3.Turner TA. Diagnostic thermography. Vet Clin North Am Equine Pract 2001; 17; p.95-113

4.Veterinary Guidelines for Infrared Thermography http://aathermology.org/organization/guidelines/veterinary-guidelines-for- infrared thermography/ - Read on 3/01/2018

5.Ellis JM, et al. Accuracy of different methods of estimating the weight of horses. Vet Rec. 1998; 143; p.335-336

6.Head J, et al. Taking the temperature of equine thermography. Vet J 2001; 162: p.166-7

7.Turner TA. Thermography as an aid to the clinical lameness evaluation. Vet Clin North Am Equine Pract 1991; 7; 311-38

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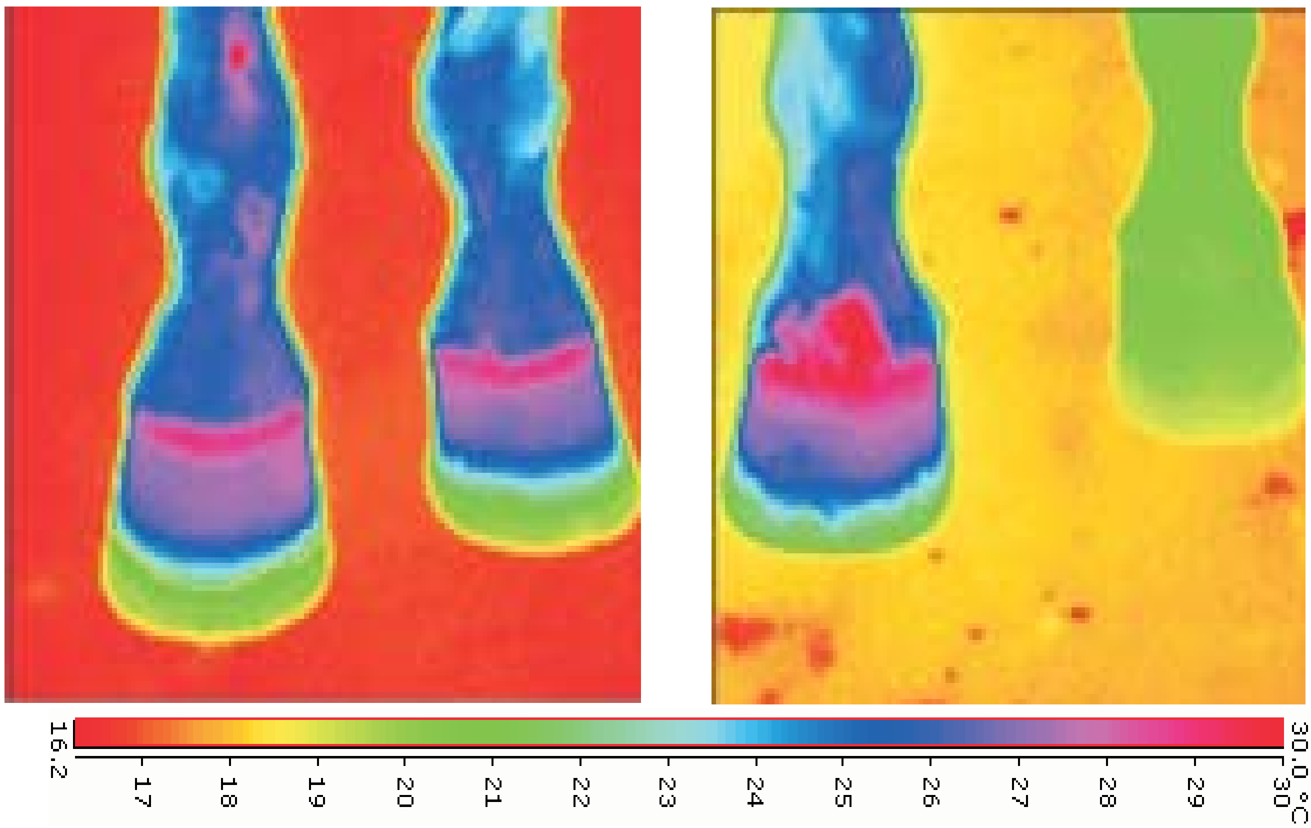

Figure 2:
a) Inconspicuous temperature distribution of the hoof.

THE IMPACT OF HEAT STRESS ON PHYSIOLOGICAL REACTIONS AND ANIMAL WELFARE

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Introduction

Welfare of animals is not only a physical situation. but also a mental state that allows understanding the feelings of animals through their behavior. has become an extremely important step in the qualitative improvement of animal welfare (Watanabe, 2007). The beginnings of this direction as a science. with particular emphasis on the welfare of livestock. dates back to the 1960s. shortly after publication of the Brambell Committee report (1965). One of the aspects causing the reduction of welfare is a heat stress. depending on the daily temperature of the environment. A farm animal that has a wide thermal tolerance range are sheep. with thermo-neutral zone of -12 to even 32 °C. what depends of their breed (Srikandakumar et al.. 2003). Nevertheless. in recent years. the environmental temperatures have increased significantly. especially during the summer months. which has diverse health implications in sheep production flocks. especially for Polish Merino sheep. when the temperature is over 25 °C. There is why the aim of our study was to determine physiological reactions of these animals in three experimentally chosen temperatures: control tests (17±1 °C) and heat stress with (30±1 °C and 50±1 °C).

Methods

The experiment was carried in climatic chambers at the Wroclaw University of Environmental and Life Sciences (Wroclaw. Poland) with the use of 20 clinically healthy Polish Merino sheep taking part in 3 stages of our study including acclimatization and control tests (17±1 °C) and a heat stress (30±1 °C and 50±1 °C). According to Cwynar et al. (2014) the adjustment period and recovery time for the experimental animals was 14 days between every stage of the study. Animal feeding was based on oats (0.2 kg per capita). with hay and water ad libitum and the duration of every experiment (different temperature levels) was 14 days. All of the environmental conditions were monitored constantly. especially in the field of temperature. humidity and gas compounds (Scada Pro. MicroB. Poland). The autonomic ventilation system was correlated with air conditioners (Nanhai. China) as well as with fan heaters (Master ERA. USA) and the thermostats (Simens. Germany). The environmental measurements were additionally controlled by thermo-hygrometer (DG-E/2. Poland) and mobile thermohygrometer (Ted. Taiwan) and rotating anemometer (Huger. Switzerland). Heart rate (HR). respiratory rate (RR) and temperatures were measured every day (6 times a day: 8.00. 10.00. 12.00. 14.00. 16.00. 18.00). Skin temperatures (ST) were measured in two thermostabile (back and groin) and two thermolabile (head. posterior limb) areas with the use pyrometer (Flir. USA). The internal temperature (IT) was measured per rectum with the use of electronic thermometer (DT 02. China). The blood samples were collected daily to EDTA and Serum Z tubes (Monovette® Sarstedt. Germany) from

Table 1.
The impact of different environmental temperatures on physiological measurements in sheep

PARAMETER			Statistical units	EXPERIMENT		
				Control test [17°C]	Heat stress **[30 °C]**	Heat stress **[50 °C**
Heart rate **[number/min.]**			min	68	75	64
			max	122	158	132
			$\bar{x}$	88^{A}	104^{B}	83^{AB}
			sd	7	14	9
Heart rate [number/min.			min	38	72	87
			max	78	122	102
			$\bar{x}$	57^{A}	146^{B}	102^{AB}
			sd	8	28	29
Skin temperature [°C]	**Thermostable areas**	Back	min	31.7	32.8	34.3
			max	37.3	37.3	37.6
			$\bar{x}$	35.7	36.4^{a}	36.7^{b}
			sd	0.8	0.4	0.4
		Groin	min	35.1	33.9	36.1
			max	38.2	37.0	38.9
			$\bar{x}$	36.4	36.7^{A}	37.8^{B}
			sd	0.8	0.6	0.2
	Thermolabile areas	Head	min	29.9	30.7	34.8
			max	34.3	37.3	35.9
			$\bar{x}$	32.6	35.0^{A}	35.5^{B}
			sd	0.7	1.7	0.2
		Posterior limb	min	26.4	27.0	31.0
			max	32.3	32.3	32.3
			$\bar{x}$	29.6^{a}	30.3^{Ab}	31.7^{B}
			sd	1.4	1.1	0.2
Internal temperature [°C]			min	38.5	38.9	39.5
			max	40.0	40.2	40.4
			$\bar{x}$	38.8^{A}	39.2^{B}	39.9^{C}
			sd	0.2	0.2	0.1

the jugular vein (vena jugularis interna) and the laboratory analysis was made with the use of ABX VET. Pentra - 400 (Horiba ABX. Canada) and Synergy (Biotek. Winooski. USA). Collected data were statistically analyzed with the use of Statistica software and the Duncan's test. The experimental procedures were accepted by the Local Ethical Committee (Wroclaw. Poland).

Results

It was found that the mean heart rate in thermo-neutral conditions was 88.23/min. (17±1 °C). with a stable respiratory rate reaching 58/min.. where low standard deviation was noticed. Higher environmental temperature (30 ºC) caused increased results with statistical differences. when HR was oscillating over 104/min. and the RR reached 146/min. Nonetheless. the impact of highest temperature (50 ºC) was a result of lower HR than in the control group (83.89/min.). but the RR with visible deepening of breaths was statistically higher (102/min.). The differences in skin temperature were also found in both thermostable and thermolabile areas. what was shown in Table 1. Finally. the measurements of the internal temperature (measured per rectum) statistically confirmed highly significant differences and the influence of sheep homeostasis in varied environmental conditions (17 ºC. 30 ºC and 50ºC). with a strong upward trend directly proportionally to the temperatures (38.8 ºC. 39.2 ºC. 39.9 ºC respectively). The stress reaction in animals was confirmed also in blood analysis. especially in blood hematology and hormone levels. The decreasing number of red blood cells (RBC; 11.28 T/l in 17 ºC up to 8.77 T/l in 50 ºC). hematocrit (HCT; 0.37 l/l in 17 ºC up to 0.28 l/l in 50 ºC) and glucose (GLU; 5.59 mmol/l in 17 ºC up to 3.60 mmol/l in 50 ºC) were observed. what was statistically proven. Simultaneously, increased concentration of adrenaline, noradrenaline and adrenocorticotropic hormone were found, but the highest differences were noticed in cortisol levels (1.62 ng/ml in 17 ºC up to 17.19 ng/ml in 50 ºC).

Discussion

Skin and internal temperature measurements in experimental and livestock animals are necessary, especially when thermal stress conditions may occurs. The skin temperature of the animals, as well as the rectal temperature (internal body temperature), constitute the basic indicator of the body's thermal balance, being at the same time a simple method. Its fluctuations are compatible with the growth, lactation or reproductive capacity of animals, which has been repeatedly confirmed in studies on the influence of temperatures (chronic and thermal stress) on animals (Silanikove, 2000; Wojtas et al., 2013; Cwynar et al., 2014). Presented study confirms the general tendency regarding the impact of high temperatures on mammals, at the same time indicating the relatively rapid adaptability of sheep to changing microclimatic conditions. According to Srikandakumar et al. (2003), Cwynar et al. (2014) and Philips (2016), the determination of the impact of heat stress as an opposite to welfare on animals must also take into account the previously mentioned level of stress hormones. Significant differences in HCT and RBC were inversely proportional to increasing temperature. Lower levels of these parameters were also observed in similar studies by Pereira et al. (2008) and Cwynar et al. (2014) as a result of enlarged water intake. Biochemical studies made in our project confirmed that the thermal stress there may be marked with the analysis of hormone levels as well as neurotransmitters. Moreover, the concentration of cortisol in the blood allows not only to determine the impact on the physiological state of the animals, but also on their emotional level (Pereira et al., 2008).

Conclusion

High temperature induces an acute stress response in sheep. causing severe changes in physiological and blood parameters.

Heat stress in sheep is one of the most invasive stressors. what directly affects homeostasis of their organism and decreasing the level of welfare.

Basic temperature measurements (IT or ST) in animals should be recommended to be used in practice (when livestocking or animal transport) as directly correlated with animal health and welfare.

Acknowledgements

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References

Brambell Committee. Report of the technical committee to enquire into the welfare of animal kept under intensive livestock husbandry systems. Command Report 1965. 2836. Her Majesty's Stationery Office. London.

Cwynar P. Kolacz R. Czerski A. Effect of heat stress on physiological parameters and blood composition in Polish Merino rams. Berliner und Münchener Tierärztliche Wochenschrift 2014. 127: 177 - 82.

Pereira AMF. Baccari F Jr. Titto EAL. Almeida JAA. Effect of thermal stress on physiological parameters. feed intake and plasma thyroid hormones concentration in Alentejana. Mertolenga. Frisian and Limousine cattle breeds. International Journal of Biometeorology 2008. 52: 199 - 208.

Philips C. The welfare risks and impacts of heat stress on sheep shipped from Australia to the Middle East. Veterinary Journal 2016. 218: 78 - 85.

Silanikove N. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livestock Production Science 2000. 67: 1 -18.

Srikandakumar A. Johnson EH. Mahgoub O. Effect of heat stress on respiratory rate. rectal temperature and blood chemistry in Omani and Australian Merino sheep. Small Ruminant Research 2003. 49: 193 - 198.

Watanabe S. How animal psychology contributes to animal welfare. Applied Animal Behaviour Science 2007. 106: 193 - 202.

Wojtas K. Cwynar P. Kolacz R. Kupczynski R. Effect of heat stress on acid-base balance in Polish Merino sheep. Archiv Tierzucht 2013. 56: 917- 923.

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INVESTIGATING THE ROLE OF DIGITAL INFRARED THERMAL IMAGING IN POST- OPERATIVE ASSESSMENT FOLLOWING SPINAL SURGERY IN HORSES

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Introduction

Loss of performance is often the first sign of pain in the horse with spinal pathology considered responsible for the majority of issues. Overriding spinous processes (Kissing Spines) is a pathological condition of the spine where the spaces between the vertical projections of the vertebrae narrow and in severe cases, touch or overlap causing pain and/or a change in behaviour; in humans it is known as Baastrup´s disease. It is suggested to be present in over 80% of clinical presentations (Girodroux et al 2009)) and further difficulties arise when assessing whether the issue is primary, secondary or tertiary. Mainstream spinal diagnostics currently include radiography, scintigraphy and ultrasound. Radiography is most commonly used and whilst it is fairly effective at highlighting anatomical abnormalities, it does not represent the activity of the underlying structures. Current diagnostics in this area are predominantly anatomical based procedures, such as radiography, as opposed to physiological and there is currently no definitive consensus on the most effective way to measure the degree of 'activity' or inflammation of an area of concern. Thermal imaging has its place in the electromagnetic spectrum of diagnostics. It offers a unique perspective into working physiology and has successfully been used in medical and veterinary research to identify and monitor the inflammatory response and more recently its reciprocal link with angiogenesis has been identified.

This study aims to explore thermal imaging's ability to detect and monitor the equine back pre and post spinal surgery. The scanning environment is non-clinical, and this study aims to explore if non-clinical environments can still yield clinically reliable data. It is hypothesised that one week following surgery there will be a significant increase in skin surface temperature followed by a gradual drop over the remaining time points. The control horses should show no significant variations in temperature. It is also expected that whilst data may experience variability due to changes in ambient temperature or other factors in the environment, the data will still be clinically relevant.

Methods

Six experimental horses were imaged pre-surgery and then weekly for 4 weeks. Six control horses were imaged at weekly intervals for 5 weeks to run as a comparison. Each horse was imaged from the same position and distance and strict protocol was requested prior to and during each imaging session. A Digatherm IR 640 pad was used for the duration of the study - it offered sensitivity of 40Mk and a +/-1% accuracy.

Currently a lack in empirical research exists which details the most effective method for data retrieval from thermal images. Consequently, three methods will be compared, thoracolumbar line (TL) analysis (figure 1), Individual Point comparison (figure 2) and circle analysis (figure 3).

Results

Post-surgery both the circle analysis and TL analysis showed a significant increase in temperature (both P=0.018). Repeated measures ANOVA yielded a significant difference between the individual time points in the circle analysis (P=0.005) (Figure 4 and 5) and also the TL analysis (P=0.047). The Individual point

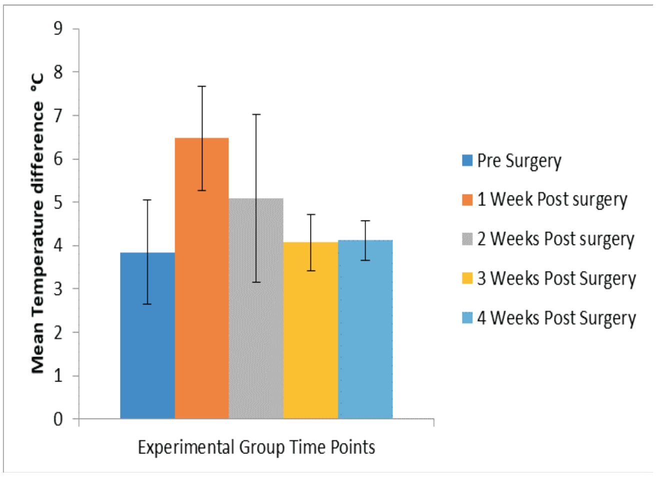

Figure 4:
Comparison of Experimental Group Means Relative to Time

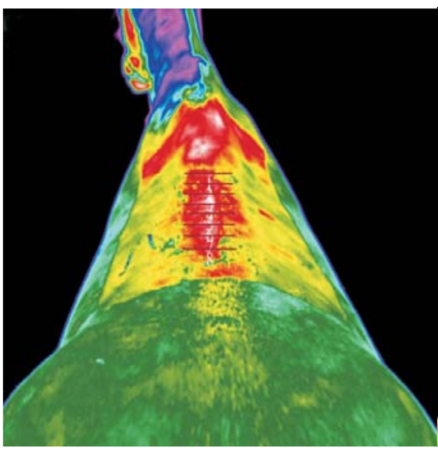

Figure 1: Individual Point Analysis

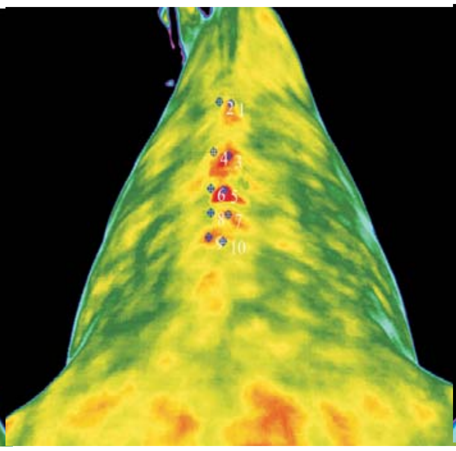

Figure 2:Individual Point Analysis

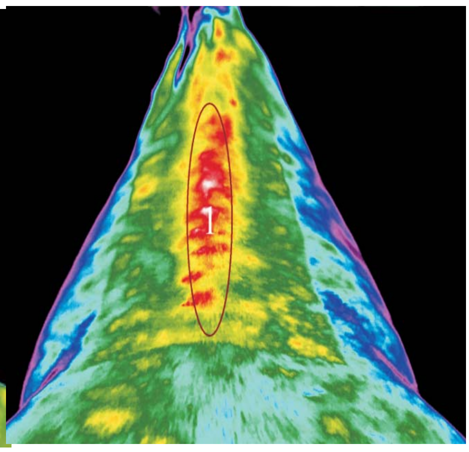

Figure 3:Individual Point Analysis

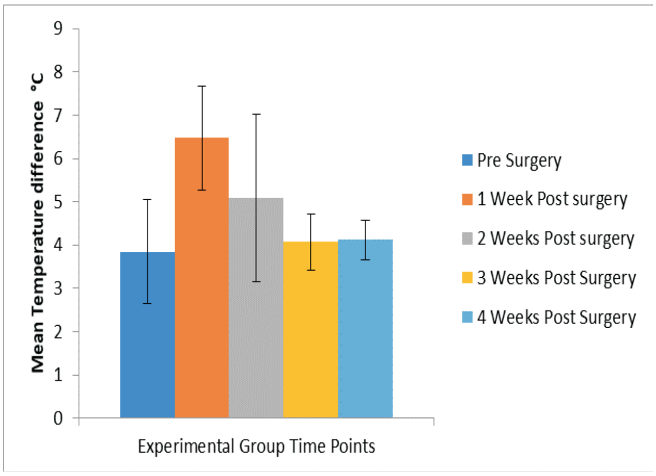

Figure 5
Comparison of Control Group Time Points

comparison analysis did not show any statistically significant results.

Discussion

Interestingly there was no significant difference between the control group and experimental group pre-surgery. This could be interpreted that the indication for surgery is not associated with alterations of skin temperature. No additional diagnostics were carried out on any of the animals and consequently other sources of pain cannot be discounted. Following surgery, temperature increased significantly indicating that thermal imaging was effective in capturing the thermal changes associated with the healing process. These temperatures decreased over time and then increased on the final week. The final week was consistent with an increase in physical activity for the majority of experimental participants.

Conclusion

The results of this study support the need for further research into equine diagnostics. It would provide invaluable data regarding equipment specifications and emissivity levels which would make thermal imaging more applicable to veterinary diagnostics. More specific criteria for the most effective method for analysing veterinary images would also be beneficial. The potential is there for an interesting collaboration between current diagnostics and thermal imaging to both assist in accurate diagnosis and potentially limit unnecessary surgery and suffering in the future.

References

Coomer R, McKane SA, Smith N, Vandeweerd JM. A Controlled Study Evaluating a Novel Surgical Treatment for Kissing Spines in Standing Sedated Horses, Veterinary Sugery 2012,4: 890-897

Girodroux M, Dyson S, Murray R. Osteoarthritis of the Thoracolumbar Synovial Intervertebral Articulations: Cliical and Radiographic Features in 77 Horses with Poor Performance and Back Pain, Equine Vet J 2009, 41(2) 130-132

Roethlisberger Holm K, Wennerstrand J, Lagerquist U, Eksell P, Johnston C. Effect of Local Analgesia on Movement of the Equine Back, Equine Vet J 2006, 38(1):65-69

Kaczmarek M, Nowakowski A. Active IR-Thermal Imaging in Medicine, J Nondestruct Eval 2016, 35:19

Purohit RC, McCoy MD. Thermography in the Diagnosis of Inflammatory Processes in the Horse, Am J Vet Res 1980, 41(8): 1167-1174

Redaelli V, Tanzi B, Luzi F, Stefanello D, Proverbio D, Crosta L, Giancamillo M. Use of Thermogrphic Imaging in Clinical diagnosis of Small Animal: Preliminary Notes, Ann. Ist. Super. Sanità 2014, 50(2): 140-146

Ring EFJ, Ammer K. Infrared Thermal Imaging in Medicine, Physiol Measure 2013, 33(3): 33-46

Soroko M, Howell K, Dudek K. The Effect of Ambient Temperature on Infrared Thermographic Images of Joints in the Distal Forelimbs of Healthy Racehorses, J Therm Biol 2017, 66: 63-67

Taylor PM, Pascoe PJ, Mama KR. Diagnosing and Treating Pain in the Horse: Where are we Today, Vet Clin Equine 2002, 18: 1-19

Turner TA. Thermography as an Aid to the Clinical Lameness Evaluation, Vet Clin North Am Eqine Prac, 1991, 7(2): 311-338

Tunley BV, Henson FMD. Reliability and Repeatability of Thermographic Examination and the Normal Thermographic Image of the Thoracolumbar Region in the Horse, Equine Vet J 2004, 36(4) 306-312

Van Hoogmoed LM, Snyder JR. Thermographic Evaluation of Injections and Neurectomy, The Vet J 2002, 164: 129-141

Zimmerman M, Dyson S, Murray R. Comparison of Radiographic and Scintigraphic Findings of the Spinous Processes in the Equine Thoracolumbar Region, Veterinary Radiology and Ultrasound 2011, 52(6): 661-671

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USE OF THERMOGRAPHY ON FRACTURE MANAGEMENT IN SMALL ANIMAL CLINICS ABOUT A CLINICAL CASE.

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Introduction

Thermography in the small animal clinic is a very relevant tool, as it can be used without restraining the animal, so the stress levels don't raise, which is important to monitor the real physiological state of the animal. This technique has been used in veterinary medicine to evaluate injury of the soft tissue and superficial bone lesions, being an adjuvant technique to ultra- sonography and radiography [1].

At the Small Animal Clinic "Mascotas", we are implementing the use of thermographic images on a daily basis complementing other diagnostic tools, to collect all the data possible for further investigation.

All animals that come into the clinic, whether they are healthy and just come for a checking or have some kind of pathology, get a thermographic examination, so we can determine the extension of the use of this technique.

Thermography allows us to detect the physiological changes within the body, and can be useful in wound management, as it reveals the body response to an injury based on inflammation.

As a diagnostic tool, it can help reveal the body reaction to a wound and also evaluate the prognosis of such.

Material and Methods

The clinical case is based on one patient that had its tibia and fibula broken. X-ray images were taken on the day of the fracture, five and fifteen days after the fracture, while thermo- graphic images were taken the day of the fracture and fifteen days after the fracture.

Images were acquired using a Fluke Ti125 camera, a portable low resolution camera (160x120 pixel), with a Thermal Sensitivity ? 0.10 °C at 30 °C target temp (100 mK) and ± 2% Accuracy - reliable temperature measurement with thermal sensitivity of 0.1°C.

Images were processed with Smart View 3.2 software for the Fluke camera. The images were set on full infrared and the high contrast palette.

The affected leg was completely shaved and waited 15 minutes of acclimatization before taking the thermal image[2][3], although it has been studied that the clipping of the hair modifies the mean temperature of the area but not the thermal pattern [4]. The other leg remained unshaved for aesthetical purposes.

All photos were taken on the same room, at 20-23ºC as proposed in other studies [5].

Previous experiences in humans reveal that some behaviors affect blood flow, such as smoking, alcohol ingest, caffeine intake or heavy meals, as well as exercise or physiotherapy [6]. In this case, we controlled that no heavy meals were given to the patient prior the thermal exam and that the dog was resting at least two hours before the thermal exam.

Results

The day of the fracture (Day 0), the leg was evaluated with x-rays (image 1) in order to diagnose the exact position and type of fracture. The fracture was classified as an oblique displaced fracture in the medial area of the tibia and the fibula. Classical treatment is the first choice in those cases, so it was stabilized for three weeks with a splint, which is a rigid strip used to immobilize and support a broken bone. A thermal image was also taken (image 2). Inflammation can be appreciated as an increase of the tempera-

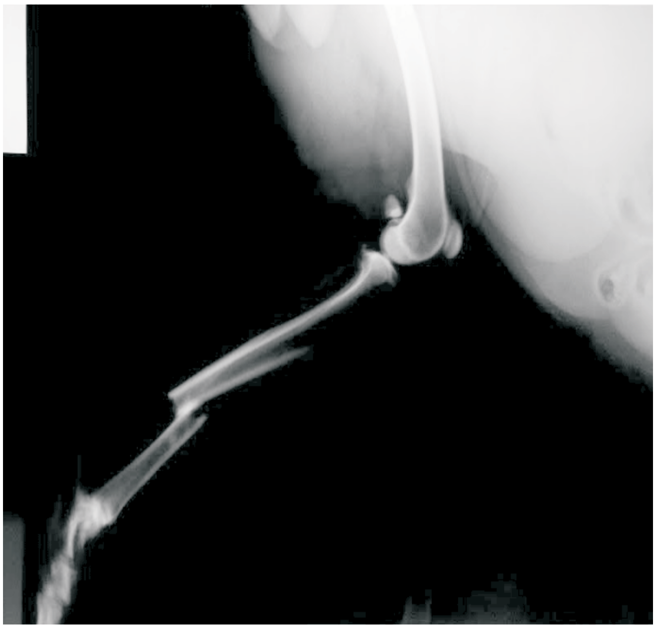

Image 1
Day 0. x-ray image of the fractured bones of our patient. It is classified as an oblique displaced fracture in the medial area of the tibia and the fibula.

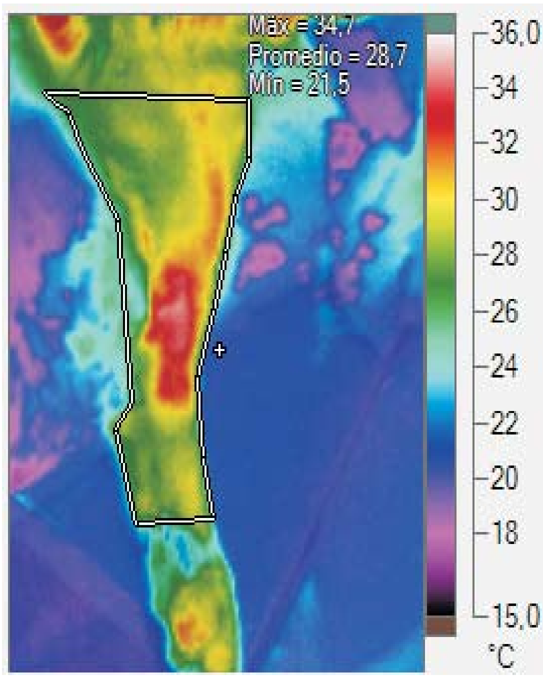

Image 2
Day 0. Thermal image of the fractured bones of our patient. We can appreciate an increase of the temperature of approximately 6ºC around the area of the fracture.

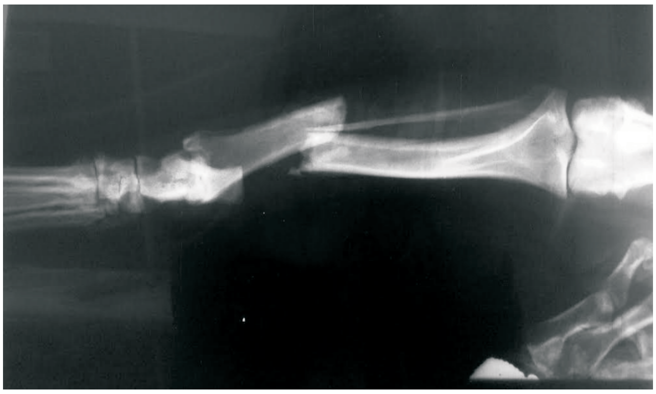

Image 3
Day 5. X-rays image of the fractured bones of our patient five days after bandage. The bandage moved due to a lack of proper rest of the animal, and the fracture got destabilized.

Image 4
Day 15. X-rays image of the fractured bones of our patient 15 days after bandage. After removing the bandage, the fracture was still completely displaced, even though this time the bandage didn't move.

ture of the surface [7]. With the thermal image, it could be seen that the area around the fracture had an increased temperature compared to the healthy temperature distribution of a leg.

After five days (Day 5), another x-ray (image 3) evaluation was performed in order to check the evolution of the fracture and if the splint had moved. Thermal study was not possible because the bandage could not be removed. In this visit, we checked that the splint had moved a bit, so the bandage should be reapplied.

Ten days after the second x-ray evaluation (Day 15), the patient came to check on the fracture, and, yet again, x-rays (image 4) were taken, as well as thermographic images (image 5) as it was already time to remove the bandage. With the help of the x-rays we could check that the fracture was still unhealed, because the callus had not been produced. Callus formation depends on the vasculature, so a lack of vasculature could cause the failure of the bone healing.

With the thermal images we can check if vascular changes are happening on those areas. Normally the healing process provokes an increase of the vascularization which causes an increase of temperature on that area. In image 5, we can see that the thermal distribution of the leg correlates to a healthy leg, meaning no increase in vascularization and therefore no healing

This last thermal image (image 5), related with the x-rays (image 4) and the clinical symptoms, helps us evaluate the healing process of the fracture, that was absent in this case. Thermography was useful in this case to decide if we should continue with bandage for another week or go to surgery.

In this case, surgery was the best choice, as thermography showed that the body was not reacting to heal the fracture and it needed a better stabilization.

Conclusion

In this case, we can see that even though the fracture was stabilized twice with traditional treatment (Manual reduction and bandage), the callus was not being produced. If there is inflammation on the fracture point, then the body is reacting to the fracture. On the other hand, if there isn't any thermal reaction, the area is not healing and we should not wait to improve our treatment.

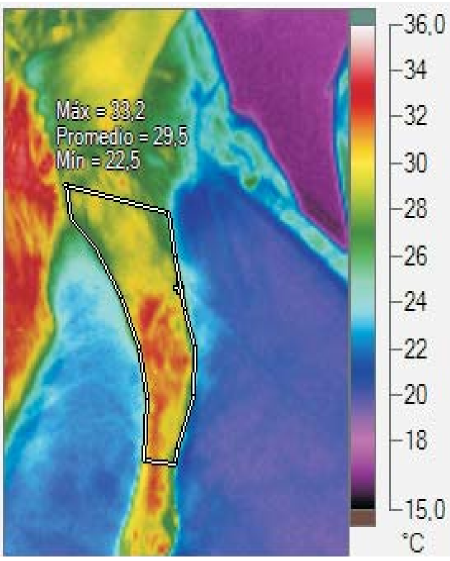

Image 5:
Day 15. Thermal image of the fractured bones of our patient 15 days after bandage. Contrary to the image 2, It can't be appreciated a significant increase of temperature around the fractured area.

Image 6:
X-rays image of the fracture, 10 days after surgery.

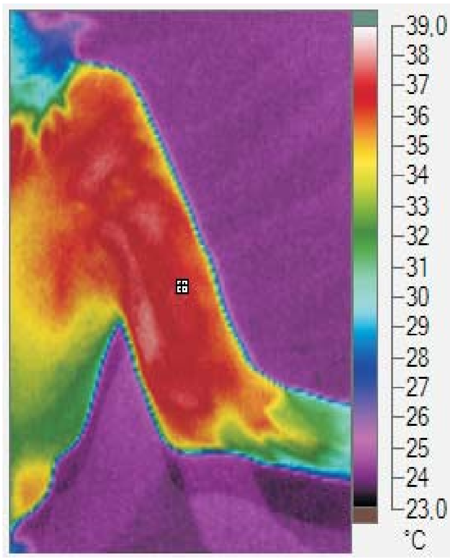

Image 7
Thermal image of the fracture, 10 days after surgery. The temperature is still high due to the general inflammation post surgery, but the thermal distribution isn't increased on the exact point of the fracture.

The thermal image informed us of the lack of physiological changes that should be happening around that area to facilitate the healing of the fracture, so we could do a more accurate prognosis and, in this case, change to a better approach.

At the end of this case, the fracture was solved by surgery. We can see the x-rays image (image 6) of the reduced fracture with the osteosynthesis plaque that was used for the resolution of this case. Also, there are images of the and the thermal reaction (image 7) of the wound 7 days after surgery, in which we can appreciate that the average temperature is elevated, but not in one exact area, but all the surgery area due to the postsurgery inflammation.

References

1.Turner TA. Diagnostic thermography. Vet Clin North Am Equine Pract 2001;17: 95-113

2.Hakgüder A et al. Efficacy of low level laser therapy in myofascial pain syndrome: an algometric and thermographic evaluation. Lasers in Surgery and Medicine 2003; 33; 339-343.

3.Park J et al. Thermography as a predictor of postherpetic neuralgia in acute herpes zoster patients: a preliminary study. Skin Research and Technology 2012; 18:88-93.

4.Loughin C, et al. Evaluation of thermographic imaging of the limbs of healthy dogs. AJVR 2007; 68: 1064-1069

5.Ringer SK et al. Assessment of scintigraphic and thermographic chan- ges after focused extracorporeal shock wave therapy on the origin of the suspensory ligament and the fourth metatarsal bone in horses without lameness. American Journal of Veterinary Research 2005; 66: 1836-1842

6.Vardasca R et al. Thermal symmetry of the upper and lower extremities in healthy subjects. Thermology International 2012; 22: 53-60.

7.Varjú G et al. Assessment of hand osteoarthritis: correlation between thermographic and radiographic methods. Rheumatology 2004; 43: 915-919.

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Session 4: Exercise and Sports

EVOLUTION OF SPORTS THERMOGRAPHY AND NEW CHALLENGES FOR FUTURE

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Introduction

After a first golden age of infrared thermography (IRT) in the 70's and 80's, thermography had a little recession due to the evolution of more accurate diagnostic tools as MRI, Tomography and ultrasound devices and the reported weakness of IRT as diagnostic tool on one of its main applications: the breast cancer (Kennedy et al, 2009). However, with the new millennium, the production of new thermal imagers with a higher resolution and affordable prices and the edition of software that allowed to quantify the skin temperatures (Tsk) of a certain regions of interest (ROI) made possible new applications of thermography that have generated an almost exponential development of the thermography in different areas (Figure 1). One of those applications has been the Sports Thermography, which had also an initial positive evolution, with some general and descriptive scientific publications in the 80's and has almost tripled its number of publications so far this decade (Figure 2) with a progressive annual increase of scientific and disclosure publications.

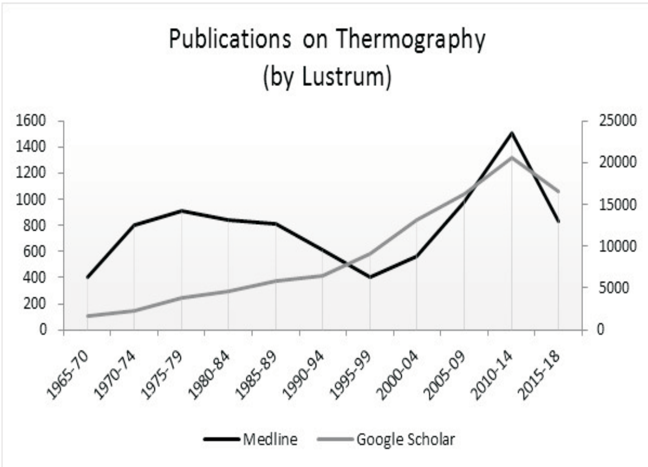

Figure 1
Evolution of the publications about "thermography" in Medline and Google Scholar by lustrum.

Methods

The work is based in an initial search with the expressions "thermography" and "(sports or exercise) and thermography" on two free access databases: PubMed (for scientific references) and GoogleScholar (which includes, apart from the scientific references more informative and generic resources).

Results

A chronological analysis of the main scientific contributions in literature will be done considering more than 212 articles on Sports Thermography. The analysis will be based on the number of citations of the articles, the year of publication and the relevance of their topics and contents on the sports and exercise context. There will be reported the current applications of thermography and their strengths and weaknesses of the thermography in the Sports area.

One of the weaknesses was a lack of guidelines to design a correct thermographic protocol, an aspect improved after the recent publication of the TISEM, a consensus document aimed to standardize the data collection including a checklist to verify the quality of the protocols on the publications in the field of sports thermography. (Moreira et al., 2017).

The work will finish with a proposal of new research lines for future development of thermography in order to get it closer to the real needs of all the agents involved in the sport training.

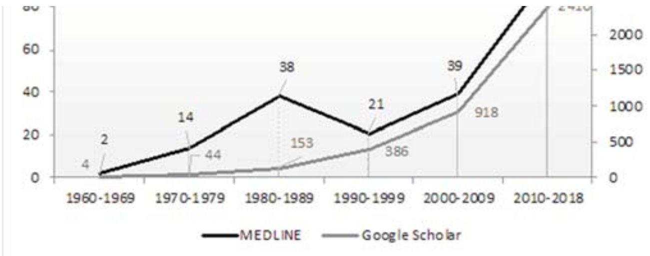

Figure 2
Evolution of the publications about "sport or exercise and thermography" in Medline and Google Scholar by decade.

References

Kennedy DA, Lee T, Seely D. A comparative review of thermography as a breast cancer screening technique. Integrative cancer therapies 2009, 8(1), 9-16.

Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJE, Costa CMA, Eglin C, Fernandes AA, Fernández-Cuevas I, Ferreira JJA, Formenti D, Fournet D, Havenith G, Howell K, Jung A, Kenny GP, Kolosovas-Machuca ES, Maley MJ, Merla A, Pascoe D, Priego-Quesada JI, Schwartz RG, Seixas ARD, Selfe J, Vainer BG, Sillero-Quintana M. Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. J Thermal Biol 2017; 69; 155-16

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DOES THE TISEM-CHECKLIST ADDRESS THE DEFICITS IN REPORTING THERMOGRAPHIC STUDIES?

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Introduction

In a Delphi consensus process, a checklist was recently developed for reporting thermographic studies conducted in the field of sports and exercise medicine [1]. The aim of the checklist is to improve comprehensive reporting and thereby enhance the comparability of studies that will allow data pooling. However, the magnitude of the deficit in reporting is not yet defined.

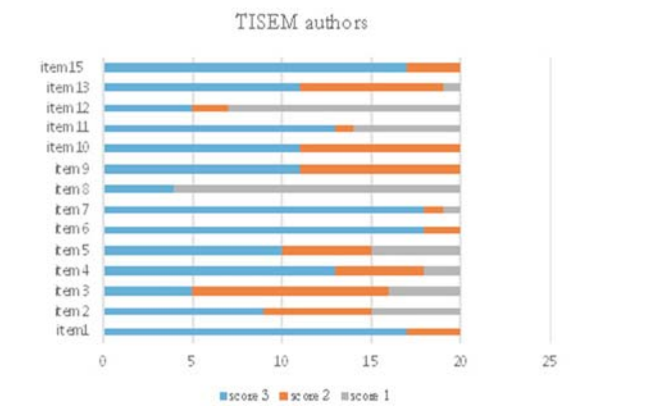
Methods

50 journal articles published between January 2016 and December 2017 which reported thermographic studies in medicine particularly in the field of sports and exercise, were analysed with TISEM-checklist. Case reports, cross-sectional cohort studies and cohorts prior and after exercise were included, but review papers were excluded. The frequency of fulfilled, non-fulfilled and unclear criteria for each of the 15 items was recorded. Complete reporting scored 3 points, incomplete or unclear information received 2 points, and missing information was labelled with 1 point. Scoring followed the principle, that an absent condition must be exclusively reported as absent to be labelled as completely reported item. Lack of information on subitems resulted in a score of 2 points.

Articles were allocated to 2 groups according the fact that at least one author had participated in the Delphi consensus (group 1: consensus author, n=20, group 2: other authors, n=30). Descriptive statistics of the distribution of score classes were performed.

Results

No article scored the possible maximum of points. 2 papers scored 40/42 points, 1 paper reported only 1/14 items completely. The criteria of item 1 ("individual data of participants") were most often met (34/50), but item 8 ("necessity to switch camera on some time prior to image capture") was the most neglected. Item 14 ("drying the skin) was applicable in 4 papers only. Articles that were co-authored by panel members of the Delphi consensus, scored in 58% 3 points and 1 point in 19% across all items, while the score percentages of authors without experience in defining the TISEM checklist were 39% for score 3 and 31% for score 1. A detailed distribution of scores per item is shown in figure 1.



Discussion

Applying the TISEM checklist allows to identify deficits in reporting conditions that can influence temperature readings from infrared thermal images. However, complete reporting does not guarantee that the reported conditions have been well controlled, or confounding is absent. Articles that used temperature measurement as the primary outcome parameter provided more complete reporting than case reports or case series in which temperature served as secondary outcome.

Limitations

Since some items of the TISEM are composed of different numbers of subitems, the score 2 represents a non-homogeneous class. Item 2 ("Avoiding factors that influence skin temperature") has 11 subitems and item 4 ("ambient temperature and relative humidity") has 4 subitems. In both cases, any missing subitem resulted in the same score of 2 points irrespective to 1, 2, 3 or 10 missing subitems. Another limitation is that the scoring is based on one observer only.

Conclusion

The TISEM checklist can detect deficits in reporting the conditions of recording and analysis of infrared imaging studies. However, if the TISEM is used as a measure for the quality of reporting, a scoring system for individual items may improve the differentiation of classes. The checklist is currently not yet fully implemented in the writing habits of authors of thermographic articles.

References

1.Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJE, Costa CMA, Eglin C, Fernandes AA, Fernández-Cuevas I, Ferreira JJA, Formenti D, Fournet D, Havenith G, Howell K, Jung A, Kenny GP, Kolosovas-Machuca ES, Maley MJ, Merla A, Pascoe D, Priego-Quesada JI, Schwartz RG, Seixas ARD, Selfe J, Vainer BG, Sillero-Quintana M. Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. J Thermal Biol 2017; 69; 155-16

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SPEED OF MOVEMENT DURING KNEE EXTENSION DOES NOT AFFECT SKIN TEMPERATURE DYNAMIC AFTER EXERCISE

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Introduction

To reach the optimal goal in resistance training many variables can be manipulated, such as type of exercises, rest intervals, intensity, training volume, repetition duration. Attention to repetition duration has recently increased (Headley et al., 2011). In fact, low-intensity resistance training with slow speed of movement (i.e., longer repetition duration) has been shown to stimulate hypertrophy and strength as training at a normal speed (Tanimoto and Ishii, 2006). Manipulating the repetition duration affects muscular blood flow, and therefore reducing the speed of movement during resistance exercise leads to a moderate blood flow restriction, inducing muscle ischemia (Tanimoto and Ishii, 2006). A previous study tested the hypothesis that the resistance exercise with slow speed of movement may have impact on skin blood flow, thus influencing skin temperature (Formenti et al., 2016). It was demonstrated that the amount of temperature change during exercises was not different between slow or normal speed of movement exercises (Formenti et al., 2016). This was also supported by a study that did not find differences in the skin temperature change between blood flow restriction resistance exercise and traditional resistance exercise (Sampaio et al., 2016). However, despite no differences in the amount of temperature change, it was found that a single set of resistance exercise with slow speed of movement induced a skin temperature change during exercise slower than that of normal speed of movement (Formenti et al., 2016). This study focused on a single set of resistance exercise, but it is common that a session of resistance exercise is composed by more than one set. Moreover, it is also possible that reducing the speed of movement would not affect the amount of skin temperature change during exercise, but rather the amount of skin temperature change during recovery in the subsequent rest phase. Therefore, in addition to differences in the skin temperature response between slow and normal speed resistance exercises, it stands to reason that differences exist also in the skin temperature response between sets. The aim of the present study was to investigate the effect of two speeds of movement of three sets of knee extension exercise on the thermographic skin temperature response during the subsequent recovery phases.

Methods

Subjects

Eight young healthy female subjects volunteering participated in the present study (24.8±4.9 years, 63.3±7.2 kg and 164±4.7 cm). None of them reported recent lower limb injuries. The study was approved by the Ethical Committee of the local University and was conducted in accordance with the Declaration of Helsinki. After a thorough explanation of the protocol, participants signed informed written consent to participate.

Experimental protocol

After a preliminary session to find out the maximum repetition (1RM) of the unilateral knee extension and to familiarize the subjects with the movement speeds, the two experimental sessions, each one involving a condition - named as 1s and 5s condition - were randomized. The participants were asked to abstain from strenuous physical activity the three days before the sessions, and to abstain from consuming alcoholic or caffeine-containing products for a 4-h period before the beginning of each session. All sessions were scheduled in the late morning to mitigate effects related to circadian rhythm variations. After a warm up of 10 min, the subjects acclimated to the room conditions (temperature 22-24°C; relative humidity 50±5%; no direct ventilation and constant intensity of light) for 10 min rimaining seated at rest on the knee extension machine (Teca srl, Ortona, Italy). Then, participants performed three sets of the 1s or 5s knee extension exercises using an intensity of ~50% of 1RM, with interset rest period of 2 min. In each of the three sets, subjects repeated the movement until exhaustion (concentric failure) following the 1s/5s pace for each concentric and eccentric phase with the aid of a metronome.

Thermographic measurements

The skin temperature was recorded during the execution of the exercises by a digital thermal infrared camera FLIR SC660 (640 x 480 bolometer FPA, sensitivity/Noise Equivalent Temperature Difference: < 30 mK @ 30°C, FOV: 24° x 18°). The camera was placed at 60 cm from the participant and pointed toward thighs of the subjects. The sample frequency was 10 Hz. The quality of all the recorded thermal videos was preventively checked by visual inspection. No video was rejected. A region of interest (ROI) was selected over the vastus lateralis (VL). The time course of the average temperature (i.e., the mean of all the pixel temperatures within the ROI) was extracted from the ROI by means of a soft-tissue tracking algorithm in order to consider properly the temperature from each thermogram, in spite of the motion artifacts. The tracking software has been developed under Matlab environment and validated in Manini et al (2013).

Data analysis and statistics

Data analysis took into account the fact that, after a decrease in skin temperature during exercise, skin temperature began to increase rapidly after the cessation of the exercise in the subsequent recovery. For each of the three recovery phases (i.e., recovery 1, recovery 2 and recovery 3), three parameters were calculated to quantify the amount and the velocity of temperature change. Delta Skin temperature was calculated as the difference between temperature at the end of recovery and temperature at the beginning of recovery. Time 50% was calculated as the time when the temperature achieved 50% of the Delta Skin temperature, as well as Time 90% was calculated as the time when the temperature achieved 90% of the Delta Skin temperature.

According to the assumption of normality of the data distribution tested by the Shapiro Wilk Normality test, a two way ANOVA RM with repeated measurements on both factors (time and conditon) was performed for each temperature parameter. A p-value lower than 0.05 was considered statistically significant. Statistical analysis was performed using Graphpad Prism software (version 7.0, Graphpad, San Diego, CA).

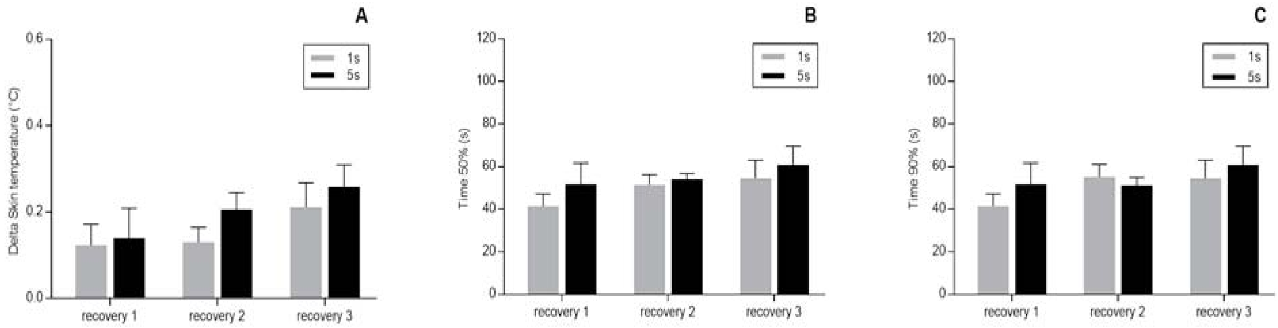

Figure 1 -
Data are means ± SEM.
A: Delta Skin temperature (end of recovery - beginning of recovery) in the rest periods after each set of knee extension exercise in both 1s and 5s condition.
B: Time 50% (time to reach the 50% of the delta skin temperature value) in the rest periods after each set of knee extension exercise in both 1s and 5s condition.
C: Time 90% (time to reach the 90% of the delta skin temperature value) in the rest periods after each set of knee extension exercise in both 1s and 5s exercise. For each variable, the two-way ANOVA RM did not reveal significant interaction (condition x time), time effect, or condition effect.

Table 1
F-values and p values derived from the Two-way ANOVA RM for interaction (Time x Condition) and main effects of Time and Condition for Delta Skin temperature, Time 50% and Time 90%.

	Time x Condition		Time		Condition	
	$F_{(2,14)}$	p value	$F_{(2,14)}$	p value	$F_{(1,7)}$	p value
Delta Skin temperature (°C)	0.667	0.52	2.917	0.08	0.665	0.44
Time 50%	0.140	0.87	0.838	0.45	3.26	0.1
Time 90%	0.532	0.59	0.803	0.46	1.043	0.34

Results

Figure 1 shows Delta Skin temperature, Time 50% and Time 90% in each of the three recoveries for both 1s and 5s condition. No significant interactions were revealed for each of the three temperature parameters ($p>0.05$), as well as no time and condition effects were found. F-values and p values derived from two way ANOVA RM are shown in Table 1 for each parameter.

Discussion and Conclusion

This study showed that the speed of movement during resistance exercise did not influence the skin temperature dynamic in the subsequent recovery phases. Furthermore, skin temperature dynamic during recovery phases was similar after each of three knee extension exercise set. After vasoconstriction during exercise - responsible for skin temperature decrement - vaso-di lation occurred in the recovery phases between exercise sets, leading to skin temperature increase. The fact that the dynamic of skin temperature during recovery phases was similar in the two conditions provided evidence that, despite the slow speed of movement induced a blood flow restriction condition (Tanimoto et al., 2006), it did not affect skin temperature. A previous study found that the amount of skin temperature change during resistance exercise was similar when exercising with normal and with blood flow restriction condition (Sampaio et al., 2016), thus supporting the notion that skin temperature was not affected by the restriction of muscular blood flow. Skin temperature dynamic was also similar in the three recovery phases for both conditions, suggesting that vasoregulation, and specifically vasodilation, did not change throughout the whole exercise session (i.e., from set 1 to set 3). However, it is worth pointing out that, despite no significant difference between conditions, Delta Skin temperature tended to be higher in 5s than 1s condition in each of the three sets. Similarly, Time 50% and Time 90% seemed to be higher in 5s than 1s condition. Moreover, Delta Skin temperature, Time 50% and Time 90% seemed to increase from recovery 1 to recovery 3. It is possible that the low sample size of the present study may have impinged on the chance to reveal significant differences between 1s and 5s conditions, as well as between recoveries, and therefore further studies with a larger sample size are required.

References

Formenti D, Ludwig N, Trecroci A, Gargano M, Michielon G, Caumo A, Alberti G. Dynamics of thermographic skin temperature response during squat exercise at two different speeds, Journal of Thermal Biology, 2016; 59; 58-63.

Headley SA, Henry K, Nindl BC, Thompson BA, Kraemer WJ, Jones MT. Effects of lifting tempo on one repetition maximum and hormonal responses to a bench press protocol. Journal of Strength and Conditioning Research, 2011; 25; 406-13.

Manini D, Cardone D, Ebisch SJH, Bafunno D, Aureli T, Merla A. Mom feels what her child feels: thermal signatures of vicarious autonomic response while watching children in a stressful situation, Frontiers in Human Neuroscience, 2016.

Sampaio L, Bezerra E, Paladino K, Libardoni dos Santos JO, Priego Quesada JI, Rossato M. Effect of training level and blood flow restriction on thermal parameters: Preliminary study. Infrared Physics & Technology 2016; 79; 25-31.

Tanimoto M, Ishii N. Effects of low-intensity resistance exercise with slow movement and tonic force generation on muscular function in young men, Journal of Applied Physiology, 2006; 100; 1150-1157.

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RELATIONSHIP BETWEEN MUSCLE DAMAGE AND SKIN TEMPERATURE AFTER AN ECCENTRIC EXERCISE

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Introduction

Athletes, coaches and medical staff have a great interest in the assessment of muscle damage due to its importance in the periodization of training and injury prevention. Muscular damage has been associated with pain 24 h to 7 days after exercise, resulting in significant impairment in functionality and muscular performance (Armstrong 1984, Pearcey et al. 2015). Mechanisms of muscle damage are related to local inflammation (Lewis et al. 2012), which can lead to an increase of skin temperature.

Infrared thermography can be an useful technique to monitor training responses if muscle damage is associated with skin temperature. In this regard, some recent studies presented promising results. Al-Nakhli et al. (2012) observed an increase of skin temperature in the exercised arms 24 h after exercise, and a correlation between skin temperature and the delayed onset muscle soreness. More recently, de Andrade Fernandes et al. (2017) evaluated the skin temperature and creatine kinase (CK) levels in soccer players after performing two consecutive matches within a 3-day interval and observed increments of skin temperature and CK after the matches. However, both variables presented a low correlation (r=0.3-0.4) between them. Therefore, more evidence is necessary to support this sport application of infrared thermography.

The objective of the study was to determine the correlation of skin temperature with CK in response to physical exercise of a localized muscle.

Method

Twenty untrained and healthy men participated in the study (age 24 ±5 years old, body mass 75 ±8 kg, height 174 ±6 cm). Participants were instructed to avoid drinking alcohol or caffeine, smoking, large meals, cosmetics, sunbathing, etc. before the assessment.

Participants completed a calf rising protocol until fatigue. Skin temperature by using infrared thermography, CK by blood samples from the ulnar vein, and muscle soreness by 10-points visual scale were measured before exercise and 48 h after.

Skin temperature was determined by an infrared thermography camera (E-60, Flir Systems Inc., Wilsonville, Oregon, USA) of 320x240 pixels with thermal sensitivity < 0.05°C. The TISEM checklist was used to certify that all the important aspects of the protocol and thermographic analysis were attended (Moreira et al. 2017). Camera was positioned 1 m far from the participant and perpendicular to the body region of interest (ROI). The images were recorded while the participant was standing up wearing underpants after a room thermal adaption of 10 min (Marins et al. 2014). An anti-reflective panel was placed behind the participant to minimize effects from infrared radiation reflected in the wall (Hildebrandt et al. 2010). One ROI was defined (posterior leg) in both lower limbs and covering the larger area over this anatomical region (Figure 1). Each ROI was selected with similar area for all participants in each measurement. Average and skin temperature variation (ΔT48h) were obtained considering an emissivity factor of 0.98 (Steketee 1973) (Thermacam Researcher Pro 2.10 software, FLIR, Wilsonville, Oregon, USA). Average of both limbs was considered because no differences were observed between them (p>0.05). The environmental conditions of the tests were 23 ±1ºC and 60 ±10% of relative air humidity.

Normality of data distibution was confirmed using Shapiro-Wilk test (SPSS Statistics 21.0, IBM Armonk, New York, USA). Difference between pre and 48h after exercise in muscle soreness, skin temperature and CK were assessed using Student t-test. Pearson correlation test was applied to verify the correlations coefficients between skin temperature measured post 48 h and CK levels 48 h after exercise.

Results and Discussion

Exercise resulted in delayed onset muscle soreness (6.7 ±2.5/10 points, p<0.01) and higher levels of CK (249 ±161 U/L in pre

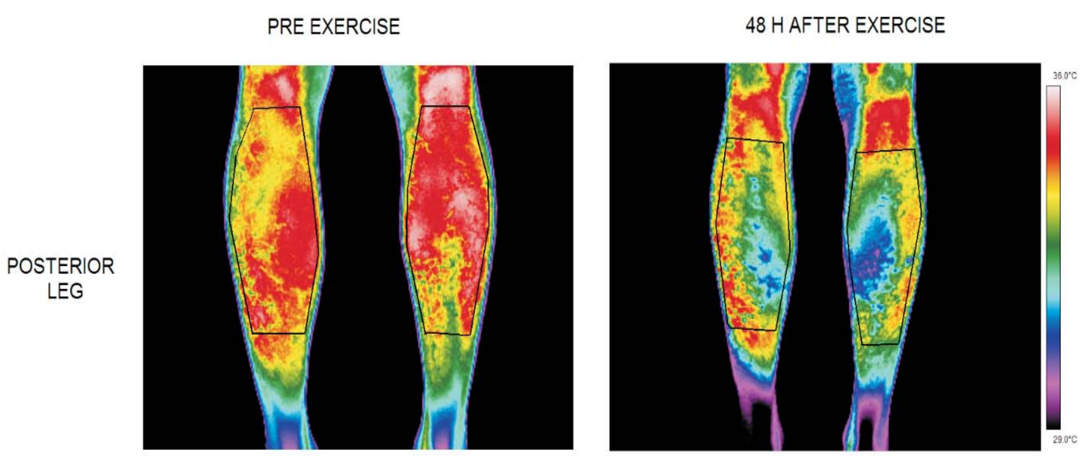

Figure 1 - Example of ROI determination for posterior leg pre-exercise and 48 h after exercise.

vs. 873 ±660 U/L 48 h after exercise; p<0.01) 48 h after exercise. These results support that there was muscle damage due to the calf exercise protocol.

Skin temperature of posterior leg did not change 48 h after exercise (32.4 ±1.1 in pre vs. 32.1 ±0.9 48 h after exercise; p=0.22), resulting in a ΔT48 of -0.3 ±1.1ºC. No significant correlations were observed between CK and skin temperature average (r= -0.18 and p=0.44) and ΔT48h (r=-0.01 and p=0.96) of posterior leg.

The application of infrared thermography in the analysis of muscle damage is related with the idea that there is an effect of inflammatory responses on skin temperature. However, the effect of this response is usually determined by the analysis of the thermal asymmetry, because one ROI is affected and the contralateral not. In the present study, we focused in control of muscle damage to a specific and superficial muscle group and in a bilateral way. Therefore, muscle damage is affected in both limbs and skin temperature could not express exactly the levels of muscle damage because it is also affected by other factors such as skin blood flow. Other possible explanation is that 48 h after exercise, inflammatory process is in the muscle and no close to the skin. Then, future studies should address if a heat stress protocol could reflect better the effect of muscle damage on skin temperature. Regardless of this, the CK levels in the circulating blood were not correlated with the damage markers and therefore such assumption needs to be driven with care when applying infrared thermography in the assessment of injury risk.

Conclusions

The main finding is that changes in skin temperature did not correlate with the CK marker of muscle damage. This is an important result as the exercise protocol was designed to cause damage in a specific muscle group where thermal images can be easily captured, and CK is widely employed to estimate magnitude of muscular damage in sports. As a practical implication, we recommend caution when assuming, that changes in skin temperature may help to determine the risk of injury and damage to the exercised muscles.

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References

Al-Nakhli HH, Petrofsky JS, Laymon MS, Berk LS. The use of thermal infra-red imaging to detect delayed onset muscle soreness. Journal of Visualized Experiments: JoVE 2012, (59).

Fernandes AA, Pimenta EM, Moreira DG, Sillero-Quintana M, Marins JCB, Morandi RF, Kanope T, Garcia ES. Skin temperature changes of under-20 soccer players after two consecutive matches. Sport Sciences for Health 2017, 13 (3), 635-643.

Armstrong RB. Mechanisms of exercise-induced delayed onset muscular soreness: a brief review. Medicine and science in Sports and Exercise 1984, 16 (6), 529-538.

Hildebrandt C, Raschner C, Ammer K. An overview of recent application of medical infrared thermography in sports medicine in Austria. Sensors 2010, 10 (5), 4700-4715.

Lewis PB, Ruby D, Bush-Joseph CA. Muscle soreness and delayed-onset muscle soreness. Clinics in Sports Medicine 2012, 31 (2), 255-262.

Marins JCB, Moreira DG, Cano SP, Sillero-Quintana M, Soares DD, Fernandes AA, Silva FS, Costa CMA, Amorim PRS. Time required to stabilize thermographic images at rest. Infrared Physics & Technology 2014; 65, 30-35.

Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJE, Costa CMA, Eglin C, Fernandes AA, Fernández-Cuevas I, Ferreira JJA, Formenti D, Fournet D, Havenith G, Howell K, Jung A, Kenny GP, Kolosovas-Machuca ES, Maley MJ, Merla A, Pascoe DD, Priego Quesada JI, Schwartz RG, Seixas ARD, Selfe J, Vainer BG, Sillero-Quintana M. Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. Journal of Thermal Biology 2017, 69, 155-162.

Pearcey GE, Bradbury-Squires DJ, Kawamoto J-E, Drinkwater EJ, Behm DG, Button DC, Foam rolling for delayed-onset muscle soreness and recovery of dynamic performance measures. Journal of Athletic Training 2015, 50 (1), 5-13.

Steketee J. Spectral emissivity of skin and pericardium. Physics in Medicine and Biology 1973, 18 (5), 686.

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THERMOGRAPHIC ANALYSIS OF THE USE OF CUSTOM-MADE FOOT ORTHOSES DURING RUNNING

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Introduction

Running is one of the most practiced physical activities because of the physical, social and mental benefits that athletes obtain. However, there is a high frequency of lower limb stress injuries associated to this activity due to the repetitive loads produced during running (Daoud et al., 2012). Some prevention systems have been developed in order to reduce this injury risk, such as improving running technique or flexibility or some ergonomic aids like prefabricated and custom-made foot orthoses (Fields, Sykes, Walker, Jackson, 2010). Although there has been a high increment in the use of insoles during running, there is controversy about whether their use can reduce the risk of overuse injuries in runners.

Some authors found changes in plantar pressure in some regions by using prefabricated and custom-made foot orthoses (Lucas-Cuevas, Pérez-Soriano, Llana-Belloch, Macián-Romero, Sánchez-Zuriaga, 2014). So that, the increment of plantar pressure and friction in different foot regions might influence skin temperature of foot soles due to the relationship between contact loads and the increments of temperature during the gait (Yavuz et al., 2014). In this sense, infrared thermography (IRT) might be a useful tool to asses if the use of foot orthoses induce changes in skin temperature, which is related to injury risk of the lower limb.

Therefore, the aim of this study was to analyse the effects of custom-made and prefabricated foot orthoses on skin temperature of different regions of foot soles after running.

Methods

24 participants, 18 males and 6 females, (Age: 35±5 years; Body mass: 71.4±12.5 Kg; Height: 1.75±0.07 m) carried out four different tests. First of all, they performed a 5 minutes maximal effort run on a 450-m track to determine their individual maximal aerobic speed (MAS) (Berthon, Dabonneville, Fellmann, Bedu, Chamoux, 1997). The second, third and fourth tests were performed at the laboratory with custom-made insoles (specially design for running and made by a podiatrist with a 3D mould of the feet), prefabricated insoles (specially design for running, bought in a sport shop fitted by participant size) and with no insoles conditions previously randomized, and they carried out a running test on a treadmill (TechnogymSpA, Gambetola, Italy) with 1% of slope. The runners wore their own running training shoes in every test (Lewinson, Worobets and Stefanyshyn, 2016). During these tests, participants warmed-up for 10 min at 60% of their MAS and run for 20 min at 80% of their MAS.

Skin temperature was measured with an infrared camera (Flir E60bx, Wilsonville, Oregon, EEUU) with a resolution of 320x240 pixels, thermal sensitivity <0.005ºC, and accuracy of ±2%, at laboratory tests in 3 different moments: 1) before running, after 10 minutes of adaptation of the room environment; 2) immediately after running; 3) 10 min after the running test. Prior to the first thermographic measurement, participants remained barefoot, sat down with the legs in an horizontal way in order to achieve a correct adaptation of the feet soles to the room temperature (Gil-Calvo, Jimenez-Perez, Pérez-Soriano,Priego Quesada 2017; Marins et al., 2014).

The images were taken from a distance of 1 m and the camera was kept perpendicular to the feet soles. Air temperature and relative humidity were controlled with a weather station (Digital thermo-hygrometer, TFA Dostmann, Wertheim-Reicholzheim, Germany) and introduced into the camera set up for every thermographic measurement, as well as reflected temperature, which was measured according to the standard method ISO 18434-1:2008. Other factors that could affect skin temperature were controlled, such as avoiding tobacco, alcohol, medicines, coffee or tea consumption 12 h before the test, avoiding heavy meals 2 hours before the test, etc.

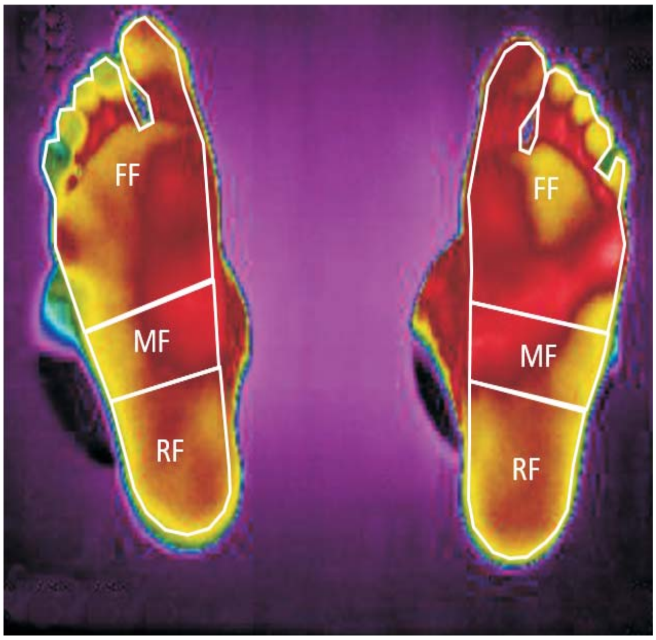

Figure 1
Regions of interest analysed: Forefoot (FF), Midfoot (MF), Rearfoot (RF)

3 regions of interest were defined and analysed in both foot soles: 1) Forefoot; 2) Midfoot; 3) Rearfoot (Figure 1). The absolute mean temperature of each ROI was computed using a commercial software (ThermacamResearcher Pro 2.10 software, FLIR, Wilsonville, Oregon, USA). All images were processed using an emissivity factor of 0.98 to obtain skin surface temperatures (Steketee, 1973). In addition to the absolute temperature values, the following temperature variations were calculated (Priego Quesada et al., 2015): ΔT (difference between the temperature immediately after and before the running test, expressed in °C), ΔT10 (difference between the temperature 10 min after and before the running test, expressed in °C), and ΔT after (difference between temperature 10min after and immediately after the running test, expressed in °C).

Data were analysed using SPSS Statistics 20.0 (IBM Armonk, New York, USA). Normality was checked by the Shapiro-Wilk test ($p>0.05$). Repeated measures ANOVAs were performed to assess the differences between ROIs in absolute temperatures and temperature variations.

Results and Discussion

Differences in absolute temperature were observed in forefoot between both foot soles ($p=0.019$), but not in midfoot or rearfoot. That result does not occur in variation of temperatures,

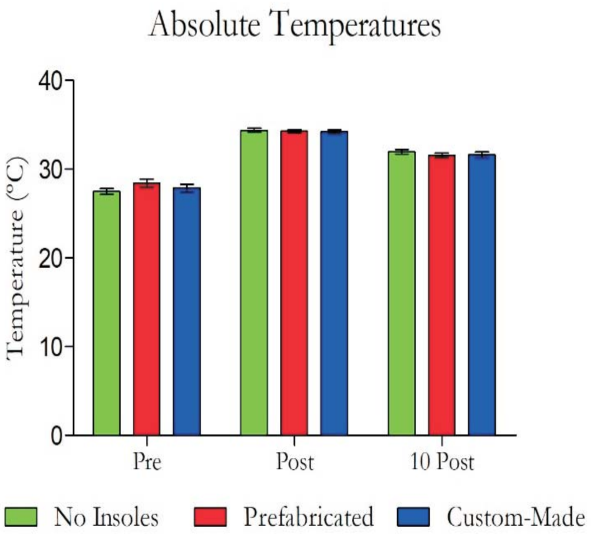

Figure 2
Absolute temperatures in the three moments observed, pre, post, 10 min post, for each condition analysed: No insoles (green), Prefabricated insoles (red) and Custom-Made insoles (blue). No significant differences were found between conditions.

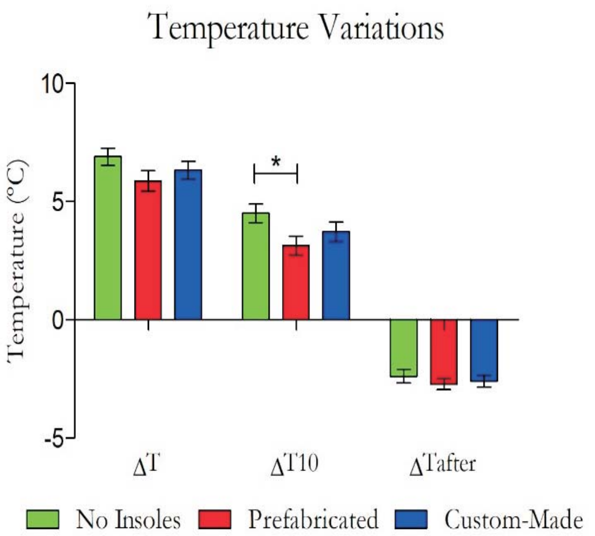

Figure 3
Temperature variations ÄT, ÄT10, ÄTafter, for each condition analysed, No insoles (green), Prefabricated insoles (red) and Custom-Made insoles (blue). *Differences between conditions p=0.019

in which there were no significant differences between both feet in any ROI (p>005), for this reason we consider the average data of both feet in the results.

In absolute temperatures, no significant differences were found between foot orthoses (p>0.05). No significant differences were neither found between conditions, when each ROI was analysed separately on each moment (p>0.05) (Figure 2).

In ΔT and ΔTafter, no differences were found between conditions in any region of interest (p>0.05). Nevertheless, in ΔT10, it was found a higher increase of the temperature 10 minutes after running compared to before running with no insoles than with prefabricated insoles (p=0.019), but no differences were found between neither no insoles condition nor prefabricated insoles condition and custom-made insoles condition (p>0.05) (Figure 3). These results were reproduced on each region of the foot soles.

As we can see in the results, foot soles temperature was similar at the beginning of each condition, which might show a good adaptation of the foot soles to laboratory temperature. In this sense, it can also be seen that immediately after running, foot soles temperature is higher in every condition, and 10 minutes after running feet soles temperature is higher than at the beginning. The higher temperature immediately after running could be explained because of the environment inside the footwear, the increment of blood flow due to the physical activity and the mechanical effect of the running activity in foot soles, and 10 minutes seems not to be enough to recover basal temperature of the foot soles after running 30 minutes.

In relation with the effects of foot orthoses, no differences were observed in absolute temperatures, in ΔT and in ΔTafter. However, in ΔT10, it exists a lower increment of the temperature in prefabricated foot orthoses than with no insoles, but not in comparison with wearing custom-made foot orthoses or between custom-made and no insoles conditions. These results could be due to a better breathability of the prefabricated foot orthoses materials, in comparison with footwear and custom-made foot orthoses materials.

The main limitations of the study was that the moisture vapour transmitted by the material and plantar pressure of the foot soles were not measured, and therefore the explanation of the results is speculative.

Conclusions

In conclusion, not using foot soles produces a higher increment of foot soles temperature 10 minutes after running, in relation with before running, than wearing prefabricated foot soles, but not compared to wearing custom-made foot orthoses. This could be due to the better breathability produced by prefabricated foot orthoses materials.

References

Bernard V, Staffa E, Mornstein V, Bourek A. Infrared camera assessment of skin surface temperature - Effect of emissivity 2013; 29(6); 583-91.

Berthon P, Dabonneville M, Fellmann N, Bedu M, Chamoux A. Maximal aerobic velocity measured by the 5-min running field test on two different fitness level groups 1997 ;105(7); 633-39.

Daoud AI, et al. Foot strike and injury rates in endurance runners: a retrospective study 2012; 44(7); 1325-34.

Fields KB, Sykes JC, Walker KM, & Jackson JC. Prevention of running injuries 2010; 9(3); 176-82.

Gil-Calvo M, Jimenez-Perez I, Pérez-Soriano P, Priego Quesada JI Foot Temperature Assessment. In: Priego Quesada JI, Application of Infrared Thermography in Sports Science; Springer, Cham, 2017. p. 235-63.

Lewinson RT, Worobets JT & Stefanyshyn DJ. Control conditions for footwear insole and orthotic research 2016;48; 99-105.

Lucas-Cuevas, AG, et al. Effect of custom-made and prefabricated insoles on plantar loading parameters during running with and without fatigue 2014; 32(18); 1712-21.

Marins JCB. et al. Time required to stabilize thermographic images at rest 2014; 65; 30-35.

Priego Quesada JI, et al. Relationship between skin temperature and muscle activation during incremental cycle exercise 2015; 48; 28-35.

Steketee J, Spectral emissivity of skin and pericardium, 1973; 18(5); 686-694.

Yavuz M, et al., Temperature as a predictive tool for plantar triaxial loading 2014; 47(15); 3767-70.

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Session 5: Thermography in the peripheral limbs

THERMOGRAPHIC ASSESSMENT OF THE FOOT: INTER-RATER AND INTRA-RATER REPEATABILITY OF THE PLACEMENT OF REGIONS OF INTEREST BASED IN THE ANGIOSOME CONCEPT

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Introduction

The thermal analysis of the feet of diabetic patients has been a popular topic among the scientific community in recent years. The definition of the regions of interest varies across studies [e.g. 1, 2] but in recent years, the use of the angiosome concept to define the regions of interest is becoming increasingly popular. In this approach, the foot sole can be divided in 4 zones corresponding to the angiosomes of the medial plantar artery (MPA), lateral plantar artery (LPA), medial calcaneal artery (MCA) and plantar artery (PA) and the dorsal surface of the foot corresponds to the anterior tibial artery (ATA) [3-5]. Few papers have addressed the repeatability of the placement of regions of interest [e.g. 6] and in the foot this topic has been overlooked. Therefore, the aim of this research is to analyse the inter and intrarater reliability of the placement of regions of interest in the foot, based in the angiosome concept.

Methods

Thermal images of the dorsal and plantar views of both feet of 13 diabetic patients (26 feet) were distributed to 2 blind assessors. Both assessors had been previously instructed about the angiosome concept and respective regions of interest (ROI) corresponding to the ATA, PA, MCA, LPA, MPA. The assessors were asked to evaluate all the thermal images of the 13 patients independently and were asked to define 6 ROI: ATA, PA, MCA, LPA, MPA and the sole of the foot. Three weeks after the first assessment, the thermal images of the same patients were assessed again by the same assessors. The patient order was randomized and the fact that the patients were the same was not shared with the assessors to avoid bias. For both sets of patients, using FLIR ResearchIR Max software (FLIR Systems, version 4.30.0.69), the mean temperature and number of pixels of each ROI were computed and analysed. Data analysis was performed using Statistical Package for the Social Sciences (SPSS Statistics, IBM, version 25). The inter and intrarater reliability was assessed calculating the Intraclass Correlation Coefficient (ICC). When assessing interrater reliability, a two-way random-effects, absolute agreement, single measurement model was used and when assessing intrarater reliability, a two-way mixed-effects, absolute agreement, single measurement model was used. The association between the differences in skin temperature and the difference in the number of pixels between the first and the second assessment was assessed with the Spearman correlation coefficient.

Results

The placement of ROI in the foot, based in the angiosome concept had excellent interrater reliability for all regions of interest (ICC: 0.991 – 0.999) and excellent intrarater reliability for both assessors (ICC: 0.993 – 0.999). Between assessments the number of pixels varied 4.68% in the ATA ROI, 8.25% in the MCA ROI, 7.88% in the PA ROI, 5.77% in the MPA ROI, 2.59% in the LPA ROI and 1.93% in the sole of the foot. No association between the differences in skin temperature and the difference in the number of pixels between the first and the second assessment was found for the ATA, MCA, PA and LPA ROI, however a low positive association was found in the MPA ROI (rho=0.462; p=0.001) and in the sole of the foot ROI (rho=0.318; p=0.022).

Conclusion

The results suggest that the regions of interest based in the angiosome concept can be placed in the foot with excellent interrater and intrarater reliability but attention should be paid to the difference in the number of pixels in the ROIs as this could be a source of bias in the analysis.

References

1. Wrobel JS, Ammanath P, Le T, Luring C, Wensman J, Grewal GS, et al. A novel shear reduction insole effect on the thermal response to walking stress, balance, and gait. Journal of diabetes science and technology. 2014;8(6):1151-6.

2. Sun P-C, Jao S-HE, Cheng C-K. Assessing foot temperature using infrared thermography. Foot & ankle international. 2005;26(10):847-53.

3. Attinger CE, Evans KK, Bulan E, Blume P, Cooper P. Angiosomes of the foot and ankle and clinical implications for limb salvage: reconstruction, incisions, and revascularization. Plastic and reconstructive surgery. 2006;117(7S):261S-93S.

4. Seixas A, Ammer K, Carvalho R, Vilas-Boas JP, Vardasca R, Mendes J. Skin Temperature in Diabetic Foot Patients: A Study Focusing on the Angiosome Concept. In: Tavares JMRS, Natal Jorge RM, editors. VipIMAGE 2017: Proceedings of the VI ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing Porto, Portugal, October 18-20, 2017. Cham: Springer International Publishing; 2018. pp. 1035-1040.

5. Nagase T, Sanada H, Takehara K, Oe M, Iizaka S, Ohashi Y, et al. Variations of plantar thermographic patterns in normal controls and non-ulcer diabetic patients: novel classification using angiosome concept. Journal of Plastic, reconstructive & aesthetic Surgery. 2011; 64(7): 860-866.

6. Ammer K. Need for standardisation of measurements in thermal imaging. Thermography and lasers in medicine. 2003:13-7.

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CAN DIABETIC FOOT ULCERS BE PREVENTED BY THERMOGRAPHY?

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Introduction

Thermal imaging as a solution to identifying Diabetic Foot Ulceration (DFU) prior to ulceration has become increasingly investigated in the past few years [1, 2].

Methods

110 diabetic patients (types 1 and 2) with a previous history of foot ulceration were recruited into a trial at three clinical centres. All patients had a previous episode of foot ulceration and were therefore classified as being at high risk of developing another ulcer. Thermal images of their feet were taken from 4 aspects of both feet (lateral, medial, dorsal and plantar) in monthly intervals over a period of 1 year or until ulceration. An infrared camera with dedicated software that enforced adherence to the trial imaging protocol was specifically developed for the trial and performance was verified by the National Physical Laboratory (NPL) before and after the trial.

The resulting infrared imaging data was assessed using four parameters commonly employed to characterise DFU: asymmetry, variance, time-differential and deviation from baseline, with a view towards establishing if the onset of ulceration could be detected before the lesion appeared. For each parameter a Receiver Operating Curve (ROC) was created for a distance kernel and the area under the curve was used as a measure of Sensitivity and Specificity. The continuous data was additionally divided into 12 spot measurements.

Results

Out of the 110 patients recruited into the study 41 eventually presented with DFU. 16 of these ulcers were directly caused by patient actions (e.g. accidents, injuries, pressure or heat trauma). Ulcers such as this cannot be predicted by any method. A further 13 ulcers were caused by a combination of behavioural and spontaneous biological causes and were also excluded from analysis. The remaining 12 ulcers occurred spontaneously without any obvious external trigger and these were analysed with for their predictive potential using the ROC method. The four parameters examined each had an area under the ROC curve with values in the range between 0.63 and 0.71, indicating a weak to medium ability to classify the data as predictive for ulceration. When separating the image data into 12 distinct spot locations the respective areas under the ROC curve results were inconclusive with values between 0.17 and 0.91.

Discussion

This work was inspired by claims that "75 % of foot ulcers are preventable" [3]. Our results demonstrate that such claims can only be valid under two assumptions: firstly, diabetic patients at risk must be monitored frequently. Once a month is insufficient. Secondly, only about a third of all DFUs appear to occur spontaneously without external trauma. Only these spontaneous ulcers and possibly those where the trauma is mild but prolonged (e.g. repeatedly wearing inappropriate footwear) can potentially be predicted and thus prevented by monitoring.

While the number of spontaneous foot ulcers analysed is small (n=12) the results confirm that thermal monitoring is in principle capable of predicting the onset of foot ulceration. However, frequent (daily) monitoring, if possible by patients' themselves, is required to exploit the full potential of the technique.

Acknowledgements

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References:

1.Frykberg RG, Gordon IL, Reyzelman AM, Cazzell SM, Fitzgerald RH, Rothenberg GM, Bloom JD, Petersen BJ, Linders DR, Nouvong A, Najafi B. Feasibility and Efficacy of a Smart Mat Technology to Predict Development of Diabetic Plantar Ulcers. Diabetes Care 2017, dc162294.

2. van Netten JJ, Prijs M, van Baal JG, Liu C, van Der Heijden F, Bus SA, Diagnostic values for skin temperature assessment to detect diabetes-related foot complications. Diabetes Technology & Therapeutics 2014, 16(11) 714-721.

3. Bus SA, van Netten JJ. A shift in priority in diabetic foot care and research: 75% of foot ulcers are preventable. Diabetes Metab Res Rev 2016, 32(Suppl. 1), 195-200.

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BETWEEN VISIT VARIABILITY OF THERMAL IMAGING OF FEET IN PEOPLE ATTENDING PODIATRIC CLINICS WITH DIABETIC NEUROPATHY AT HIGH RISK OF DEVELOPING FOOT ULCERS

A. Macdonald[1], N. Petrova[2], S. Ainarkar[3], J. Allen[1], C. Lomas[1], W. Tang[2], P. Plassmann[4], A. Whittam[5], J. Bevans[3], F. Ring[6], B. Kluwe[6], R. Simpson[5], L. Rogers[5], G. Machin[5], M. Edmonds[2]

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Introduction

People with diabetic neuropathy are at high risk of developing foot ulcers which can be slow to heal and are associated with considerable morbidity. It is suggested that up to week prior to an ulcer forming the skin may have localised elevated temperature. It is believed that the temperature increase corresponds to inflammation which precedes skin breakdown (1,2). A consortium of scientists, engineers and clinicians collaborated in a major multicentre project with a view to developing and trialling a bespoke thermal foot imaging device, DFIRSTTM . DFIRSTTM encompasses a Micro-Epsilon TM 400 thermal camera which has 382x288 pixels and a stated thermal resolution of 0.08 °C (3). Two clinical trials were a carried out involving 3 clinical centres; imaging of 100+ volunteers with healthy feet and, secondly, monthly imaging of 100+ patients with diabetic neuropathy over the course of a year. This extensive imaging program enabled a study into the between visit variability of foot temperature measurements in people with diabetic neuropathy but no active foot pathology.

Methods

Patients with diabetic neuropathy who had already had at least one foot ulcer but currently intact skin were recruited at three podiatry centres across the UK. Patients were excluded if the patients had evidence of peripheral arterial disease (missing dorsalis pedis and posterior tibial pulses), Charcot foot, fracture or an implantable device. The study was approved by London-Surrey Borders Research Ethics Committee and carried out in accordance with the Declaration of Helsinki. After giving informed consent, patients rested in a temperature-controlled room for 10 minutes with elevated, bare feet. Then patients' feet were imaged using the DFIRSTTM device. After a further 10 minutes resting patients' feet were imaged for a second time. Subsequent to imaging all patients were given standard podiatric treatment and they returned for a second visit typically one month later. 33 regions of interest (ROIs) were analysed on four aspects of the foot (12 plantar, 15 dorsal, 3 medial and 3 lateral ROIs, as illustrated in reference 4).

Results

Table 1 summarises the results for 96 diabetic patients (74 male, age 63.1 ± 10.8 years, mean ± standard deviation) who were imaged at two visits 28 [28, 31] days apart (median [IQR]) and did not ulcerate in that time. Room temperature was recorded as 23.0 ± 1.0 °C at the first visit and 23.4 ± 1.2 °C at the second visit (mean ± standard deviation). It is demonstrated that mean foot temperature (MFT) (as calculated from averaging 33 ROIs, MFT33) varied by a median of 1.2 °C between visits for individuals but MFT for the group overall were very similar at both visits. 17% and 20% (for visits 1 and 2 respectively) of the ROI temperature difference measurements exceeded the published thresholds proposed as significant in the detection of imminent foot ulcers (1,2,6) although none of these patients ulcerated between visits 1 and 2.

Table 1:
Temperature differences between ROIs and whole feet for two visits by 96 patients with diabetic neuropathy.

	Visit 1			Visit 2		
All in °C	Median (°C)	IQR [LQ,UQ] (°C)	% Outside threshold*	Median (°C)	IQR [LQ,UQ] (°C)	% Outside threshold*
dT	0.2	[-0.6, 1.1]	17	0.1	[-0.7, 1.1]	20
Mod dT	0.9	[0.4, 1.7]	17	0.9	[0.4, 1.8]	20
R MFT33	30.0	[27.2, 31.8]	n/a	29.9	[28.0, 31.8]	n/a
L MFT33	29.4	[27.4, 31.8]	n/a	29.7	[27.6, 31.8]	n/a
R-L MFT33	0.1	[-0.5, 0.8]	25	0	[-0.8, 0.7]	31
Mod R-L MFT33	0.8	[0.2, 1.3]	25	0.7	[0.2, 1.4]	31
					Visit 2-1	
Change in dT				-0.1	[-0.8, 0.7]	n/a
Change in Mod dT				0.8	[0.3, 1.5]	n/a
Mod Change in R MFT33				1.2	[0.5, 2.2]	n/a
Mod Change in L MFT33				1.3	[0.4, 2.4]	n/a
Mod Change in R-L MFT33				0.6	[0.2, 1.1]	n/a

dT (relative difference in temperature at ROIs, R-L), Mod dT (absolute difference in temperature at ROIs),
MFT33 (Mean foot temperature derived from all 33 ROIs).
*Threshold for ROI dT measurements is 2.2°C (1,2), threshold for MFT33 measurements is 1.35°C (6). n/a = not applicable

Discussion

Since thermography is increasingly being suggested as a tool in the monitoring of disease, specifically inflammation, it is important to know what typical variation is amongst patients who do not present the looked-for pathology. In this case we were looking for areas at risk of skin breakdown. Patients presented with intact feet and were given typical protective podiatric treatment designed to minimise that risk. Many regions of interest demonstrated elevated temperature when compared with the contra-lateral site. The proportion was greater than the 5% observed in a study of healthy feet (4,5). Interpretation of these observations is not straightforward since we have observed examples of hot areas which correlate with clinically significant visual observations (such as callus), hot areas which have no obvious visible clinical sign, and areas which are visibly red or vulnerable which do not show up as hot areas on the thermogram.

Conclusion

Localised hot areas on the skin are of interest to clinicians seeking to diagnose skin vulnerable to ulceration. Our study demonstrated many hotspots on the feet of patients at high risk of diabetic foot ulcer, and quantified the variation seen from visit to visit. However, understanding of the significance of these hotspots is not yet complete.

Acknowledgements

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References:

1Lavery LA, Higgins KR, Lanctot DR, Constantinides GP, Zamorano RG, Athanasiou KA, Armstrong DG, Agrawal CM. Preventing diabetic foot ulcer recurrence in high-risk patients use of temperature monitoring as a self-assessment tool. Diabetes Care 2007; 30(1) 14-20

2Armstrong DG, Holtz-Neiderer K, Wendel C, Mohler MJ, Kimbriel HR, Lavery LA. Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients. Am. J. Med. 2007, 120(12) 1042-1046

3Machin G, Whittam A, Ainarkar S, Allen J, Bevans J, Edmonds M, Kluwe B, Macdonald A, Petrova N, Plassmann P, Ring F, Rogers L, Simpson R. A medical thermal imaging device for the prevention of diabetic foot ulceration. Physiological Measurement 2017; 38(3), 420

4Macdonald A, Petrova N, Ainarker S, Allen J, Plassmann P, Whittam A, Bevans J, Ring F, Kluwe B, Simpson R, Rogers L, Machin G, Edmonds M. Thermal symmetry of healthy feet: a precursor to a thermal study of diabetic feet prior to skin breakdown. Physiological Measurement 2016, 38(1) 33-44

5Macdonald A, Petrova N, Ainarker S, Allen J, Plassmann P, Whittam A, Bevans J, Ring F, Kluwe B, Simpson R, Rogers L, Machin G, Edmonds M. Reproducibility of Thermal Images: Some Healthy Examples In: Ng EYK, ed, Application of Infrared to Biomedical Sciences, Springer, Singapore 2017, pp. 265-276

6van Netten JJ, Prijs M, van Baal JG, Liu C, van der Heijden F, Bus SA. Diagnostic values for skin temperature assessment to detect diabetes-related foot complications. Diab. Technol. Ther. 2014, 16(11), 714-721

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RELATIONSHIP BETWEEN SKIN TEMPERATURE AND SOFT TISSUE HARDNESS IN DIABETIC PATIENTS: PRELIMINARY STUDY

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Introduction

Previous research has reported an increase in skin temperature of the feet of diabetic patients [1]. Possible explanations may be the presence of autonomic neuropathy [2], infection [3] or increased local pressure [4]. The presence of callosities increases the pressure exerted in soft tissues and is regarded as a risk factor for ulcer development. Increased soft tissue hardness has been reported in diabetic patients with neuropathy [5] and its potential role in the development of plantar ulcers has been discussed [6]. No relationship has been established between the presence of callosities and the presence of hot spots in diabetics [7] but the relationship between skin temperature values and soft tissue hardness has yet to be studied. Therefore, the aim of this study was to investigate whether a relationship exists between skin temperature and soft tissue hardness in diabetic patients.

Methods

This study has been approved by the local ethical committee all participants read and signed the informed consent form for this study. Thirteen adults with diabetes (mean age: 66.5 years; mean BMI: 26.2 Kg/m2) enrolled for this study. The analysis was done at the foot level therefore, 26 feet were analysed. After a 10-minute acclimation period, thermal images were recorded in a room with controlled ambient temperature and relative humidity, away from airflow and infrared radiation sources. All the images were recorded in the same period of the day. Thermal images of the plantar aspects of the feet were recorded with an infrared camera (FLIR Systems, E60, Wilsonville, OR, USA) with a sensor array size of 320x240 and ±2% of accuracy of the overall reading and with emissivity set to 0.98. The camera was positioned perpendicular to the feet, 1 metre away from the feet. Soft tissue hardness was assessed using a Shore-A PCE-DDA 10 durometer (PCE Instruments, Meschede, Germany) in eight locations: at the calcaneum (medial and lateral), midfoot (medial and lateral), first metatarsal head, between the second and third metatarsal heads, between the fourth and fifth metatarsal heads and the hallux. Thermal images were analysed with FLIR ResearchIR Max software (FLIR Systems, version 4.30.0.69). Regions of interest were defined in the same areas where soft tissue hardness was assessed (figure 1), and mean temperature values were extracted and further analysed. Data analysis was performed using Statistical Package for the Social Sciences (SPSS Statistics, IBM, version 25). Data distribution was assessed with the Shapiro-Wilk test and non-parametric correlation (Spearman rho) was selected to analyse the association of the study variables. Statistical significance was admitted if the p≥0.05.

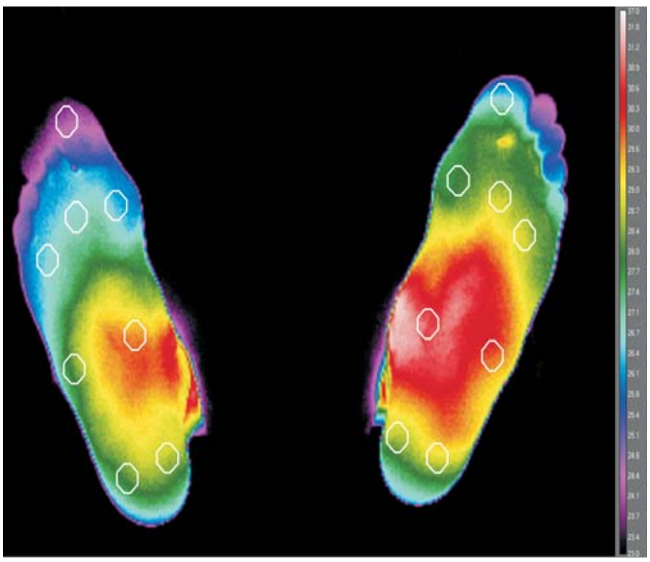

Figure 1
Regions of interest at the plantar aspect of the foot.

Results

Analysing each of the selected regions separately, no significant correlation was found between skin temperature and soft tissue hardness. Averaging skin temperature and soft tissue hardness in the calcaneum (medial and lateral), in the midfoot (medial and lateral and in the metatarsal heads (1st, 2nd-3rd and 4th-5th) led to different results. A negative, moderate association was found between skin temperature and soft tissue hardness in the metatarsal heads (rho=-0.517; p=0.014), but not in the heel and midfoot.

Conclusion

The results suggest that skin temperature and soft tissue hardness seem to be negatively and moderately associated in the region of the metatarsal heads, but this relationship requires more research to further understand the association between skin temperature and skin hardness.

References:

1. Ring E. Thermal imaging today and its relevance to diabetes. J Diabetes Sci Technol. 2010;4(4):857-62.

2. Yavuz M, Brem RW, Glaros AG, Garrett A, Flyzik M, Lavery L, et al. Association between plantar temperatures and triaxial stresses in individuals with diabetes. Diabetes care. 2015;38(11):e178-e9.

3. Harding J, Wertheim D, Williams R, Melhuish J, Banerjee D, Harding K, editors. Infrared imaging in diabetic foot ulceration. Engineering in Medicine and Biology Society, 1998 Proceedings of the 20th Annual International Conference of the IEEE; 1998: IEEE.

4. Armstrong DG, Lavery LA, Liswood PJ, Todd WF, Tredwell JA. Infrared dermal thermometry for the high-risk diabetic foot. Phys Ther. 1997;77(2):169-75; discussion 76-7.

5. Klaesner JW, Hastings MK, Zou D, Lewis C, Mueller MJ. Plantar tissue stiffness in patients with diabetes mellitus and peripheral neuropathy. Archives of Physical Medicine and Rehabilitation. 2002; 83(12): 1796-801.

6. Thomas VJ, Patil KM, Radhakrishnan S, Narayanamurthy VB, Parivalavan R. The Role of Skin Hardness, Thickness, and Sensory Loss on Standing Foot Power in the Development of Plantar Ulcers in Patients with Diabetes Mellitus-A Preliminary Study. The International Journal of Lower Extremity Wounds. 2003;2(3):132-9.

7. Ammer K, Melnizky P, Rathkolb O, Ring E, editors. Thermal imaging of skin changes on the feet of type II diabetics. Engineering in Medicine and Biology Society, 2001 Proceedings of the 23rd Annual International Conference of the IEEE; 2001: IEEE

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VARIABILITY IN PERIPHERAL REWARMING AFTER COLD STRESS AMONG 255 HEALTHY NORWEGIAN ARMY CONSCRIPTS ASSESSED BY DYNAMIC INFRARED THERMOGRAPHY

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Introduction

More than half of Norway is above the Polar Circle. In the harsh Norwegian climate, the annual number of army conscripts undergoing basic military winter training is approximately 7500. People in the northern part of the country, and especially in the inland areas, are exposed to winter conditions with temperatures often reaching -40°C. The incidence of cold injuries among soldiers during winter service in northern part of Scandinavia has been reported to be around 2% per year [1, 2]. Since exposure to cold climate is an inevitable consequence of military training, there is a need for increased focus on prevention and risk factor identification for cold injuries in soldiers [3]. However, there are no evidence-based techniques for identifying individual risk factors for susceptibility to cold injuries [4]. There are although, research findings underpinning the fact that nerve function is essential in terms of regulation of peripheral micro- vascularization as part of the pathophysiology [5]. Dynamic Infrared Thermography (DIRT), involving the use of thermal provocations tests, has been used in investigating circulatory disturbances especially in the hands such as vasospastic disorders seen in Raynaud's phenomenon [6]. Since vasomotor responses in the skin are good indications of peripheral nerve function, it has been assumed that slow rewarmers after a mild cold provocation test might be less protected against cold injuries [7]. The main aim of this study was to investigate the variability in skin rewarming of the fingers monitored with infrared thermography in a large, random cohort of young healthy army conscripts, after exposing the hands to a standardized cold provocation test. A second aim was to relate the variability in peripheral skin rewarming to a variety of intrinsic and extrinsic variables.

Methods

The study subjects consisted of 260 army conscripts from two cohorts. In August 2014, 122 conscripts enrolled in the Panzer-Battalion (August cohort). In January 2015, 138 conscripts enrolled in the Artillery-battalion (January cohort). All conscripts carried out their basic training at Setermoen garrison (68.9°N, 18.3°E) in Troms County, North-Norway, one of the coldest military campuses in the country.

The inclusion criterion was normal findings at medical screening during enrolment. There was a loss to follow up of 5conscripts, leaving 255 conscripts for analyses. The conscripts were not allowed to smoke, use smokeless tobacco (snuss), or to drink caffeine-containing liquids less than 2 hours before DIRT. They were also instructed not to drink any hot or cold beverages less than 1 hour before, and not to wash their hands in cold water less than 30 minutes before DIRT. An informed consent was obtained before enrolment into the study. The regional ethical committee approved the research protocol. DIRT took place under standardized and stable conditions. With exposed forearms. the conscript was comfortably seated using a standard office stool with an adjustable height. During DIRT, both hands were positioned palms down on a grid made of thin nylon netting strung on a plastic frame (figure 1).

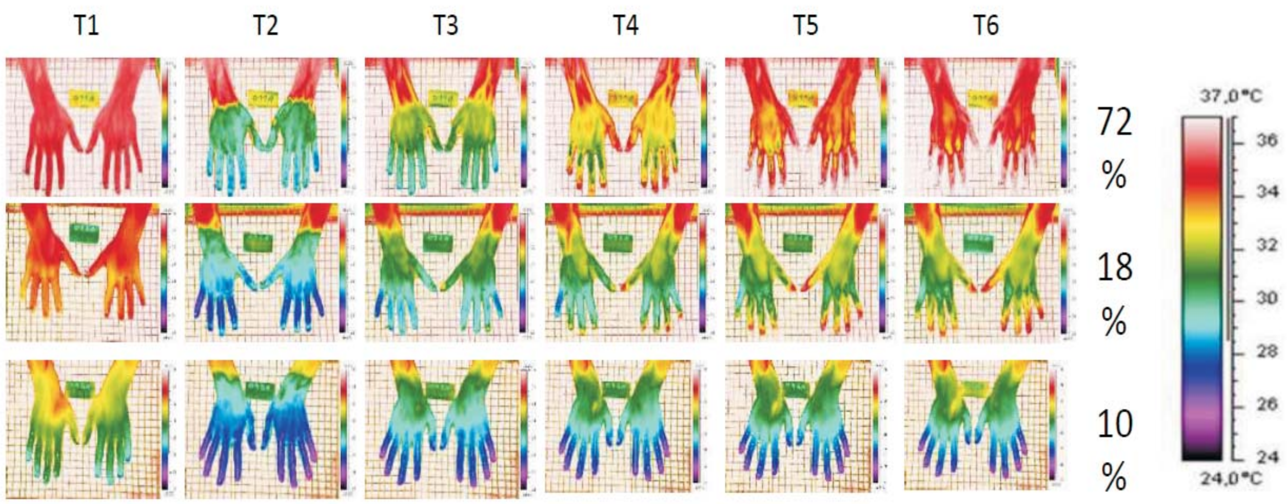

Figure 1
An example of the DIRT examinations in 3 individual recruits from the August cohort (a rapid rewarmer - top row; an intermediate rewarmer - middle row and a slow rewarmer - lower row). The distribution of these three different rewarming patterns are in per cent (%) of the August cohort, n=120. The thermographic images were obtained from six different time points: one before (T1) and one immediately after the cold challenge (T2) and thereafter at one minutes intervals during the 4 minutes spontaneous rewarming period (T3-T6).

Following the pre-cooling phase (T1), the hands were briefly removed from the nylon grid and each placed inside a thin plastic bag that extended to the elbows. The gloved hands were then simultaneously immersed in 20°C water (± 1 degrees) for 1 minute up to the level of the wrists. Directly following the cold challenge, the plastic bags were removed, and the hands replaced on the nylon grid (T2). During the 4 minutes recovery, thermal images were taken continuously, and measurements were performed at each minute (T3-T6). Three infrared (IR) cameras were used in the data collection; FLIR ThermaCAM™ T650 C, FLIR ThermaCAM™ A645sc and FLIR ThermaCAM™ S65HS. ThermaCAM ResearchIR® version 3.5 software was used for assessing the average temperature along a straight-line region of interest (ROI) positioned at the mid-dorsal side of all fingers. Each line extended from the middle of the nailbed and to the interdigital web gave 10 average individual finger-temperatures. These 10 averages were then used to calculate a mean temperature of all the fingers at six different time points. These average values were used as a numerical expression of the temperature status of the hand at the selected measured time points (T1-T6). These values are used for statistical analysis.

Results

The main finding of this study is the large variability in the rewarming ability following a standardised cold provocation test in a large cohort of young healthy army conscripts. On average, 72% of the cohort showed complete rewarming within 4 minutes (rapid rewarmer). An intermediate rewarming pattern was found in 18% of the soldiers where only part of the hands and fingers rewarmed to the T1 values (intermediate rewarmer). Ten percent in this cohort did not return to their T1 values within the 4 minutes recovery phase (slow rewarmer). In the slow rewarmers, the rewarming ability was correlated with a low average temperature of the hands prior to the cooling test. The mean skin temperature values in the August cohort were higher compared to the January cohort, both prior to and following the cold stress test (T1 and T2). The January cohort also had a lower mean skin temperature at T6. A statistically significant difference in mean skin temperature was found between the two cohorts, both at T2 and at T6. The August cohort was on average 2.1 °C warmer at T2 and 3.2 °C warmer at T6. The study tested for also for association between rewarming and socio-demographic variables, nicotine status and other personal characteristics, adjusted for cohort, and with and without adjustment for pre-cooling (T1).

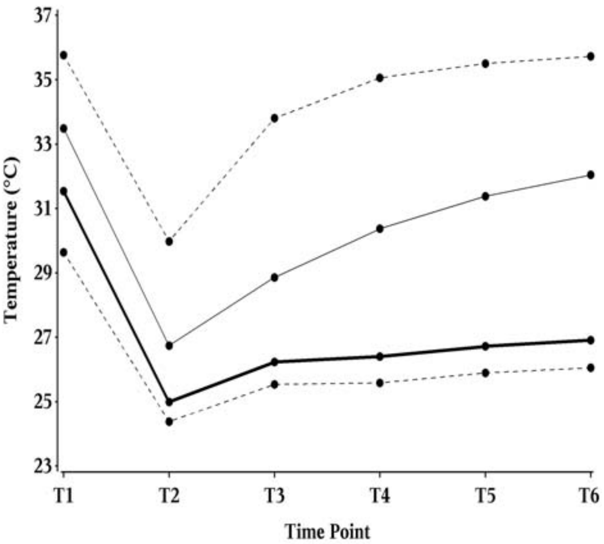

Figure 2
Nomogram (with percentiles) of average finger skin temperatures at the six selected time points (T1-T6). Combined data for the August and January cohort (n=255). Dashed lines bottom/top represents 2.5 and 97.5 percentiles. Middle line represents mean values, while the bold line represents the 10 percentiles.

Discussion

The importance of using infrared thermography to assess skin temperature is increasing in clinical settings. However, no evidence-based, consensus guideline exists to address the methods for collecting data in such situations, and and inter- and intra-examiner variability has been questioned. We prepared the research venue carefully in order to maintain the ambient and experimental conditions as stable as possible. The protocol used in this study made it possible to distinguish between rapid, intermediate and slow rewarmers.

The methodology used in our study might (and should) be questioned in terms of method of cold challenge, selected region of interest (ROI), the use of thermal contrast, seasonal differences, acclimatization and numerous subjective and personal factors in the experimental setting. smokers and users of smokeless tobacco belonged to the group of rapid rewarmers.

In our study, soldiers exposed to a couple of hours with abstinence from smoking showing a more rapidly recovering from a cold challenge. And further, conscripts reporting episodic periods of white/blue fingers showing a rapid rewarming . These unexpeced finding cannot easily be explained and will be discussed.

Acknowledgements

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References

1.Lehmuskallio, E., et al., Frostbite of the face and ears: epidemiological study of risk factors in Finnish conscripts. BMJ, 1995. 311(7021): 1661-3.

2.Ervasti, O., et al., The occurrence of frostbite and its risk factors in young men. Int J Circumpolar Health, 2004. 63(1): 71-80.

3.Castellani, J.W., et al., American College of Sports Medicine position stand: prevention of cold injuries during exercise. Med Sci Sports Exerc, 2006. 38(11): 2012-29.

4.Rintamaki, H., Predisposing factors and prevention of frostbite. Int J Circumpolar Health, 2000. 59(2): 114-21.

5.Imray, C., et al., Cold damage to the extremities: frostbite and non-freezing cold injuries. Postgrad Med J, 2009. 85(1007): 481-8.

6.Hutchison, R.L., Frostbite of the hand. J Hand Surg Am, 2014. 39(9): 1863-8.

7.Brandstrom, H., et al., Autonomic nerve system responses for normal and slow rewarmers after hand cold provocation: effects of long-term cold climate training. Int Arch Occup Environ Health, 2013. 86(3): 357-365.

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CASE STUDIES: INFLUENCE OF VARYING ENVIRONMENTAL TEMPERATURES ON INDIVIDUALS WITH PERSISTENT COLD HANDS

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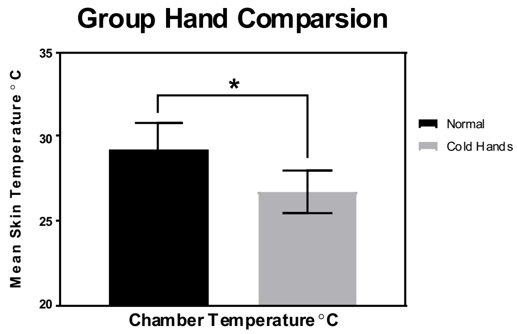
Introduction

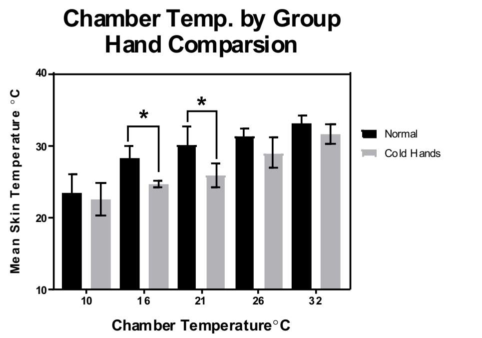
Acral tissues (feet, hands, ears, and nose) are anatomically designed to enhance thermoregulation by regulating heat transfers from the core-skin-environment (1). This is accomplished by arteriovenous anastomoses (AVA), low resistance vessels that allow direct blood flow from the arterioles to venules. This heat transfer mechanism for the AVA's is regulated by adrenergic vasoconstrictor control that modulates blood flow to the skin plexus. In 1862, Maurice Raynaud in his medical school thesis described "spontaneous gangrene of the extremities" (2). He observed "dead fingers" that turned "deadly white" or "yellow" due to stress. This condition has been called digital vasospastic phenomenon, Raynaud's disease, and more recently Raynaud's phenomenon to underscore the nature and various causes of the vasospasm. In 2000, Flavahan confirmed that Raynaud's syndrome is responsive to sympathetic stimulation of adrenergic agonist but also mediated by local sensitivity of the arterioles (3). The afflicted areas are localized with distinct borders in the acral tissues and the hand does not usually include pallor in the thumb. These Raynaud phenomenon individuals experience thermal attacks that are episodic and can be triggered by cold, disease, and stress.

We have observed some individuals that experience "cold hands" while exposed to a thermoneutral environment (18-25°C). While our normative populations presented with a mean hand skin temperature (anterior and posterior) of 30.2 ± 2.3°C, those "cold hand" individuals (CHI) presented with hand temperatures of 25.8 ± 1.6°C in the thermally comfort environment. This represents a 4.4°C difference in individual hand temperature within the same environmental conditions, similar core temperatures, and similarly dressed. Like those with Reynaud's phenomenon, this thermal observed response afflicts the acral tissues by reducing blood flow that result in colder tissue temperatures. Unlike the Reynaud's individuals, none of these individuals have a history of primary or secondary Reynaud's phenomenon, no distinct borders or reported pallor or cyanotic color changes in the hands and lack the expressed symptomatic periodicity. While these individuals are aware of their "cold" acral tissues for long durations, none were able to associate a cause that elicits the response. Therefore, this study was designed to investigate acral hand tissue response to varying environmental temperatures from 10-32°C (50-90°F).

Methods

Four cold hand individuals and four normal response participants signed a University approved Human Subjects Consent form. The participants were college aged and apparently healthy as determined from a participation questionnaire. The individuals were scheduled for five randomly assigned environmental sessions at 10, 16, 21, 26, and 32°C (50, 60, 70, 80, 90°F) with the relative humidity held constant at 35% on five occasions separated by 24 hours and performed during the same time of day. The environmental exposure consisted of standing in the environmental chamber during which infrared images (Computerized Thermal Imaging, Ogden Utah) of the anterior and posterior hands were taken after an equilibration period (Pre) and 20 minutes post. Image analysis for mean skin temperature of the hands was determined from a polygon that traced the hand from the wrist and encompassing the fingers. Core temperature was recorded via rectal probe at 0, 10, and 20 minutes. Men wore athletic shorts and women were dressed in athletic shorts and sports bra.





Results

A significant (P= 0.046) difference between normative controls and our CHI participants were observed when comparing the mean skin hand temperatures across all intervention chamber temperatures. Significant differences in mean hand skin temperatures were observed between groups at both 16 and 21°C temperatures, but not at the coldest (10°C) and warmest (26, 32°C) environmental temperatures.

Conclusions

We do not know the mechanism(s) behind this CHI response. Observations of an abnormal vasoconstrictive response as seen in the CHI participants can be initiated by various trigger stimuli and can be the result of different mechanisms, similar to that observed with Raynaud's. Both groups demonstrated a progressive increase in mean hand skin temperature as the environment becomes warmer. Based on our case study observations, CHI maintain vasoconstriction below 21°, while normal participants released vasoconstriction above 16°. These observations suggest that thermographic evaluations of CHI individuals may show discrepant results for both ambient environmental, exercise, and cold-water testing procedures.

References

1.Pascoe DD, Mercer JB, de Weerd L. Physiology of Thermal Signals. In: Diakedes M, Bronzino JD, Peterson DR. eds, Medical Infrared Imaging: Principles and Practice, CRC Press, NY, 2013, pp. 6-1 - 6-5.

2.Fava A, Boin F. Historical Perspective of Raynaud's Phenomenon. In: Wigley FM, Herick AL, Flavahan NA, eds, Raynaud's Phenomenon: A guide to Pathogenesis and Treatment, Springer, NY, 2015, pp. 1-11.

3.Flavahan NA, Flavahan S, Liu Q et al. Increased α2- adrenergic constriction of isolated arterioles in diffuse scleroderma. Arthritis Rheum. 2000; 43: 1886-1990.

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ACUPUNCTURE FOR FROSTBITE SEQUEL, MONITORED BY DYNAMIC INFRARED THERMOGRAPHY - A CASE REPORT FROM A SOLDIER IN THE NORWEGIAN ARMED FORCES

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Introduction

Frostbites have for decades been a relevant problem in the military and continue to be so. Newer therapies aimed at prevention of extensive tissue injuries have shown promising results in experimental studies and case reports. The pathophysiology in cold injuries and sequelae are still poorly understood although peripheral neurovascular function is impaired. Acupuncture has previously been described to influence the local circulatory mechanisms. Dynamic Infrared Thermography (DIRT) has been used to document microvascular effects following acupuncture stimulation.

Case Summary

The patient was a 19 years old previously healthy, non-smoking, female patient. She had no previous history of cold injuries, no other injuries or medical problems, and was not taking any medication. During outdoor military training in February 2015 in the harsh North-Norwegian climate, she noticed that she began to lose feeling in her fingers that during the exercise turned into dark discoloration with blisters. Even though she wore gloves, she was diagnosed with a second-degree frostbite on the fingertips of both hands. There was spontaneous recovery but when followed up at one year after the problem, she still complained of sensory-motor disturbances and hypersensitivity to cold. During the follow-up, she was examined by DIRT and in January 2016 she was offered off-label treatment with acupuncture. Acupuncture points were used to enhance peripheral blood circulation i.e. Baixie, LR3 and LI4. TCM acupuncture points were added to these points according to the 's symptom of feeling cold in general i.e. KI7 and ST36. Acupuncture treatments were given once a week for 12 weeks, in total 12 treatments.

Methods (DIRT)

The infrared (IR) cameras used in the data collection was a FLIR ThermaCAM™ T650 C with a thermal resolution of <20 mk NETD. The emissivity was set to 0.98. We used the rainbow palette in this study. The IR camera was calibrated using a blackbody controller unit with accuracy of ± 0.2 °C. From the stored data, ThermaCAM ResearchIR® version 3.5 (FLIR Systems AB, USA) software was used to capture and prepare the thermal images. The thermographic imaging took place under standardized and stable study conditions. Measurements were made in a room with an ambient temperature of 23 ± 1 °C. The patient was acclimatized for a minimum of 30 minutes to the indoor room temperature facial thermographic images showed the nose was vaso-dilated, presumably due to open arterio-venous anastomo-

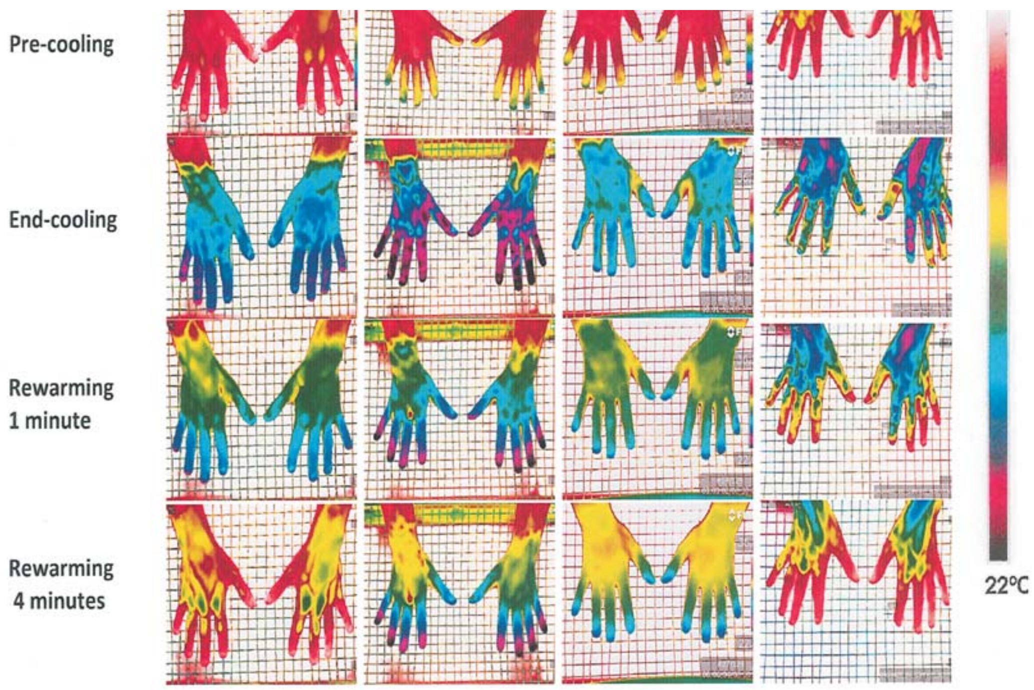

Figure 1
Summary of examinations with Dynamic Infrared Thermography. The thermographic images of the injured soldier (column 2-4) are compared to thermography obtained from examination of 260 Norwegian army conscripts (column 1), which in this paper is labelled "average" thermography. The images are presented of different time-slots; Pre-cooling, End-cooling, and rewarming at 1 and 4 minutes.

ses. With exposed forearms (shirtsleeves rolled up), she was comfortably seated on a standard office stool whose height could be adjusted to suit her positioning. During the time when thermal images were being recorded, the hands were positioned with palms down on a grid made of thin nylon netting strung on a plastic frame. The nylon grid was positioned 7 cm (+/- 0.5 cm) above a uniformly heated base plate (40 ± 2°C) that ensured a thermally uniform and stable background for the thermal imaging.

Following the initial pre-cooling thermographic imaging, the hands were briefly removed from the nylon grid and each placed inside a thin plastic bag that extended approximately to the elbows. The plastic-gloved hands were then simultaneously immersed in 20°C water (± 1 degrees) for 1 minute up to the level of the wrists. Directly following the cold challenge, the plastic bags were removed, and the hands were placed, palm down, on the nylon grid and maintained there for 4 minutes (the spontaneous rewarming period), during which thermal images were continually recorded at 1 second intervals.

After the acupuncture sessions, a post-acupuncture thermography was performed in April 2016. This last examination showed improved rewarming ability, similar to an the average rewarming pattern found among a population of presumptively heathy patient based on the examination among 260 army conscripts in the Norwegian Armed Forces (figure 1).

Discussion

This case report describes the immediate responses to a 12 weeks acupuncture session. The strength of our study is that acupuncture might contribute to improvement from a clinical condition without any evidence-based treatment alternatives. Acupuncture is an inexpensive, feasible and pragmatic approach for a condition that certainly needs more attention from a clinical perspective. In addition, acupuncture can be regarded as a safe treatment in hands of experienced practitioners.

The science of thermography has a history spanning a few decades, and inter- and intra-examiner variability has been questioned (3). However, medical thermography is a valid and reliable tool in understanding pathophysiology of microcirculation (4-6). This has been proposed to be of particular importance in frost injuries in the extremities (7-9), although the relevance has been questioned (10). In addition to be diagnostic in these patients (7, 11), thermography may also contribute to monitor effect of acupuncture treatment (4, 8).

A further step in clinical thermography in the military setting, might be to use thermography in a preventive setting in presumptive healthy normal individuals (12). However, further studies are needed to investigate the validity and reliability in thermography as a useful tool in monitoring the clinical course and effect of treatment for frostbite injuries.

The patient has stated that it was important that the treatment was regarded as safe and preferably without injections of pharmaceutical drugs. "*With these criteria as a background, acupuncture as a treatment suited me well. My experiences were followed up on from one treatment to the next, as well as the treatment in its total. It brings me joy that the results from before and after treatment indicates that my fingers sensitivity has been improved. During the last winter I was able to do outdoor activity that was impossible for me during the first year after the injury/before I was treated with acupuncture*".

Results

After treatment, the patient reported slightly less cold sensitivity. There was a clinical improvement in control of microvascularization stated by the patient on how she could cope with low temperatures. A proxy for her subjective feelings was obtained by thermographic examinations before and after treatment. Acupuncture therapy might be a new and promising treatment for frostbite sequelae.

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References:

1.Systems F. FLIR T600-Series Infrared Camera: Flir Systems; 2017 [cited 2017]. Available from: http://www.flir.com/science/display/?id=46818.

2.Ltd Hg. Infrared Systems Development IR-574 / 301 Blackbody Controller Santa Fe: Hofstra group Ltd; 2017 [cited 2017]. Available from: https://www.hofstragroup.com/product/infrared-systems-development-ir-574-301-blackbody-controller/.

3.Ring EF, Ammer K. Infrared thermal imaging in medicine. Physiological measurement. 2012;33(3):R33-46.

4.Golden FS, Francis TJ, Gallimore D, Pethybridge R. Lessons from history: morbidity of cold injury in the Royal Marines during the Falklands Conflict of 1982. Extrem Physiol Med. 2013;2(1):23.

5.Buzanello MR, Moro AR. Slaughterhouse workers exposed to cold: proposal of reference thermography values for hands. Work. 2012;41 Suppl 1:2876-81.

6.Gold JE, Cherniack M, Buchholz B. Infrared thermography for examination of skin temperature in the dorsal hand of office workers. European journal of applied physiology. 2004;93(1-2):245-51.

7.Pauling JD, Shipley JA, Raper S, Watson ML, Ward SG, Harris ND, et al. Comparison of infrared thermography and laser speckle contrast imaging for the dynamic assessment of digital microvascular function. Microvascular research. 2012;83(2):162-7.

8.Imray C, Grieve A, Dhillon S, Caudwell Xtreme Everest Research G. Cold damage to the extremities: frostbite and non-freezing cold injuries. Postgrad Med J. 2009;85(1007):481-8.

9.Junila J, Kaarela O, Makarainen H, Waris T. Assessment of tissue viability by thermography after experimentally produced frostbite of the rabbit ear. Acta radiologica. 1993;34(6):622-4.

10.Morrison SA, Gorjanc J, Eiken O, Mekjavic IB. Finger and Toe Temperature Responses to Cold After Freezing Cold Injury in Elite Alpinists. Wilderness & environmental medicine. 2015;26(3):295-304.

11.Hallam MJ, Cubison T, Dheansa B, Imray C. Managing frostbite. BMJ. 2010;341:c5864.

12.Norheim AJ, Mercer J, de Weerd L, Borud EK, Sagen T, Hjelle D. [Thermography in cold injuries in the military]. Tidsskrift for den Norske laegeforening : tidsskrift for praktisk medicin, ny raekke. 2014;134(17):1645.

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REFERENCE TEMPERATURE DATA OF NORMAL KOREAN LOWER EXTREMITY

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Introduction

Data Center for Korean Body Temperature (DC for KBT) was approved in the National Center for Standard Reference Data (NCSRD) No. 32 in 2016 by the Korean Agency of Technology & Standards under the Ministry of Trade, Industry and Energy. DC for KBT aims to make the reference standard temperature table by measuring the average temperature of each region of interest (ROI) made for each posture of infrared (IR) thermographic image of normal Koreans. The 2017 research goal is to create a reference temperature table for the normal adult's lower extremities. The purpose of this study is to present the production process and results of the reference body temperature data of the normal Korean lower limb.

Materials and Methods

In 2017, 517 normal adults were measured. The measurement posture of whole body is divided into 22 postures. The ROI of each posture is measured by using the IR thermographic images of the six among 22 postures corresponding to the lower extremity (Fig. 1). National Health Insurance Service (NHIS) Ilsan Hospital, Yonsei University Gangnam Severance Hospital and Ajou University Hospital participated in this study. The room temperature was kept constant at 24 ± 1°C. The selection of the normal person is the same as the distribution of the population in Korea from 20s to 60s. The criteria of normal adults should not be malformed in the face or limbs. There should be no scoliosis, kyphosis or lordosis, and the symmetry should be left and right as seen from the eyes. There should be no specific diseases as a result of national health check-up program. In addition, there are some cases of chronic diseases such as hypertension and diabetes which are controlled by medications and maintain normal levels. Some chronic diseases such as those who maintain normal liver function without liver cirrhosis are included as normal persons. The exclusion criteria are as follows. In IR thermography, when the temperature difference between left and right is more than 1°C due to operation wound, spine, hip, knee, ankle, or part of the lower extremity is identified. Spinal disease, peripheral arterial obstructive disease, varicose vein, diabetic foot, peripheral neuropathies. Some ROI exemptions are as also defined.

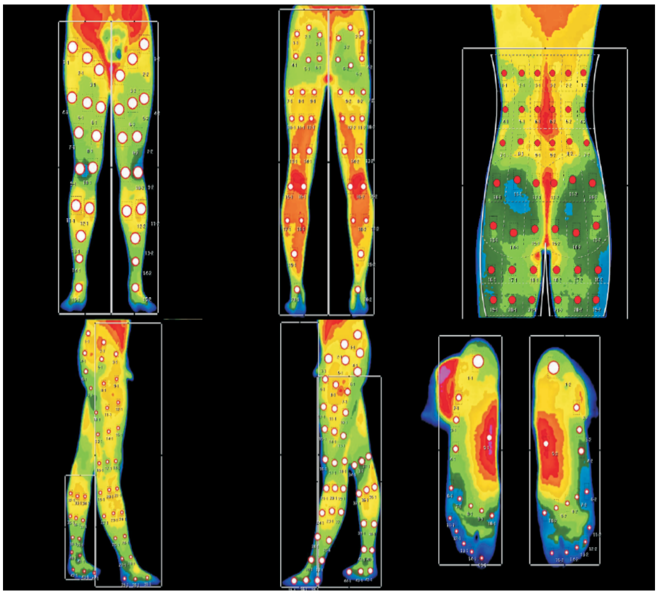

Figure 1
Six postures and ROIs of temperature measurement.
1.Posture of leg, anterior. 30 ROIs.
2) Posture of leg, posterior. 40 ROIs.
3) Posture of lower back & Buttocks. 42 ROIs
4) Posture of leg, right. 44 ROIs
5) Posture of leg, left. 44 ROIs.
6) Posture of sole. 30 ROIs.

To obtain the uncertainty of the measurement, the following actions were performed. The reliability test was conducted on three IR cameras. First, we set the ambient temperature to 24 ° C and the temperature of the blackbody was measured from 15 to 40 °C in 3 °C increments. Secondly, the black body was fixed at 30 °C and the ambient temperature was measured at 20, 22, 24, and 26 °C, and the IR camera was measured at 1 minute intervals for 30 minutes at each temperature. The error between the black body and the IR camera was within ± 1 ° C. The manufacturer of the black body used for this test was Precision Infrared Calibrator (FLUKE/4180). Calibration certification report from the institution certified by Korean Laboratory Accreditation Scheme (KOLAS) of the black body had a measurement uncertainty of 1.7 °C and an emissivity of 0.95. Next, three IR cameras were received calibration certification report from the institutions certified by KOLAS for traceability and calibration.

Based on this, we made an uncertainty equation. The three institutions passed the institutional review board (IRB) of each institution for this study. Then we measured the ROIs of the lower extremities of 517 normal adults.

Results

The average temperature of the ROIs was measured at 6 postures. Posture of lower back & buttocks defined 42 ROIs, 21 on the left and 21 on the right. Posture of leg, posterior defines 40 ROIs, 20 on the left and 20 on the right. Posture of leg, anterior defines 30 ROIs, 15 on the left and 15 on the right. Posture of leg, right and posture of leg, left defined 20 ROIs respectively. Posture of sole defined 30 ROIs, 15 on the left and 15 on the right.

A reference temperature data base of normal Korean lower extremity was completed and divided into 20s, 30s, 40s, 50s, and 60s by age group, and 60 reference data were finally obtained by dividing into male and female.

Table 1 shows the reference temperature for female, age group 40s, and the posture of leg, anterior.

We calculated various uncertainty values by finding various uncertainty components. Type 1 uncertainty was standard deviation. Type 2 uncertainties were 1) Maximum uncertainty value among 10 times repeat measurement, 2) Resolving power of read indicator's value, 3) Combined Standard Uncertainty of calibration report of each IR Camera, and 4) Maximum uncertainty value of thermometer (for room temperature measurement).

For example, looking at the formula for calculating the uncertainty of female, age group 40s in ROI 1-1 of Table 1, we have

Table 1
Example of reference temperature of normal Korean lower extremity. Age group: 40s, Posture: Leg, anterior

ROI	Male					Female				
	N	Average	Standard Deviation	Average Lt(1)-Rt(2)	p	N	Average	Standard Deviation	Average Lt(1)-Rt(2)	p
1-1	54	32.96	2.07	4.25	-0.06	67	31.53	2.56	5.21	-0.19
1-2	54	33.02	2.08	4.27		67	31.72	2.52	5.13	
2-1	54	33.14	2.11	4.33	-0.04	67	31.65	2.51	5.11	-0.06
2-2	54	33.18	2.16	4.43		67	31.72	2.54	5.17	
3-1	54	33.30	2.41	4.92	-0.05	67	31.87	2.66	5.41	-0.15
3-2	54	33.35	2.39	4.88		67	32.03	2.59	5.27	
4-1	54	32.72	2.13	4.37	0.10	67	31.54	2.53	5.15	0.00
4-2	54	32.61	2.07	4.25		67	31.54	2.57	5.23	
5-1	54	32.71	2.05	4.22	-0.03	67	31.45	2.53	5.15	0.01
5-2	54	32.74	2.07	4.25		67	31.45	2.55	5.19	
6-1	54	32.95	2.15	4.41	0.08	67	31.34	2.53	5.15	-0.05
6-2	54	32.87	2.24	4.59		67	31.39	2.55	5.19	
7-1	54	32.07	1.98	4.08	0.10	67	30.98	2.29	4.68	0.04
7-2	54	31.97	2.01	4.14		67	30.93	2.32	4.74	
8-1	54	32.53	2.00	4.12	-0.17	67	31.39	2.40	4.90	-0.18
8-2	54	32.70	2.14	4.39		67	31.57	2.42	4.94	
9-1	54	31.99	1.95	4.02	0.18	67	31.18	2.14	4.39	0.25
9-2	54	31.81	1.87	3.87		67	30.93	2.18	4.47	
10-1	54	31.87	1.90	3.92	-0.27	67	30.63	2.13	4.37	-0.15
10-2	54	32.14	2.05	4.22		67	30.78	2.17	4.45	
11-1	53	33.97	2.14	4.39	-0.08	66	32.87	2.46	5.02	-0.14
11-2	53	34.05	2.25	4.61		66	33.01	2.42	4.94	
12-1	53	33.78	2.10	4.31	0.12	66	32.37	2.50	5.10	0.35
12-2	53	33.66	2.20	4.51		66	32.02	2.49	5.08	
13-1	53	32.94	2.15	4.41	0.24	67	32.03	2.39	4.88	0.08
13-2	53	32.70	2.21	4.53		67	31.95	2.31	4.72	
14-1	53	32.40	1.87	3.87	0.41	67	31.79	2.38	4.86	0.14
14-2	53	31.98	1.91	3.94		67	31.65	2.36	4.82	
15-1	53	31.31	2.04	4.20	0.21	67	30.08	2.45	5.00	-0.01
15-2	53	31.10	2.00	4.12		67	30.09	2.50	5.10	

Table 2
Summarized table of components of various uncertainties in this study. Age group: 40s, Sex: female, Posture: Leg, anterior, ROI 1-1

Name of uncertainty		Definition	Value
$u(T_{m,s})$		Standard deviation of measured value	2.56
$u(T_{m,rep})$		Maximum uncertainty value among 10 times repeat measurement	0.000
$u(t_{m,res})$		Resolving power of read indicator's value	$0.01/2\sqrt{3}$ = 0.003
$u(\delta T_{ref}) = \sqrt{\frac{N_1 u^2(\delta T_{ref1}) + N_2 u^2(\delta T_{ref2}) + N_3 u^2(\delta T_{ref3})}{N}}$,where $N = \sum_{i=1}^{3} N_i$	$u(\delta T_{ref1})$	Combined Standard Uncertainty of calibration report of IR Camera 1	0.333
	$u(\delta T_{ref2})$	Combined Standard Uncertainty of calibration report of IR Camera 2	0.327
	$u(\delta T_{ref3})$	Combined Standard Uncertainty of calibration report of IR Camera 3	0.369
$u(T_{env})$		Maximum uncertainty value of thermometer (for room temperature measurement)	0.349
Combined Standard Uncertainty $u_c(T) = \sqrt{u^2(T_{m,s}) + u^2(T_{m,rep}) + u^2(T_{m,res}) + u^2(\delta T_{ref}) + u^2(T_{env})}$			2.61
Expanded Uncertainty $U = k.u_2(T)$ (95%, $k = 2$)			5.21

obtained various components of uncertainty and obtained their combined standard uncertainty. Based on this, expanded incertainty (U) was obtained (Table 2).

Table 3 shows the temperature measurement percentile for each ROI for female, age group 40s, and posture of leg, anterior.

Discussion

Institutions certified by KOLAS to measure the uncertainty of the IR camera are not yet traceable to the "real" temperature of the ITS-90, resulting in a calibration certification report of around 0.3°C. Since the long term stability is not secured, we will receive the calibration report annually as an alternative means.

Based on the two papers we published earlier, a reference standard temperature of at least 900 normal adults is required. Each year, 500 normal adults will be taken and measured for three years by IR camera in 22 postures. After three years, there will be 1,500 normal adults, and all referece standard temperatures in 22 postures will be made by 5 age groups. We made the reference temperture data of the lower limb at 2017, will add 1,000 legs and upper limbs at 2018, and we will have 1,500 lower limbs, upper limbs, face and trunk at 2019. In 2020, we will create a reference standard temperature for female breasts. Although 2017 was the first year of the temperature measurement and did not yet meet the reference standard data, continuing temperature measurements will yield good results in the future. It will also continue to add new uncertainty factors as they appear and will make continued efforts to reduce the uncertainty.

With reference standard temperature data, it will be easier and more precise to compare studies with thermographic images of specific patients. In addition, it can be used for the automatic detection of abnormal temperature region in accordance with the change of the artificial intelligence era and the judgment of the effect of the treatment.

Conclusion

In the year 2017, reference temperature data of the normal Korean lower extremity were made using temperature data of 500 normal adult subjects with 6 postures based on traceability and uncertainty. We will continue to add uncertainty factors in the future, and we will produce 22 reference standard temperature data using an IR camera for 1,000 adults in 2018 and 1,500 normal adults in 2019.

References

ISO/IEC. International vocabulary of metrology - Basic and general concepts and associated terms (VIM). 3rd eds, ISO/IEC GUIDE 99, 2007.

ISO/IEC. Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) in Uncertainty of measurement; ISO/IEC Guide 98-3, 2008.

Kim YS, YE Cho, Zhang HY. Thermatomes of the lumbosacral nerve roots. J Korean Neurosurg Soc 1995; 24; 33-46.

Zhang HY, Kim YS, Cho YE. Thermatomal change is cervical disc herniations. Yonsei Med J 1999; 40; 401-12.

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Table 3
Percentile of temperature for Posture of Leg, anterior in 40s female

ROI	N	1st percentile	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile	99th percentile
1-1	67	25.52	25.89	27.59	29.73	32.24	33.44	34.20	34.37	35.97
1-2	67	25.70	26.17	28.27	30.24	32.40	33.58	34.27	34.59	36.32
2-1	67	25.58	26.24	28.08	30.39	32.22	33.51	34.14	34.79	35.91
2-2	67	25.35	26.01	28.15	30.50	32.30	33.71	34.28	34.69	36.43
3-1	67	24.74	26.38	28.07	30.07	32.38	33.85	34.69	35.39	36.96
3-2	67	25.34	26.33	28.92	30.25	32.46	33.82	34.98	35.62	36.62
4-1	67	25.24	26.05	27.78	30.25	32.11	33.45	34.23	34.78	35.39
4-2	67	25.40	25.90	27.79	30.05	32.13	33.47	34.39	34.80	35.82
5-1	67	25.25	26.15	27.64	29.87	32.16	33.36	33.97	34.60	35.32
5-2	67	24.82	26.20	27.68	30.32	32.19	33.42	34.11	34.40	35.67
6-1	67	24.85	26.12	27.75	29.73	31.96	33.44	33.74	34.16	35.28
6-2	67	24.85	26.13	27.75	29.95	32.17	33.33	33.95	34.25	35.36
7-1	67	24.80	25.74	27.67	29.84	31.75	32.58	33.30	33.48	34.32
7-2	67	24.19	25.92	27.26	29.48	31.81	32.40	33.23	33.60	33.87
8-1	67	24.93	26.04	28.03	30.58	32.53	32.89	33.80	34.12	35.09
8-2	67	24.83	26.16	27.79	30.43	32.52	33.23	34.02	34.28	35.47
9-1	67	25.39	27.30	27.95	29.69	31.74	32.82	33.50	33.79	35.66
9-2	67	24.53	26.67	28.04	29.76	31.30	32.35	33.61	33.94	34.79
10-1	67	24.67	26.47	27.70	29.54	31.10	31.95	33.13	33.70	34.09
10-2	67	24.70	26.22	27.13	29.80	31.25	32.33	33.24	33.37	34.14
11-1	66	25.14	28.14	28.88	31.60	33.54	34.48	35.49	35.75	37.12
11-2	66	25.95	28.55	29.19	32.05	33.40	34.78	35.63	35.81	37.82
12-1	66	24.78	27.74	28.61	31.01	32.98	33.98	35.26	35.51	36.88
12-2	66	25.01	27.56	28.31	30.57	32.54	33.84	34.93	35.29	36.28
13-1	67	25.67	27.05	28.00	30.77	32.48	33.57	34.62	35.37	35.86
13-2	67	26.01	26.90	28.44	31.26	32.20	33.55	34.64	34.96	36.16
14-1	67	25.78	26.89	28.39	30.22	32.15	33.60	34.61	34.75	35.57
14-2	67	25.17	27.33	28.11	30.35	32.18	33.34	34.42	34.74	35.69
15-1	67	23.61	24.95	25.94	28.70	30.45	31.87	33.12	33.55	34.22
15-2	67	23.57	24.64	26.53	28.94	30.36	31.75	32.99	33.59	34.46

Session 6: Surgical applications

CHANGING THE SPECTRUM OF SURGICAL SITE INFECTION: VISUAL TO INFRARED

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Introduction

We have explored the thermal signatures of wound healing in two surgical specialties; colorectal surgery1 and obstetrics2. We observed a thermal signature associated with infected surgical wounds characterised by areas of low intensity radiation (temperature). Here we present the results of a third patient cohort.

Study aim: to characterise the thermographic profile of the healing/infected wound in obese women during the first 30 days after Caesarean section (CS) and to show proof of concept to stratify patients to surgical site infection (SSI) risk on the basis of the early post-operative thermal signature.

Methods

Participants: Women with a booking body mass index (BMI) ≥30 kg.m-2 undergoing elective or emergency CS were eligible for study recruitment. Abdominal thermal images were taken 24-48 hours after CS with three further imaging sessions targeted to days 7, 15 and 30 postpartum.

Imaging: Abdominal thermal imaging was undertaken using a portable thermal camera (FLIR Systems T450sc) with image resolution 320x240 pixels.

Analyses: Serial abdominal thermograms were obtained from each participant to provide the image profiles and temporal changes in abdominal temperature. For patient demographics and temperature profiles of each region of interest (ROI) descriptive analyses were conducted using SPSS with additional analyses undertaken using repeated measures and logistic regression models. Temperature values are presented as mean (standard deviation, SD). In this study a prototype predictive SSI algorithm was tested using a combination of ROI's

Results

Of 53 women recruited over a 10-month interval (October 2016- July 2017), thermal images were obtained in 50 women aged 21-44 (median 32) years. All women were obese with BMI (kg.m-2) corresponding to categories: obese, 30-34.9 (n=27) severely obese 35-39.9 (n=15) morbidly obese ?40 (n=8). Fifteen women (30%) developed SSI between days 6 to 30 (mean, day 17). The response to imaging was overwhelmingly positive and thermography at the bedside and in the community proved feasible overall. Average wound temperature day 2 (34.9; 0.6) day 7 (34.5; 0.9) day 15 (34.0; 0.9) day 30 (33.8; 0.7) was significantly higher than abdominal temperature at all time points ($p<0.001$). Differences in temperature between wound and abdominal skin reference (mean wound-mean abdomen) for those who later developed SSI was of borderline significance at day 2 ($p=0.052$). By day 7, mean wound (34.5oC) temperature was significantly higher ($p<0.05$) than mean abdominal temperature (33.1oC) for those women who later developed SSI. Further inspection of images revealed islands of low intensity radiation. Using our prototype algorithm, the appearance of cold spots within the wound at days 2 and 7 provided correct predictions for moderate to high risk of infection in 73% of cases.

Discussion

Obese women had a high risk (30%) of SSI after CS with infections developing towards the end of the second week. In an era of concern for the emergence of antibiotic resistance, we have sought to develop a novel approach to wound infection risk stratification on the basis of the early post-operative abdominal thermal signature. For the future, new ways to achieve rational surgical antibiotic prophylaxis are needed. Exploring the potential to 'rule in', 'rule out' later risk of SSI at early times after surgery is under development using our algorithm prototype; the results to 'rule in' at days 2 and 7 for SSI shows potential for this wound infection surveillance approach.

References

1. Siah R, Childs C. Thermographic mapping of the human abdomen: Methodology in healthy subjects and wound infection surveillance in patients after closure of enterostoma. J Wound Care. 2015; 24(3):112-20.

2. Childs C, Siraj MR. et al. Thermal territories of the abdomen after caesarean section birth: infrared thermography and analysis approaches to surgical site assessment Journal of Wound Care 2016; 25 499-512

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PERFUSION PATTERNS OF PERIUMBILICAL AND LATERAL ROW PERFORATORS OF THE LOWER ABDOMEN EVALUATED WITH DYNAMIC INFRARED THERMOGRAPHY (DIRT) AND INDOCYANINE GREEN (ICG) FLUORESCENCE ANGIOGRAPHY - A PILOT STUDY.

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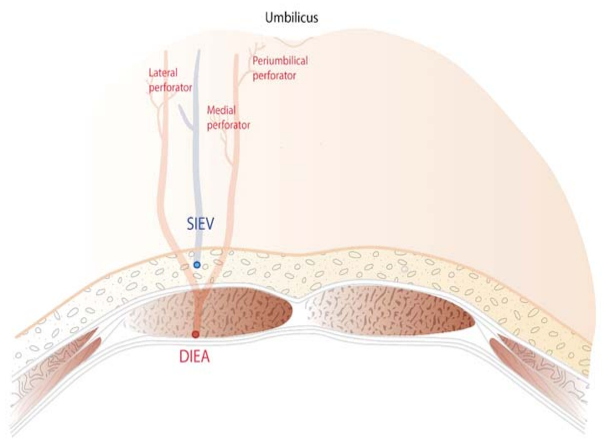

Figure 1
A schematic diagram showing some of the main blood vessels; the superficial inferior epigastric vein (SIEV), lateral, medial and periumbilical perforators of the deep inferior epigastric artery (DIEA). The DIEA may have different branching patterns.

Introduction

Perforator flaps have become increasingly popular in reconstructive surgery to close defects or to reconstruct form and function. These flaps consist of skin and subcutaneous tissue and receives its blood supply from a so-called perforator. Perforators arise from a source artery and pass through a muscle or in between muscles before they perforate the overlying fascia on their course to the overlying subcutaneous tissue and skin. The venous drainage of perforator flaps is by veins that accompany the artery. The lower abdomen has an abundant number of perforators. The deep inferior epigastric artery perforator (DIEP) flap is a perforator flap from the lower abdomen and has become increasingly popular in autologous breast reconstruction. The DIEP flap receives its blood supply from a perforator that arises from the deep inferior epigastric artery (DIEA) (Fig.1). The DIEA may divide into a medial and lateral row of perforators. Computer tomography angiography (CTA) has become the gold standard to select the most suitable perforator to provide blood supply to the DIEP flap. Based on CTA findings, DIEP flaps are frequently based on the medially located periumbilical perforator (1). We have used dynamic infrared thermography (DIRT) for preoperative perforator selection (2). Perforators transport warm blood to the skin surface and produce a hot spot on the infrared images. In our studies using DIRT, DIEP flaps were mainly based on lateral row perforators. DIEP flaps can be based on either a large periumbilical perforator as selected from CTA or on a large lateral row perforator selected with DIRT. However, the different findings from CTA and DIRT could indicate that medially periumbilical perforators and lateral row perforators have different perfusion dynamics.

Aim of the study

To investigate the perfusion patterns of the largest periumbilical perforator on CTA and lateral row perforator on DIRT on the lower abdomen in a DIEP flap.

Methods

Patients selected for DIEP breast reconstruction and abdominoplasty were included in this study. In both patient categories a DIEP flap was dissected free and based on the largest periumbilical (medial) perforator on CTA or the largest lateral row perforator indicated by preoperative DIRT. The superficial inferior epigastric vein (SIEV) was left open. Using a FLIR SC645 infrared camera (Flir Systems, Oregon, USA), set to an emissivity of 0.98, intraoperative DIRT was performed by applying a metal plate at room temperature to the flap surface followed by registration of the rewarming of the flap. The lateral row perforator was clamped, and DIRT was performed again. At the same time the patient was subjected to indocyanine green (ICG) fluorescence angiography (3). The ICG was given intravenously and the ICG perfusion pattern was registered. Afterward the periumbilical perforator was clamped, and the lateral row perforator was opened followed by a new ICG injection. Both the rewarming patterns and perfusion patterns of ICG for each perforator were compared.

Results and Discussion

Preliminary analysis of the DIRT results showed in all patients a hot spot that could be related to the lateral row perforator. However, in most patients the medially located periumbilical perforators showed no or only a weak hot spot although CTA indicated a large periumbilical perforator. By clamping the lateral row perforator, a hot spot became visible above the medial perforator. The ICG patterns could be correlated to the DIRT findings. Opening and closing the SIEV had an impact on the perfusion patterns. An open SIEV showed that the flap could drain through this vein. Based on the vascular anatomy of the lower abdomen the periumbilical perforator may receive its blood supply from the internal mammary artery (IMA) and the DIEA. Our ICG findings indicate for the first time that the DIEA is the main blood supplier to the periumbilical perforators. The results also indicate that the perforators from the DIEA have a dual venous drainage, namely the SIEV and the concomitant vein of the DIEA. This dual venous drainage system may be involved in temperature regulation.

References

1. Weum S, . Mercer JB. de Weerd L. Evaluation of dynamic infrared thermography as an alternative to CT angiography for perforator mapping in breast reconstruction: A clinical study. BMC Medical Imaging 2016; 16:43

2. de WeerdL, Weum S, Mercer JB. The value of dynamic infrared thermography (DIRT) in perforator selection and planning of free DIEP flaps. . Annals of Plastic Surgery20 09, 63: 278-283.

3. MilandÅO, de WeerdL, Weum S, MercerJB. Visualising skin perfusion in isolated human abdominal skin flaps using dynamic infrared thermography and indocyanine green fluorescence video angiography. Eur. J. Plast. Surg. 2008; 31:235-242.

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OPERATING ROOM: WHICH TEMPERATURE IS COMFORTABLE FOR BOTH PATIENTS AND SURGEONS?

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Introduction

It is important to control the body temperature of patients undergoing surgical treatments adequately. The patients may have peripheral circulatory insufficiency, delayed wakening from anesthesia, risk of myocardial ischemia and surgical site infection, if they have perioperative hypothermia. On the other hand, the number of laparoscopic and thoracoscopic surgeries has increased dramatically in the past 20 years. They have many advantages for the patients. However, it was reported that many patients undergoing laparoscopic surgery developed hypothermia. In previous studies it was shown that female patients having laparoscopic surgery tend to have hypothermia rather than male patients, and that male patients with low body mass index (BMI) tend to have hypothermia rather than high BMI patients. For avoiding intra-operative hypothermia, new operating rooms were built at the Kagawa University Hospital with a new concept in which the air flow for the patient is independent from the air flow for the surgeons. In this study the usefulness of the new operating rooms for controlling body temperature adequately in laparoscopic surgery was evaluated.

Subjects

The subjects of this study are 87 gastric cancer patients and 176 colorectal cancer patients, who underwent surgical therapy from January 2011 to July 2017 in Kagawa University Hospital. Forty gastric cancer patients and 83 colorectal cancer patients underwent laparoscopic procedures in the old operating rooms, and 47 gastric cancer patients and 93 colorectal cancer patients underwent them in the newly-built operating rooms (Table 1).

Methods

All patients underwent surgery in the lithotomy position. They were warmed at their chest and upper limbs using devices with warmed air bags. Gastric cancer patients were also warmed on their backs, but the colorectal cancer patients could not be warmed on their backs because of the use of a body fixing device to maintain the Trendenberg position. The temperature of the air flow for the patients was set to 23.5 centigrade, and that for the surgeons was set to 22 centigrade at the starting point of surgery, and the temperatures were changed freely according to the surgeon's requests during the operation. The body temperature of the patients was measured continuously by a sensor which was inserted in the bladder with a urine guide tube. The temperatures were recorded in the anesthetic reports automatically. The body temperatures just before surgery, and then every ten minutes from 10 to 100 minutes after starting the operation, were extracted for the evaluation. The temperature difference (ΔT) between the temperature of the starting point of surgery and that of each ten minutes after starting surgery was calculated. The ΔT of the patients undergoing surgical therapies in the old operating rooms was compared with that of the patients undergoing them in the new operating rooms. (This study was recognized by the ethical committee of Kagawa University.)

Results

1: Gastric Cancer

The mean ΔT of the male patients who underwent surgery in the old operating rooms was -.4 ± 0.5 at 30 minutes, -0.4 ± 0.3 at 60

Table 1 – Patients who underwent laparoscopic surgery

	Number of Patients	Male Patients	Female Patients
Gastric Cancer	87	30	57
In old operation room	40	9	31
In new operation room	47	21	26
Colon Cancer	176	109	67
In old operation room	83	45	38
In new operation room	93	64	29

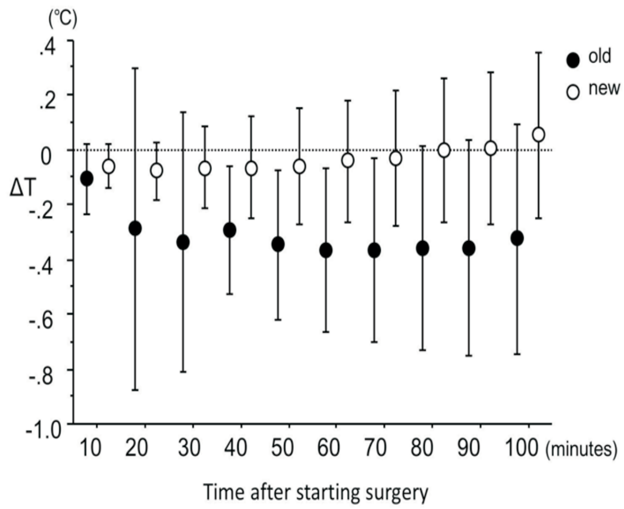

Figure 1
ΔT of the male gastric cancer patients underwent surgery in old peration rooms and new operation rooms

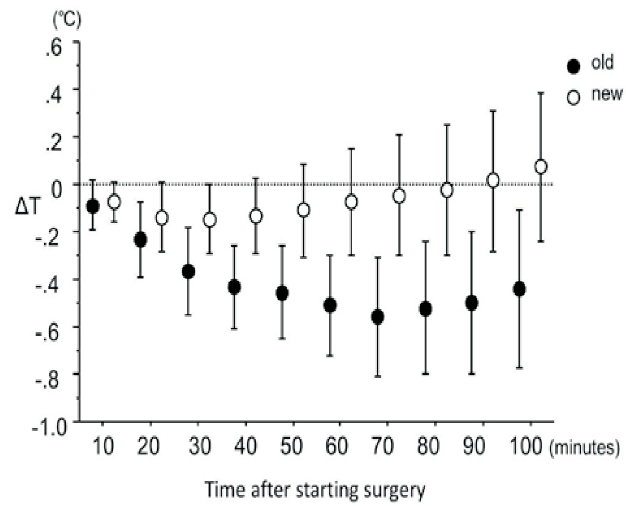

Figure 2
ΔT of the female gastric cancer patients underwent surgery in old operation rooms and new operation rooms

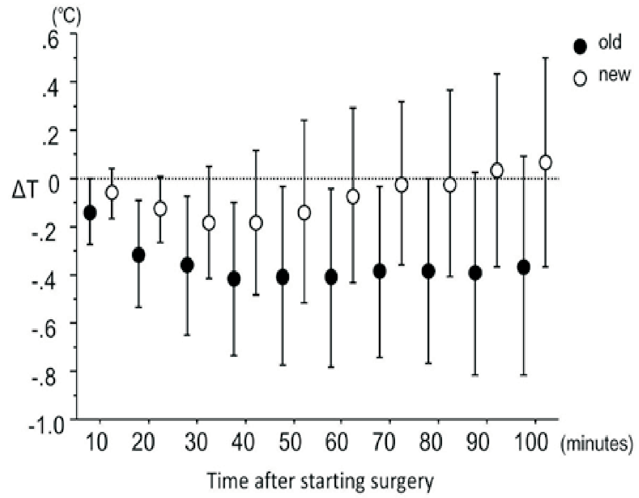

Figure 3
DT of the male colorectal cancer patients underwent surgery in old operation rooms and new operation rooms

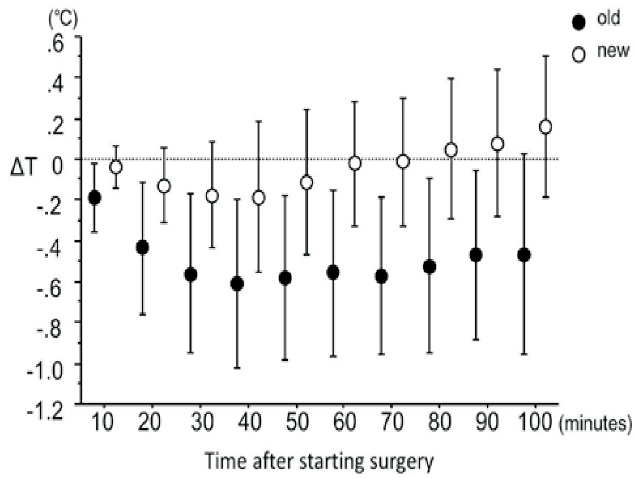

Figure 4
ΔT of the female colorectal cancer patients underwent surgery in old operation rooms and new operation roomss and new operation

minutes and -0.4 ± 0.4 centigrade at 90 minutes after starting laparoscopic surgery. For those patients who underwent it in the new operating rooms, it was -0.1 ± 0.2, -0.0 ± 0.2 and +0.0 ± 0.3 centigrade respectively. These differences were statistically significant (Figure 1). The mean Δ T of the female patients who underwent surgery in the old operating rooms was -0.4± 0.2 at 30 minutes, -0.5 ± 0.2 at 60 minutes and -0.5 ± 0.3 centigrade at 90 minutes after starting laparoscopic surgery. For those patients who underwent it in the new operating rooms, it was -0.2 ± 0.1, -0.1 ± 0.2 and +0.0 ± 0.3 centigrade respectively. These differences were also statistically significant (Figure - 2).

2: Colorectal Cancer

The mean ΔT of the male patients who underwent surgery in the old operating rooms was -0.4 ± 0.3 at 30 minutes, -0.4 ± 0.4 at 60 minutes and -0.4 ± 0.4 centigrade at 90 minutes after starting laparoscopic surgery. For those patients who underwent surgery in the new operating rooms, it was -0.2 ± 0.2, -0.1±0.4 and +0.0 ± 0.4 centigrade respectively. These differences were statistically significant (Figure - 3). The mean Δ T of the female patients who underwent surgery in the old operating rooms was -0.6 ± 0.4 at 30 minutes, -0.6 ± 0.4 at 60 minutes and -0.5 ± 0.4 centigrade at 90 minutes after starting laparoscopic surgery. For those patients who underwent it in the new operating rooms, it was -0.2 ± 0.3, -0.0±0.3 and +0.1 ± 0.4 centigrade respectively. These differences were also statistically significant (Figure - 4).

Discussion

It is well known that there is an insuperable difference between an adequate temperature for the patients and that for the surgeons. The most comfortable temperature for the patients is 28 centigrade and that for the surgeons is 21 centigrade or cooler, because the patients are naked and remain stationary during the operations, and the surgeons wear surgical gowns and are in a state of activity. In most cases, the temperature of the operating room is controlled to an adequate temperature for the patients when the patients enter the operating room. It is changed to a temperature adequate for the surgeons after inducing anesthesia. Thus, the temperature of the operating room in the surgical period is too cool for the patients. Moreover, the peripheral vessels of the patients are dilated by the anesthetics. The heat of the patient's body is lost rapidly during the perioperative period. For avoiding hypothermia, the patients are warmed by some kinds of warmer during the operation. But, in laparoscopic surgery the area of the skin exposed to room air is wide and the area available for warming is small in comparison to surgery by laparotomy. In addition, the carbon dioxide gas used for pneumoperitoneum is cold. Thus, the patients undergoing laparoscopic surgery tend to have hypothermia. Female patients, and male patients with low BMI are more influenced by the carbon dioxide gas than male patients with high BMI, because they have thin visceral adipose tissue and their blood flow contacts the cold gas almost directly. The results of the experiments prior to the construction of the surgical center showed the usefulness of the new air conditioning system, which divides the air flow for the patients from the air flow for the surgeons. The measurement of the temperature distribution of the newly-completed operating rooms showed that the temperature of the surgical table was 23.7+-1.0 centigrade, and that of the surgeon's shoulder was 21.8+-1.1 centigrade when the temperature of the air flow for the patients was set to 25 centigrade and that for the surgeons was set 21 to centigrade. This means that the air conditioning system with the new concept seems to be useful for the coexistence of comfort for the patients and also for the surgeons. Furthermore, the warm air does not blow against the surgeon's head and it blows against the patients directly in the laparoscopic surgery, because the surgeons do not have a stoop posture in laparoscopic surgery. The results of this study demonstrate the air conditioning system introduced in the new surgical center is useful for controlling the patient's body temperature adequately. One of the reasons for these favorable results is that the warm airflows come down to the patient's body. Another big advantage is that cool air is directed towards the surgeons, who do not request to lower the room temperature under such favourable conditions.

Conclusion

The air conditioning system with the new concept was useful not only for the surgeon's comfort but also for the comfort, health and safety of the patients.

Acknowledgement

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References

Frank SM, Beattie C, Christopherson R, et al. Unintentional hypothermia is associated with postoperative myocardial ischemia. Anesthesiology 1993; 78: 468-476.

Frank SM, Fleisher LA, Breslow MJ, et al. Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events. JAMA 1997; 277: 1127-1134.

Hannan EL, Samadashvili Z, Wechsler A, et al. The relationship between perioperative temperature and adverse outcomes after off-pump coronary bypass graft surgery. J Thorac Cardiac Surg 2010; 139: 1568-1575.

Insler SR, O'Connor MS, Leventhal MJ, eat al. Association between postoperative hypothermia and adverse outcome after coronary bypass surgery. Ann Thorac Surg 2010; 70; 175-181.

Winkler M, Akca O, Birkenberg B, et al. Aggressive warming reduces blood loss during hip arthroplasty. Aneth Analg 2000; 91: 978-984.

Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. New Engl J Med 1996; 334: 1209-1215.

Bashirov E, Cetiner S. Emre M, et al. A randomized controlled study evaluating the effects of the temperature of insufflated CO2 on core body temperature and blood gases (an experimental study). Surg Endosc 2007; 21: 1820-1825.

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Session 7: Dynamic thermography applications

THE EVOLUTION OF ANALYTICS IN BREAST THERMOLOGY: THE QUEST TO IDENTIFY SIGNAL FROM NOISE

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Introduction

The development of thermal imaging was a quantum extension of human perception with the ability to visualize what previously could have only been felt. Medicine was the first non-military recipient of this new ability. The early adopters applied pattern recognition to their diagnostic evaluation of thermal imaging, much as was done with the prevailing imaging modality, radiology, irrespective of the fundamental differences in the nature of the two modalities. The early analog instruments were not conducive to any meaningful quantitative analysis and diagnostic evaluation was dependant on the development of empirical wisdom of experts. Breast cancer detection was among the earliest medical applications of thermal imaging. Well after its initial application and some disappointing results, basic science revealed the infrared characteristics of breast cancer as fundamental to its pathophysiology in an era when radiometric thermal cameras have facilitated a quantitative analysis. Thermology necessarily incorporates objective and quantitative methodology in the evaluation of characteristics of breast cancers pathophysiology. Thermology, then, is a transfiguration of thermography but is it time to abandon the system expert evaluation in favour of an expert system analysis?

Discussion

Three distinct empirical parameters developed from clinical feedback in the early era of breast thermography. Atypical, high-energy and complex vascular patterns were discerned overlying breast cancers. Some practitioners developed extensive libraries of these atypical vascular patterns from instances of biopsy-proven breast cancers in an effort to applying those patterns to screen undiagnosed patients. The difficulty was that the configurations of vascular patterns in the female breast is highly individual with greater variation than finger prints.

Though early adopters soon determined there wasn't an absolute temperature threshold to indicate breast cancer, the evaluation of relative temperature differences was associated with a likelihood of breast cancer. However, it soon became clear that given such conditions as pregnancy, lactation, oestrogen and progesterone derangements, dermatitis and mastitis; breast cancer wasn't necessarily the highest energy feature in the breasts.

Assuming a regular and positive growth evolution for breast cancer, some thermographers would attempt to associate thermal features that appeared disproportionately increased in area or energy levels between two replicate sets of images ninety days apart. However, time-based evolution necessarily assumes uninterrupted and continuous growth of breast cancer and the absence of any other notable conditions to modify the vascular patterns or energy levels of the breasts' vascular features.

These three evaluative parameters constituted the complete range available to thermographers until basic medical science determined unregulated hyperemia of core body-temperature blood proximal to breast cancer as the basis its thermal 'signature'.

Several forms of dynamic evaluation have been developed to evaluate the neuro-vascular regulatory defect that is proximal to breast cancer.

- The Dynamic Area Telethermometry (DAT) employed the capture of high speed and high-resolution streaming images processed by digital-subtraction software to detect thermoregulatory 'dead-zones'.
- A purely physiologic dynamic challenge that involved a standardized stimulus to the autonomic nervous system and the evaluation of patterns that demonstrate exceptional deficiency of an adaptive response.
- An active cooling of the skin with refrigerated forced air (Sentinel) and the discernment of patterns of a 'reluctance' to the cooling.

Dynamic evaluation is greatly facilitated by radiometric infrared cameras and analytic software that enables a level of specificity and objectivity unmatched by the expert evaluations of empirical thermography (pattern recognition, asymmetric temperature differential and time-based evolution). Given the vast potential application for breast cancer screening by infrared imaging, the paucity of adequately trained experts and the ambiguity of empirical breast thermograpy: is empirical thermography obsolete and should it be relegated in favour of methods of dynamic evaluation?

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POSSIBILITIES WITH THERMAL MODELING AND SIMULATION OF THE HUMAN BODY

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Introduction

Assessment of body temperature in general and thermal comfort in particular both belong to a very challenging topic on the border between medicine and technique. As for temperature, it is not uniform throughout the body but varies between different parts depending on physiological events. Concerning thermal comfort, the challenges lie both in that relevant parameters are neither easily defined nor easily determined, and in that the individual experience of a situation might vary; i.e. comfort is a state of mind rather than a state of the thermodynamic system. The latter is also related to body temperature in that the normal level seems to be individual rather than identical for the entire population (Sund-Levander, 2017). In a clinical situation, reliable information about patient specific body temperature can be para-m ount when assessing patient status, making diagnoses, and planning for interventions.

This work aims to demonstrate the potential of a thermo-r egulatory simulation model of the human body that can be connected to models of various types of surrounding environments in a standardized way. Intended use includes assessment of body temperature, thermal comfort, and performance capability. In addition, it complements temperature measurements and can contribute to increased knowledge about how the measurements could be conducted for more reliable results.

Methods

The thermoregulatory model is based on Fiala's model (Fiala 99, Fiala 01), which subsequently was further developmed, by Westin 08. It consists of one spherical and 15 cylindrical (one-dimensional) segments representing different parts of the body. Legs, arms and neck contain layers of skin, fat, muscle and bone of individually varying thickness, while the innermost "layer" of the head (the sphere), thoracic part and abdominal part is as the brain, lungs, and viscera, respectively. The heat transfer through each part is modeled using a finite difference approximation. The skin can be covered by one or more layers of clothing.

From a functional perspective, the model is based on two regulatory systems: a passive system and an active system. The passive system accounts for the heat transfer in the body segments, including the contribution from the blood perfusion, and heat exchange with the immediate surroundings. The active system is a control system that senses changes in the thermal state of the body and responds with actions corresponding to shivering, sweating, vasodilatation, vasoconstriction, and respiration to maintain the body in (or push it towards) a state of healthy/sustainable thermal equilibrium. In the program, the passive system is represented by Pennes' one-dimensional bioheat equation, while the active system is based on the Stolwijk-Hardy error function concept. The input to the model can be measurements based on real situations, or output from another simulation model of the immediate surrounding of the person.

Results and Discussion

Initial simulations show very promising results. The human thermoregulatory model delivers temperatures in all layers of all segments of the body. This makes it very suitable for parameter studies of the temperature distribution within bodies of different composition and age characteristics. Thus, the model provides a potential tool to determine temperatures inside the body based on measurements of the e.g. skin temperature. Another application is to model and investigate the individual response to various changes of the surrounding thermal conditions, e.g. for a pilot during a flight including exposure to high sun radiation, heating due to high speed or also severe cooling. The modeled person can be equipped with any type of clothing. Through the mechanisms of the active and passive systems, it is also possible to assess the amounts of heat that are generated or removed via the regulatory functions. Altogether, the simulation model also shows great potential to use when addressing the topics of factors that influence temperature readings in clinical situations, and what accuracy that can be expected in clinical practice.

As another application of the model, thermal comfort and sensation of wellbeing are paramount to ensure rational decisions and actions of humans in numerous situations, constantly, every day. Aircraft pilots, drivers of forest vehicles and mining equipment are examples of complex situations where people operate vehicles in remote locations, possibly under harsh conditions in solitude. Results from the model opens for assessment of the estimated mental performance and capability to safely and efficiently conduct tasks like these. In addition, knowledge of the thermal status of the body can be valuable for assessment of situations when persons are exposed to extreme hot or cold environments, e.g. to demonstrate a child's physological response to heat exposure in a parked vehicle. Yet another example, the simulation model can be used in a reversed way for detailed post-mortem investigations of the body temperature for various surrounding conditions like heating or cooling in air or water.

To conclude, we believe that a thermoregulatory model like the one described has a huge potential to add on to knowledge and methodology when assessing body temperature and capability of humans to conduct certain tasks under demanding thermal conditions.

References

Sund Levander M, Grodzinsky E. Variation in normal ear temperature. American Journal of the Medical Sciences, 2017, in press.

Fiala D., Lomas J. and Stoher M., A Computer Model of Human Thermoregulation for a Wide Range of Environmental Conditions, Journal of Applied Physiology, 1999, 87, 1957-1972.

Fiala D., Lomas J. and Stoher M., Computer Prediction of Human Thermoregulatory and Temperature Responses to a Wide Range of Environmental Conditions, Journal of Applied Physiology, 2001, 45, 143-159.

Westin, J. K., An Improved Thermoregulatory Model for Cooling Garment Applications with Transient Metabolic Rates, PhD Thesis, 2008, University of Florida, Orlando, Florida.

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MODELLING EVENT-RELATED THERMAL RESPONSE BY MEANS OF GENERAL LINEAR MODEL

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Introduction

Thermal imaging is validated to infer sympathetic and parasympathetic arousals [1]. In fact, temperature variations are mainly related to the vasodilatation and vasoconstriction, regulated by the autonomic activity. Moreover, the sweat secretion induced by the sudomotor nerve activity [2] influence the superficial temperature as well. However, the amplitude of the thermal changes is informative of the autonomic arousal only if there is a linear relation between the autonomic activity and the amplitude of temperature variation. It is known in literature that if the same white noise aversive stimulus is administered with different intensity, it produces effects as higher as the stimulus is [2]. Thus, it is licit to suppose that a system that produce this kind of response would generate thermal responses that are scaled versions of a template. Moreover, when two responses overlap, usually the amplitude of the second response is not affected by the first one if some baseline can be estimated for it [3]. The employment of mathematical models for the analysis of thermal signals makes necessary to test if the assumptions underlying the model are satisfied. In this study, a test of the linear and time-invariance assumptions about thermal responses (TR) is provided, to show the validity of the application of the General Linear Model (GLM) [4]. Moreover, a comparison between the GLM results obtained with skin conductance response (SCR) and thermal imaging is reported. In the GLM approach, a time series is modelled as a weighted sum of one or more known predictor variables (e.g., the onset and offset of an experimental condition) plus an error term. The aim of the analysis is to estimate if, and to what extent, each predictor contributes to the variability observed in the time series. Using the matrix notation, the GLM can be expressed as: $Y=X\beta+\varepsilon$; where Y is a an $n \times 1$ column vector representing the investigated time series; X is $n \times p$ design matrix, with each column representing a predictor variable; β is the $p \times 1$ of unknown weights of each predictor variable that indicate the association with the data Y. ε is the error associated to each observation [4].

Methods

We recruited 54 healthy participants (30 male, 24 females, mean age ± standard deviation: 24.8±6.3 years, range 19-30 years). All the measurements were performed according to the guidelines reported in Cardone & Merla (2017) [1]. The study was conducted in agreement with the Declaration of Helsinki and it was approved by the local ethics committee. Pregnant women, participants who were taking drugs or with circulatory diseases that could impact the thermal measurement were not included. White noise sounds (1 s length; 10 ms onset and offset ramp; ?85 dB sound pressure level) was delivered via speaker in three experimental conditions: single, double and triple stimuli with inter stimulus intervals (ISIs) of 2 s, 5.5 s, or 9 s. This was done to avoid subjective expectations about subsequent stimuli. The last stimulus of each trial was followed by 30, 35, or 40 s of silence. The first trial was preceded by 10 s of silence. 8 trials were realised for the single, double (8 for each ISI) and for the triple stimuli condition, for a total of 40 trials. The facial temperature was recorded by means of a digital thermal infrared camera FLIR SC660 (640 x 480 bolometer FPA, sensitivity/Noise Equivalent Temperature Difference: < 30 mK @ 30°C, FOV: 24° x 18°). The camera was placed at 60 cm from the participant and pointed toward the face of the subject. The sample frequency was 15 Hz. One region of interest (ROI) on the nose tip was considered as indicative for the evaluation of autonomic activity [1]. The time course of the average temperature was extracted from the ROI using a soft-tissue tracking algorithm in order to avoid movement artifacts [5]. Thermal data were filtered with a bi-di rectional third-order Butterworth low-pass filter (0.4 Hz) [6]. The time series was then z-transformed to account for between subjects' variance in TR amplitude. In order to ensure a conservative estimation of residual variance, a Principal Component Analysis (PCA) was performed for each subject and across all the participants, in order to assess the variance explained by the evoked response. The first principal component was used to characterise the canonical response function (CRF). For the estimation of the CRF, a least-square minimization approach was carried out. Skin conductance was recorded on the thenar/hypothenar of the non-dominant hand using AD Instrument Powerlab system. It is provided of Galvanic Skin Response (GSR) amplifier with low voltage, 75 Hz AC excitation and automatic zeroing. The finger electrodes are made by brightly polished stainless steel and are fitted with Velcro tape. The sample frequency was of 1kHz. SCR data were filtered with a bi- directional third-order Butterworth bandpass filter (0.01-5 Hz) [7] and down-sampled to 15 Hz sampling rate. The tonic and the phasic components of the signal were separated using a continuous decomposition analysis provided by Ledalab, a Matlab based software [8]. The phasic component was then z-transformed. To test the linearity of the system, it was investigated if TRs can be deconvolved even at short ISIs and if repetition effects at different ISIs were present. In order to test the time-invariance of the system, the signal variance explained by one impulse response function was evaluated in event-related responses without overlapping. Both for TR and SCR a GLM based analysis was carried out. The CRF used for the SCR was defined by Bach et al., 2010 [7]. For the TR the shape of the CRF is the same but the parameters were estimated as previous described. To test the linear invariant features, a PCA across all the participants of TRs was performed to determine the CRF.

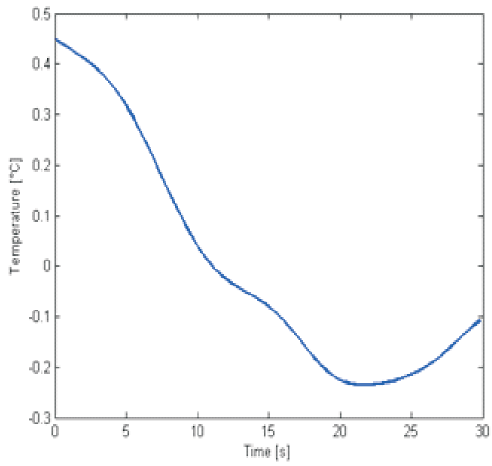

Figure 1
First principal component to a single stimulus across all the participants

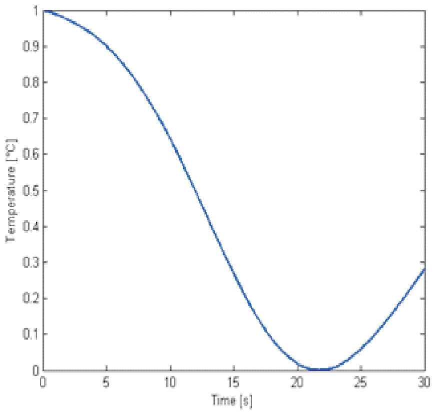

Figure 2
Canonical Response Function normalized between 0 and 1 for the thermal signal collected over the nose tip

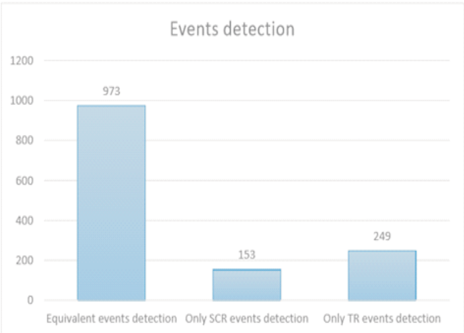

Figure 3
Events detected from SCR and TR

Table 1
Sensitivity and Specificity of the TR in detecting the autonomic activity, validated on the SCR results

	ID	0	1	Tot
Counts	**0**	973	153	1126
	1	249	877	1126
%	**0**	86.4	13.6	100,0
	1	22.1	77.9	100,0

Results

The response function explained 61.7% of total variance for the experiment. The response function is depicted in the Figure 1. For each participant we determined a response function by performing PCA on responses to single stimuli. The first PCA component was then fitted to trials with double events by convolving it with two stick functions for each event onset and combining this with a constant component. The repeated measurement ANOVA established that there was not a main effect regarding the ISI ($F(1.510,37.738) = 0.967$; $p=0.374$; $\eta^2=0.037$) and no interactions regarding the ISI was significant. The CRF was then modelled as a Gaussian smoothed bi-exponential function [7]. The parameters of this analytical form of the CRF were estimated using the full dataset with a least-square approach. The events detected by the SCR were considered as the only stimuli that produced an autonomic response. In this way, we checked the amount of responses concurrently detected by the two techniques and the ones not equally detected (Figure 3). When only the TRs where detected, they were considered false positive. In Table 1 the sensitivity and specificity of the analysis are reported.

Discussions

In this study, a test of the feasibility of the application of the GLM based analysis to the thermal signals is provided. Hence, it was investigated the time-invariance and linearity of TRs as these constitute two important assumptions for this kind of approach. On this basis, a canonical response was modelled. The SCR and TR gave almost the same results. In fact, the TRs modelling exhibits a sensitivity of 86.4% and 77.9% of 1-specificity with respect to SCR. However, not each stimulus produced a response in the participants, or, at least, SCR nor TR were able to detect them. This could be related to a response habituation, and this implies that the system has memory. This is consistent with a linear model, since it incorporates simple repetition effects. It is possible that the repetition effect is due to peripheral and central adaptation to the stimulus [3]. This study opens the possibility to investigate the thermal signal under a new point of view. In facts, with a modelling of the thermal activity it is possible to overcome the analysis based only on descriptive parameters, opening the possibility to detect thermal responses not only at group level, but also at single subject level or even through an event-related approach. However, given that the present study explores only the response to one specific aversive stimulus, further investigations are necessary to examine the response to other kinds of stimuli and the possible application during the administration of cognitive tests and ecological experiments as well. In fact, with respect to SCR measurements, fIRI is completely contactless, hence it is able to preserve the ecological features of tests, thus providing a powerful tool for application in clinical diagnosis ambit.

Conclusion

To the best of our knowledge, this is the first time that the fIRI response to an aversive stimulus is modelled by a GLM approach. The results confirm the fulfillment of the assumptions of linearity and time-invariance of the thermal response, thus the possibility to investigate this signal trough a mathematical linear model. Moreover, the comparison of the results obtained with TR and SCR are consistent, suggesting that fIRI can be an important tool for clinical assessment of impaired autonomic responses in completely ecological situations. However, further studies are necessary to better investigate the TR to different stimuli and cognitive tasks.

References

1.Cardone D, Merla, A. New Frontiers for Applications of Thermal Infrared Imaging Devices: Computational Psychophysiology in the Neurosciences. Sensors 2017, 17(5), 1042.

2. Yoshida M, Kikumoto M, Matsumoto K. Correspondence of nasal skin temperature and subjective condition to white noise" Physiopsychology and Psychophysiology 1995;13(1) 29-38.

3.Boucsein W. Electrodermal activity. Springer Science & Business Media, 2012.

4.Monti MM. Statistical analysis of fMRI time-series: a critical review of the GLM approach." Frontiers in Human Neuroscience 2011; 5.

5.Manini B et al. Mom feels what her child feels: thermal signatures of vicarious autonomic response while watching children in a stressful situation. Frontiers in Human Neuroscience 2013, 7 .

6.Pinti P, Cardone D, Merla A. Simultaneous fNIRS and thermal infrared imaging during cognitive task reveal autonomic correlates of prefrontal cortex activity. Scientific reports 2015, 5 ()

7.Bach DR., et al. Modelling event-related skin conductance responses." International Journal of Psychophysiology 2010;75(3) 349-356.

8.Benedek M, Kaernbach C.. A continuous measure of phasic electrodermal activity. Journal of Neuroscience Methods 2010, 190, 80-91.

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DYNAMICS OF THE LOCAL TEMPERATURE OF SKIN, INNER SURFACE OF CHEEKS AND BUCCAL GINGIVA AFTER THE APPLICATION OF AN STANDARD INSTANT ICE PACK TO PATIENT'S FACE

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Introduction

It is generally thought that applying an ice pack to patient's cheek skin reduces local inflammation and local temperature in skin, deep tissues of the cheeks and even in gums. Therefore, everywhere dentists apply an ice pack to patient's cheeks skin as they hope to reduce the inflammation and local temperature of the tissues inside the oral cavity after operations on the jaws. At the same time, as we have shown earlier, the short-term local cooling of limbs, myocardium or intestines causes suppression of aerobic metabolism intensity and a multidirectional reflex reaction of blood vessels: first, vessels spasm and then vasodilation [1-3]. It was shown that vasodilation increases the influx of warm blood and raises the temperature of the cooled area, and the use of local and general anesthetics prevents vasospasm [4].

In this regard, our research was aimed at studying the dynamics of the local temperature in facial skin and tissues in the oral cavity during and after a single short-term application of an ice pack to patient's cheek skin.

Methods

The study involved 12 healthy adult volunteers aged 25-42 years. The air temperature in the room was within 24 - 26 °C. Infrared thermography was performed with ThermoTracer TH9100XX thermal imager (NEC, USA) with the temperature range of +26 +37°C. Values of the local temperature of soft and hard tissue in the oral cavity was determined with the use of infrared thermography in 3 moments when the mouth was opened voluntarily: before, immediately and 10 minutes after the application of ice pack. The role of ice packs we used the standard instant ice Packs. A standard instant ice pack was applied to one volunteer cheek once for a period of 10 minutes. In addition to thermal imaging diagnostics, was constant monitoring of buccal gingiva local temperature with bedside monitor brand BeneView T6, T8 (Mindray, China). The sensor was applied to buccal gingiva the upper jaw in the area of premolar before beginning cooling and removed 10 minutes after finished cooling.

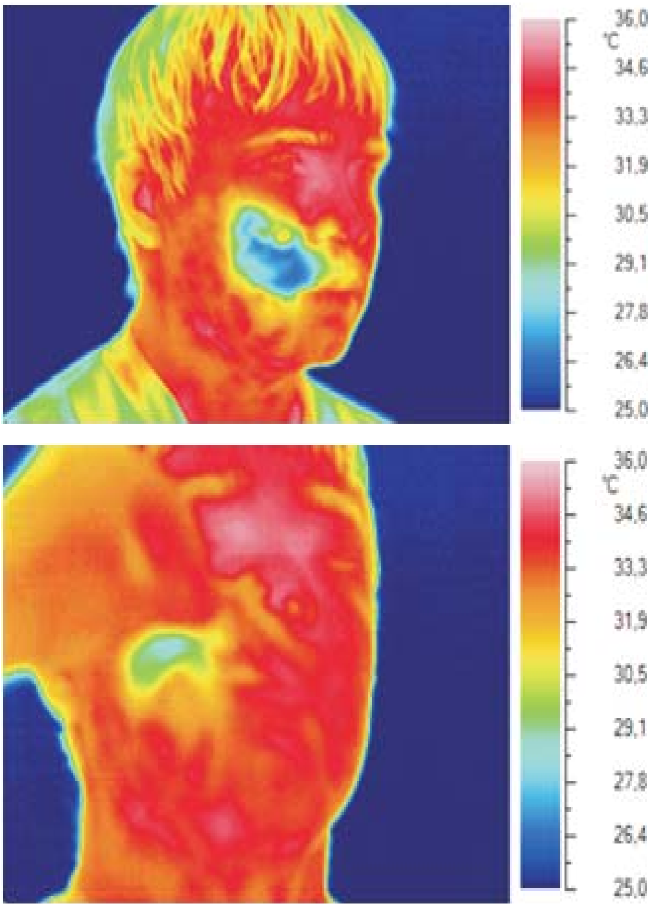

Figure 1
The infrared image of the skin of right side of the face (top) and the inner surface of the cheek and buccal gingiva (bottom) of an adult healthy volunteer (Male, A.N., 26 y.o.) immediately after the application of the ice pack for 10 minutes to his right cheek.

Result

Our results showed that the normal cheek skin temperature in healthy adult volunteers was in the range of +32 - +35°C, and the temperature of soft and hard tissues in the oral cavity was in the range of 34.0 to 36.9 °C.

It is shown that a short application of the ice pack to the cheek skin reduces the temperature of the skin at the site of interaction and forms a zone of local hypothermia that lasts up to 30 minutes after removal of the pack. In 2 minutes after the cooling starts, the temperature in the cheek skin in the zone of cooling pack application drops below 26 °C, and in 3 minutes after ice application, the degree of cooling reaches its maximum values. It is established that the local hypothermia zone has dimensions and shape that represent a cold imprint left by the cooling object, if it was not moved from its place. After that, the temperature in this area of the cheek rises above its initial values, and we observe an area of local hyperthermia, which lasts up to 10 - 30 minutes (Figure 1).

It is shown that the dynamics of the local temperature inside the oral cavity was different. Using an electronic temperature sensor placed in volunteers' oral cavity we found that during the application of the ice pack to the cheek, the temperature inside the oral cavity first did not change for 2 to 3 minutes. After that the temperature of the inner surface of the cheeks it decreased by 0.2-1.0° C and remained the same for about 10 minutes, and after that (2 minutes after removal of the ice pack), the temperature rose above its initial values by 0.2-0.5° C and remained at this level for up to 10 minutes. At the same time the local temperature of the gums and teeth remained virtually unchanged (Fig. 2). In particular, we found out that in 3 minutes after the cooling of the cheek skin had begun, the temperature of the soft tissues in the oral cavity could increase by 0.5-1.5 °C in some people, and it could remain at this level for up to 30 minutes.

Thus, the application of the ice pack to the face skin for a period of 10 minutes immediately causes there an area of local hypo-

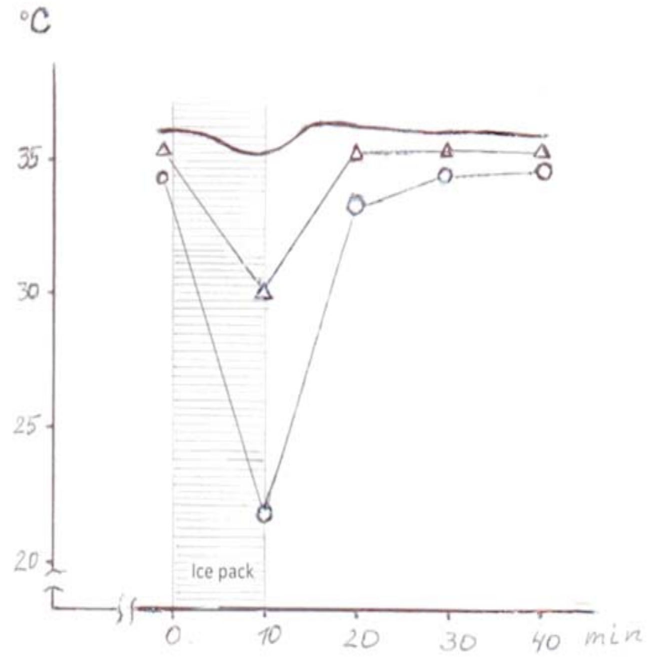

Figure 2
The change in local temperature in the skin of the cheek in adult healthy volunteer under the influence of the application on this cheek ice pack for 10 minutes (Male, A.K., 42 y. o.). Temperature value in the skin (o----?), in the inner surface of the cheek (∇ ----∇) and in buccal gingiva (-----)

thermia, where the temperature decreases by more than 10 °C and remains at this level during the entire period of the ice pack application. After removing the ice pack, local hypothermia persists in some people for another 30 minutes. After that, the temperature in this area increases in all people and an area of local hyperthermia, which lasts for 10 - 30 minutes, is formed. During this period, the changes in the local temperature in the oral cavity are less and have different dynamics. In particular, in some people, the temperature in the oral cavity remains unchanged until the ice pack is removed. In some people, the local temperature of the buccal gingiva in the corresponding face side can decrease within 1°C while the ice pack is being applied. However, after removing the ice pack, the temperature of the cheek inner surface and gums mucosa in all volunteers quickly rises above its initial values, and local hyperthermia, which lasts from 5 to 30 minutes, is formed.

Conclusion

Applying standard instant ice pack on the outer surface of the cheek for 10 minutes reduces the temperature of the skin below 26 °C and in the inner surface of the cheek by an average up to 31º?. The temperature of the buccal gingiva remains virtually unchanged.

References

1.Urakov AL, Ushnurtsev SA, Zamostyanova GB. Influence of hypothermia and antianginal drugs with malonate-like effect on glycolysis and oxidative phosphorylation in the myocardium. Pharmacology and Toxicology, 1983; 1; 51-54.

2. Urakov AL, Pugach VN, Kravchuk AP, Sabsai MI, Baranov AG. Use of heat and cold to regulate blood flow and maintain hemostasis of the internal organs. Pathological Physiology and Experimental Therapy, 1984; 5; 43-46.

3.Urakov AL, Baranov AG, Sutyagin SP, Odiankov EG, Ipatova EN, Kapachinskaya LG, Petlenko VB, Kolodkin DE, Baramba RI. Improve blood flow in organs and prevention of thrombosis with the cold. Bulletin of Experimental Biology and Medicine, 1985; 7; 19 -20.

4.Urakov A, Nasyrov M, Chernova L. How fingers became warm after cooling. Thermology International, 2015; 25 (3); 123.

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ASSESSMENT OF AUTONOMIC RESPONSE IN ALZHEIMER'S DISEASE PATIENTS DURING THE EXECUTION OF MEMORY TASKS: A FUNCTIONAL THERMAL IMAGING STUDY

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Introduction

Alzheimer's disease (AD) is a form of dementia that begins with memory failures that becomes more severe with the progression of the disease. The diagnosis of AD is currently carried out by means of clinical tests, such as the Free and Cued Selective Reminding Test (FCSRT) [1]. It starts with an encoding phase, during which the patient is requested to remember 12 pictures shown in class of four at once. After that, the Immediate Free Recall (IFR) follows. The participant is required to recall all these figures and, if he/she cannot remember independently all the figures, the doctor reminds the semantic fields of the not retrieved pictures. This phase is called Immediate Cued Recall (ICR). This procedure is repeated for three times consecutively and again after a period of 30 minutes (Delayed Free Recall (DFR) and Delayed Cued Recall (DCR)). To separate the IFR and DFR, some filler tests are provided. In this study the Clock Drawing Test (CDT), Digit Span Test (DST)], the Corsi Block Tapping Test (CTT), and Benton Visual Retention Test (BVRT) [2] have been administered. However, the cognitive performances could be influenced by the psychophysiological state of the subject [3], thus it is important to monitor the emotional state through the assessment of peripheral autonomic activity, during the execution of clinical tests [4]. Functional infrared imaging (fIRI), thanks to its contactless features, is a suitable tool for this kind of measurement to preserve the free interaction between doctor and patient. The aim of the present study is to investigate whether the variation of facial temperature parameters during the mnemonic/cognitive tasks is indicative of different autonomic states in early AD with respect to healthy controls (HC).

Figure 1
ROIs position of a representative participant: Corrugator (ROI 1), Upper Nose (ROI 2), Nose Tip (ROI 3),
Right and Left Perioral (ROIs 4 and 5 respectively),
Right and Left Chin (ROIs 6 and 7 respectively)

Methods

Fourteen healthy people (mean age ± SD: 68.4±6.3 years; M/F: 11/3) and sixteen patients (mean age ± SD: 75.5±5.4 years; M/F: 8/8) with a diagnosis of Mild probable Alzheimer's disease, according to the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) participated to the study. The exclusion criteria were moderate-severe cognitive impairment (Minimental test (MMSE) <25/30) vascular dementia, behavioral or psychiatric disorders, hydrocephalus, brain lesions, history of stroke or traumatic brain injury and circulatory diseases that could impact the thermal measurement. The Research Ethics Board of the University of Chieti-Pescara approved this study, conducted according to the Declaration of Helsinki. The facial temperature was recorded during the administration of the tests, by means of a digital thermal infrared camera FLIR SC660 (640 x 480 bolometer FPA, sensitivity/Noise Equivalent Temperature Difference: < 30 mK @ 30°C, FOV: 24° x 18°). The camera was placed at 60 cm from the participant and pointed toward the face of the subject. The sample frequency was 1 Hz. Seven regions of interest (ROI), reported as indicative for the evaluation of autonomic activity [4], were selected: Corrugator, Upper Nose, Nose Tip, Right and Left Perioral, Right and Left Chin (Figure 1). The time courses of the average temperature were extracted from each ROI using a soft-tissue tracking algorithm able to track the ROIs across all the images of the video [5]. For each time series of each ROI, the difference between the mean value of temperature during each test and the mean value of the temperature during its previous baseline was computed. Furthermore, to investigate the balance between the sympathetic and parasympathetic system of the temperature variation, the spectral power in the low frequencies (LF) band (0.03-0.15 Hz) and in the high frequencies (HF) band (0.15-0.35 Hz) of the temperature has been evaluated [6]. Since data resulted not normally distributed (Shapiro Wilk Test was performed), Wilcoxon- Mann-Withney test was used to evaluate group differences between AD and HC. Finally, to better investigate the capability to discriminate the two groups by means of the autonomic response during these tests, a Linear Discriminant Analysis was carried out.

Results

Group differences for the scores of the tests administrated were tested through an independent t-test between HC and AD. The scores of the FCSRT and of the filler tests discriminate the two groups ($p<0.003$), except the DST ($t(29)=0.815$; $p=0.422$) and CTT ($t(29)=1.238$; $p= 0.226$). Group differences for the mean values were assessed during the CTT for all the ROIs ($z<-2.111$; $p<0.035$) and for the Nose Tip during the DST ($z=-2.598$; $p=0.009$). Regarding the LF/HF ratio, group differences were assessed during the CTT for Corrugator, Upper Nose, Nose Tip and Right Chin ($z>2.073$; $p<0.038$) and during the Encoding phase for Upper Nose, Right and Left Perioral and Right and Left Chin ($z>2.684$; $p<0.007$). Since the ROI on the Nose Tip resulted significant for the CTT for all the three parameters investigated, a discriminant analysis using these variables has been carried out. The original cases are classified properly for the 76,7 %. With the cross validation, the percentage of the cases correctly classified is 73,3% (Table 1)

Table 1
Linear Discriminant Analysis for fIRI parameters on the Nose Tip during CTT

		ID	0	1	Tot
Original	Counts	0	11	0	11
		1	2	9	11
	%	0	71,4	28,6	100,0
		1	18,8	81,3	100,0
Cross Validation	Counts	0	10	1	11
		1	2	9	11
	%	0	71,4	28,6	100,0
		1	25,0	75,0	100,0

Discussion

The aim of this study was to assess whether differences in the autonomic system activity during the performance of cognitive/ mnemonic tests exist between AD and HC. The psycho- physiological state of the participants was monitored by means of fIRI. In particular, the variation of the facial temperature and the LF/HF ratio of the thermal time series have been evaluated. The HC group showed a lower variation of temperature for the CTT and DST. A lower skin temperature variation could be due by a superficial vasoconstriction consequent to a sympathetic system activation, which therefore resulted larger in HC than AD patients. This was confirmed by the LF/HF results; in facts, the HC group showed a higher ratio with respect to AD. Many authors have already investigated autonomic disorders in AD patients [7]. Moreover, it is known from literature that AD patients exhibit impaired variations in the thermoregulation [8]. However, the cited studies were carried out during a resting condition, whereas in the present study, the subjects were requested to perform a battery of cognitive tests, thus the results depended mainly on the performance and the possible expectation associated with them. The greater sympathetic activity assessed for the HC during both DST and CTT could have been produced by a stress condition. In fact, verbal learning depends on experimental stress [9]. However, the scores of these tests did not show significant differences between the two groups. In fact, the CTT and DST are selective for the short-term memory deficit, but not very discriminant for AD [2]. The reported results suggest that the performances of the DST and CTT might depend on the psychophysiological state of the participant. LF/HF ratio was significantly higher for the HC with respect to AD also during the encoding phase. So far, deficits in encoding and semantic memory in AD have been investigated and they seem to be related to a lack of attention and a decrease of cognitive effort [10]. In addition, the sympathetic activity during the encoding phase can influence the retrieval [11], therefore monitoring the autonomic system during this process could be of great interest, because it influences the recall, from which the AD diagnosis is carried out in the FCSRT. Furthermore, the possibility to discriminate the two groups by means of the autonomic response during the CTT, considering the Nose Tip, was investigated by means of discriminant analysis. An accuracy of 73,3% was obtained. This result, although preliminary, seemed to suggest that autonomic response in AD patients during the execution of cognitive/mnemonic tests could be highly indicative of the disease.

Conclusion

To the best of our knowledge, this is the first time that the autonomic activity is recorded by means of thermal response in AD patients during the administration of cognitive/mnemonic tests, in completely ecological conditions. The findings suggested that the administration of clinical tests could elicit different autonomic responses in AD patients with respect to HC, but further studies are necessary to better investigate the influence of the psychophysiological state to the performance, hence to the AD diagnosis.

References

1.Lemos R et al. The free and cued selective reminding test: Validation for mild cognitive impairment and Alzheimer's disease. Journal of Neuropsychology 2015, 9(2) 242-257.

2.Pasquier F. Early diagnosis of dementia: neuropsychology. Journal of Neurology 1999; 246(1) 6-15.

3.Eysenck MW et al. Anxiety and cognitive performance: attentional control theory." Emotion 2007 7(2) 336.

4.Cardone D, Merla A. New Frontiers for Applications of Thermal Infrared Imaging Devices: Computational Psychopshysiology in the Neurosciences. Sensors 2017, 17(5), 1042.

5.Manini B et al. "Mom feels what her child feels: thermal signatures of vicarious autonomic response while watching children in a stressful situation." Frontiers in human neuroscience 7 (2013).

6.Malliani A, Lombardi F, Pagani M. Power spectrum analysis of heart rate variability: a tool to explore neural regulatory mechanisms. British Heart Journal 1994; 71(1): 1.

7.Femminella GD et al. Autonomic dysfunction in Alzheimer's disease: tools for assessment and review of the literature." Journal of Alzheimer's Disease 2014, 42(2): 369-377.

8.Diamond PT, Diamond MT. Thermoregulatory behavior in Alzheimer's disease." Journal of the American Geriatrics Society 1991; 39(5) 532-532.

9.Spielberger CD, Smith LH. Anxiety (drive), stress, and serial-position effects in serial-verbal learning." Journal of Experimental Psychology 1966; 72(4): 589.

10.Dick MB, Kean M-L, Sands D. Memory for internally generated words in Alzheimer-type dementia: Breakdown in encoding and semantic memory." Brain and Cognition 1989; 9(1): 88-108.

11.Smeets T et al. True or false? Memory is differentially affected by stress-induced cortisol elevations and sympathetic activity at consolidation and retrieval. Psychoneuroendocrinology 33.10 (2008): 1378-1386.

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DOES INFRARED FUNCTIONAL IMAGING COULD HELP CLINICIANS TO DIAGNOSE LATE-ONSET REACTIONS TO FOOD?

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Introduction

Thermography is a widely accepted and validated method as a non-invasive, non-painful, and non-radiological procedure of physiological occurrences of tissues, organs, and systems. Theses occurrences are expressed through adaptive responses of the Sympathetic and Parasympathetic Nervous Systems, visualized by cameras of infrared radiation on human skin. The authors investigated the possibility of Functional Digital Infrared Thermography (FDIT) to be a complementary method added to investigation procedures of late-onset of food allergies, once the inflammatory processes of the intestines trigger neuro- immunological events, with probable reflexes in the abdominal visceral dermatomes.

Objectives

This preliminary study aimed to observe if the changes in heat distribution in the skin of the abdominal region could be interrelated with the results of food allergy tests of patients randomly collected from a set of hundreds of thermograms, who were confirmed as having Gell & Coombs type II-III late food allergies.

Methods

There were 31 patients (18 adults and 13 children), from 2015 to 2017, ranging from 2 to 72 years old, of whom 22 were females and 9 males. The thermograms were performed prior to the clinical and immunological tests, which confirmed the relationship between clinical symptoms, major complaints, and late-onset of food allergies, due to the favourable result of the adoption of an Elimination Diet. A Flir 650 Sc camera and Software Tools + were used in this study. The air humidity was controlled at the time of capture to be below 50% and the ambient temperature was stable around 24-25 °C. The distance between the camera and the patients ranged from 1.0 to 1,5 meters of distance. All patients were acclimatized for 15 minutes for thermal stabilization. A lateral symmetry and caudal cranial of the order of 0.3 °C, observed in the four quadrants, were used as a criterion of thermographic normality of the abdominal skin of the patients. The observation of the asymmetries was highlighted by a high-resolution rainbow colour palette.

Results

All the patients who were confirmed as having late food allergies presented thermal asymmetries higher than 0.3 °C, which were distributed in the four quadrants of the skin surface of the abdomen. Using thermal symmetry as a criterion of functional physiological normality, the finding of thermal asymmetries in these patients with late food allergies may suggest that inflammatory bowel disease can be reflected in the abdominal skin and visualized in the infrared spectrum.

Conclusion

Visualization of these abdominal thermal asymmetries by clinicians who work with late allergies could be a preliminary thermal signal of the presence of inflammatory processes in the intestines. Further studies will be needed to establish whether such asymmetries are exclusively related to food allergy sufferers and whether they may have a characteristic distribution pattern in these cases.

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Session 8: Rheumatology, rehabilitation and clinical measurement

THERMOGRAPHY AND SONOGRAPHY FOR THE DIFFERENTIATION OF EXTRA- AND INTRA-ARTICULAR CAUSES OF KNEE PAIN

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Introduction

The knee is a complex joint: art. femorotibiale - completed by the medial and lateral meniscus, art. femoropatelare, and art. Tibiofibulare proximale. The intra-articular findings include: lateral and medial menisci lesion, meniscal calcification and ossification, chondral or possibly osteochondral intra-articular lesions, degenerative changes of cartilage, damage to the anterior and posterior cruciate ligament, lig. transversus genus, lig. meniscofemorale anterior, posterior, suprapatellar or medial synovial plica, synovial hypertrophy (pigmented villonodular synovitis), hyperplasia of the suprapatellar and prefemoral fat body (lipoma arborescens). The most common extra-articular findings include ligament findings, findings on muscle insertions around the knee joint, bursae mucosae, cysts and ganglia, popliteal aneurysm, popliteal phlebothrombosis.

The year 2016 was declared an international year of joint pain by the international algesiological associations IASP and EFIC. The scientific community has reached a consensus in the new rational taxonomy of pain management. To achieve the greatest possible success in the treatment of painful musculoskeletal conditions, it is necessary to focus the treatment not only on anatomic structures, but also on the pathophysiology of pain mechanisms: inflammatory nociceptive pain, non-inflammatory nociceptive pain, and neuropathic pain. Structured targeting of treatment is served by imaging methods to detect the affected structure: X-RAY, CT and MRI scans, sonogram imaging. The basic types of pain can be distinguished by the analysis of temperature patterns of affected areas of the locomotor system by means of infrared thermal imaging: inflammatory nociceptive pain, non-inflammatory nociceptive pain, sympathetically maintained pain, sympathetically independent pain. The aim of our study is to refer to the differential - diagnostic possibilities of thermography combined with sonography in the painful knee syndrome. With their help, targeted and tailored treatments can be provided to achieve the greatest possible effect in terms of a new rational taxonomy within pain management.

Methods

Our study is a retrospective study of patients admitted for a treatment of knee pain between January 1, 2015 and January 31, 2016. The study only included patients who had undergone a complex examination - clinical, musculoskeletal, thermographic, sonogram. Ti32 Fluke thermal imager (US production) with a temperature resolution of 0,05°C was used for the thermographic examination. The patient was equilibrated in a darkened room at 25°±1,0°C for 20 minutes. Standard views and body positions specified in the Glamorgan protocol were used. The basic criterion for the evaluation of thermographic images of the examined area is the description of temperature deviations from the normal temperature pattern. In the thermally active focal findings we evaluate the absolute temperature parameters: Tmax., Tmed., and Tmin. We compare them to the temperature parameters in the contralateral symmetrical area (if the temperature pattern is contralaterally normal) or to the surrounding tissue. In the area of interest, we evaluate both hyperthermia and hypothermia. Temperature findings with Tdif. Equal or greater than ± 0.5°C were regarded as positive.

The MyLabGold sonogram produced by the Esaote company by a linear-array transducer with a frequency band ranging from 7.5 to 12 MHz, has been used in our workplace for ultrasound examinations. We focused not only on the area of pain, but we examined the whole knee in each patient, dividing it into four quadrants - frontal, lateral, medial, posterior.

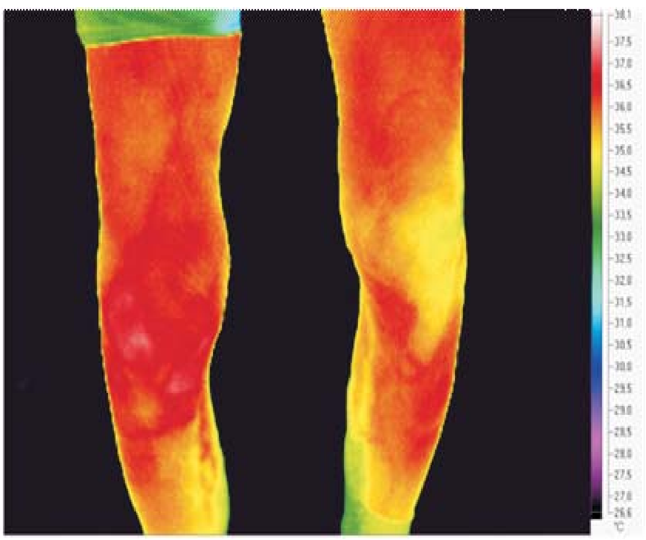

Figure 1a. Intraarticular finding.
High temperature at the right knee in a patient with gonarthrosis IV. grade

Figure 1b. Periarticular osteophytes and calcifications

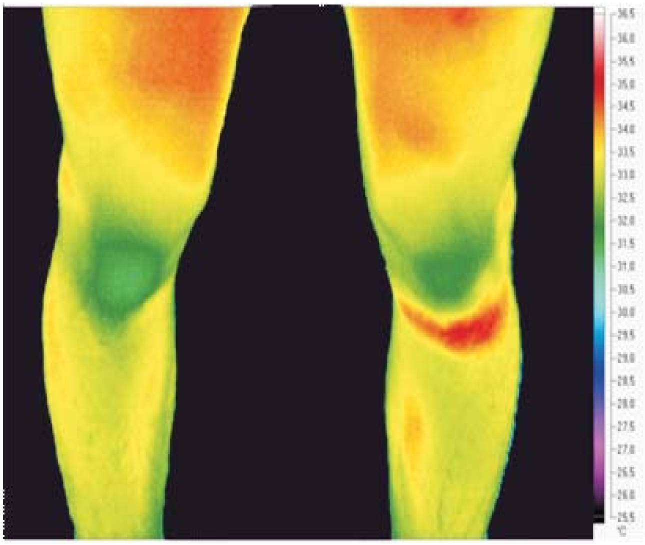

Figure 2a. Extraarticular finding.
High temperature at the right tuberositas tibiae.

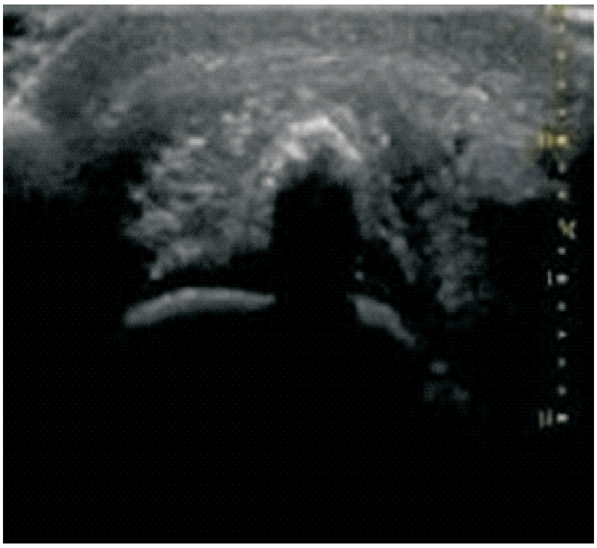

Figure 2b. Release of tibial apophysis

Results

The overall number of patients was 99; of that 61 men and 38 women, aged 7 - 82 years, 43 years on average. The diagnoses causing referral were injuries, strains in 40 patients, osteoarthritis in 33 patients, post-surgery in 15 patients, and miscellaneous disorders such as rheumatoid arthritis, gout, post-infectious arthritis and endocrinological disorders in 11 patients.

Thermography imaging findings: 76 findings of elevated thermal activity - we include them in the category of inflammatory nociceptive pain. 3 findings of decreased thermal activity - we include them in the category of sympathetically maintained pain. 20 findings of unchanged thermal activity - we include them in the category of non-inflammatory nociceptive or sympathetically independent pain. Sonographic findings: cysts, bursae, ganglia, insertions, calcifications: 82, corpora libera, periarticular osteophytes, chondropathies, meniscal lesions: 57.

Figure 1 shows an example of high temperature due to intra- articular pathology, and figure 2 are typical extraarticular findings.

Conclusion

Sonography will, in most cases, help to differentiate extra-articular findings from those of intra-articular origin. To correctly target the treatment, it is necessary to know not only the structural finding, but also the pathophysiological finding based on the characteristics of the various pain mechanisms using thermography: inflammatory nociceptive pain, sympathetically maintained pain, non-inflammatory nociceptive pain and sympathetically independent pain.

References

1.Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJ, et al. Thermographic imaging in sports and exercise medicine: a Delphi study and consensus statement on the measurement of human skin temperature. Journal of Thermal Biology. 2017; 69:155 -62.

2.Gabrhel J, Popracová Z, Tauchmannová H, Ammer K. The Role of Infrared Thermal Imaging and Sonography in caused by extra-articular changes the Assessment of Patients with A Painful Elbow. Thermology International. 2017; 27(2):58-66.

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EXPERIENCES AND OPPORTUNITIES IN THE SETTING UP OF A VASCULAR OPTICS CLINICAL MEASUREMENT AND RESEARCH FACILITY

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Overview

The Newcastle Microvascular Diagnostics Service (MDS) provides a comprehensive array of vascular optics and thermal technologies for assessing micro-circulatory blood flow and function [1]. Thermography is a key modality and offers advantages with versatility and ease of use. The facility also has capability for nailfold capillaroscopy, laser Doppler perfusion / laser speckle contrast imaging, Optical Coherence Tomography (OCT), as well as a range of non-imaging techniques [2]. The test portfolio covers four main areas: connective tissue disease and Raynaud's phenomenon, specialist limb studies (i.e. amputation level, muscle compartment perfusion and venous physiology), neurovascular assessment, and burn wound depth assessment. The MDS greatly benefits from a state-of-the-art temperature and humidity-controlled clinical measurement room, enabling thermal physiology investigations to be performed efficiently and with confidence. Extensive research and development (R&D) is also undertaken, with collaborations across a range of academic, clinical and industrial partners. Vascular optics medical device development is also undertaken. The history and development of the Newcastle Microvascular Diagnostics brand, the types of tests performed, R&D undertaken, clinical management, staff training and resilience, and future service directions will each be summarized in the talk.

References:

1.Allen J. Development of a Clinical Microvascular Imaging and Vascular Optics Facility: The Newcastle Upon Tyne (UK) Experience. January. In: Vardasca R, Mendes JG(eds): Innovative Research in Thermal Imaging for Biology and Medicine. IGI Global, 2017; chapter: 1, pp.1-33

2. Allen J, Howell KJ. Microvascular imaging: Techniques and opportunities for clinical physiological measurements. Physiological Measurement 35(7) R91-141

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Poster Session 1

INFRARED THERMOGRAPHY - A NEW TOOL IN ANIMAL WELFARE ASSESEMENT?

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Introduction

In dairy cattle holdings dehorning procedure is one of the well know methods to eliminate buds in horned breeds. The dehorning process is widely known in livestock practice, usually being painful for the animals, causing pain and stress (Cwynar et al., 2017). United Kingdom farmers indicated that dehorning procedure in calves causes pain of seven on a ten-grade scale of pain, while the highest suffering level is related to finger amputation or caesarean (Huxley and Whay, 2007). The perception of animals during dehorning procedure is not well known, even when stress and pain reactions are presented in cattle behavior or vocalization. While physiological reactions in animals (including acute stress) may be confirmed in blood biochemistry by the invasive way (injection), the infrared thermography (IRT) is non-invasive imaging method, able to detect infrared radiation when significant effect on the autonomic nervous system is observed (Stewart et al., 2008). There is why the aim of our study was to determine the physiological reactions in calves with the use of infrared thermography and hormonal analysis of the cattle blood to confirm the IRT measurements.

Methods

The experiment was carried on 18 clinically healthy Polish Holstein-Friesian calves in the age of 30 days (±3 days). The blood samples were collected to EDTA and Serum Z tubes (Monovette® Sarstedt, Germany) from the jugular vein (vena jugularis interna) and the laboratory analysis was made with the use of ABX VET, Pentra - 400 (Horiba ABX, Canada) and Synergy (Biotek, Winooski, USA). Blood was collected six times form each animal (time: 0, 10 min., 30 min., 60 min., 2h, 24 h) since the dehorning procedure was started. The infrared thermography

was made using VarioCamhr Resolution IR camera (Infra Tec, Germany), resolution 640 × 480 pixels, spectral range 7.5 - 14 ?m and the constant environmental temperature was 21 °C. Eight IRT images were taken with every experimental animal (time: 0, 1 min., 5 min., 10 min., 30 min., 60 min., 2h, 24h). Images were taken 1 m from the animals and with the angle of 90° to the animal's head. The protocol for thermography examination was as previously described by Soroko and Davies-Morel (2016) and Cwynar et al. (2017). The study was made in summer, there is why to minimize the effect of environmental factors, thermography was always performed within an enclosed cowshed (in the calves´ box) to avoid sun radiation and air - draft. The study was made without analgesia effect - similarly to widely known procedures in livestock practice. The experimental procedures were accepted by the Local Ethical Committee (Wroclaw, Poland).

Results

The blood analysis of selected hormones indicated that the cortisol concentration clearly presents the level of stress and pain in dehorning procedure in calves. It was found that the lowest cortisol level was noted just before dehorning in all the experimental animals and the mean value of this element was 3,89 ng/ml (range: 2,84 - 4,61 ng/ml). Half an hour after dehorning the concentration of cortisol statistically increased, reaching 20,56 ng/ml (range: 17,70 - 32,68 ng/ml). One hour after dehorning the statistically significant decrease in cortisol level was observed, but even after 24 hours, the physiological concentra-

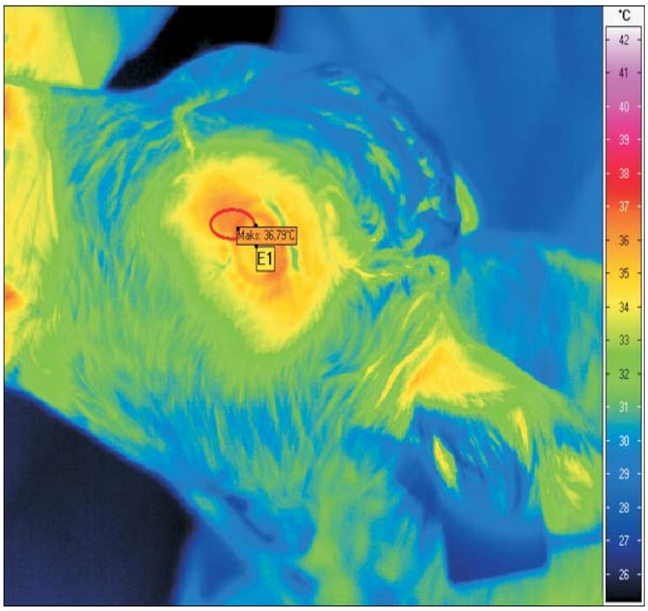

Figure 1
Thermographic image of the left lateral aspect of calve's head before dehorning procedure. The ROI: E1 indicates the area of the eye (the medial posterior palpebral border of the lower eyelid and the lacrimal caruncle) where the maximum eye temperature was 36.8 °C.

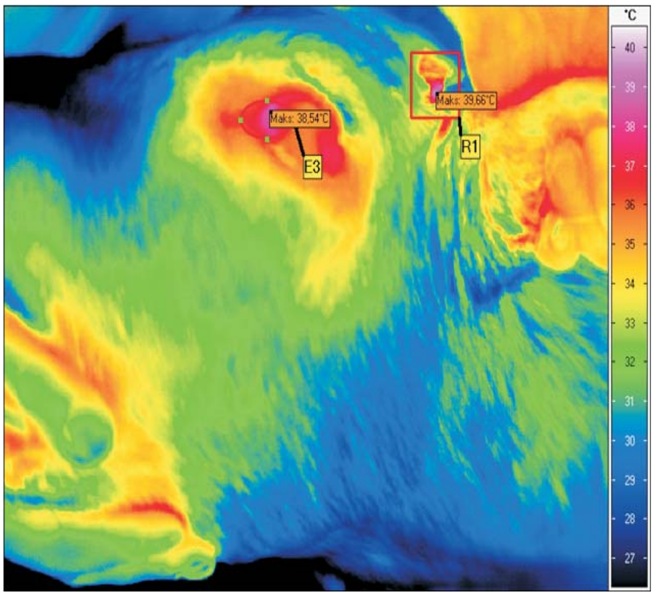

Figure 2
Thermographic image of the left lateral aspect of calve's head 1 min. after dehorning. The ROI: E3 indicates the area of the eye (the medial posterior palpebral border of the lower eyelid and the lacrimal caruncle) where the maximum eye temperature of 38.5 °C is indicated and R1 indicates the area of the horn where maximum temperature is 39.7 °C.

tion of cortisol was not found. The regions of interests (ROIs) were marked on IRT images (Figure 1 and 2). There were statistically significant differences between the temperatures of medial posterior palpebral border of the lower eyelid and the lacrimal caruncle before and after dehorning. The highest results were found in the first hour after the procedure.

Discussion

The dehorning procedure is one of the most typical and routine practice in dairy cattle farms. As it is a painful and stressful method, it stays in opposition to the animal welfare rules. On this basis the correlation between the stress hormones and a practical and non-invasive technique of IRT was made. In our study the strong pain and significant level of stress (high numerical rating in a scale of pain), higher concentrations of cortisol in blood were found, similarly to previous findings (Stewart et al., 2008; Caray et al, 2015; Cwynar et al., 2017). It should be noted that the level of cortisol in the blood is associated with the circadian physiological cycle in animals and the determination of this parameter should be preceded by the knowledge and diurnal analyzes of cortisol fluctuations in the blood. The IRT images were found as a new additional diagnostic tool in animal welfare determination, indicating areas of higher temperatures due to stress and pain which was previously confirmed by McCafferty (2007) and Soroko and Davies-Morel (2016). The ROI areas were chosen as the most universal areas in calves; these parts are not covered be the pelage profile and there is an animal friendly (non-invasive) access to the measurements of the temperature changes in the medial posterior palpebral border of the lower eyelid and the lacrimal caruncle. The eye temperatures due to the uncovered blood vessels may express first symptoms of the stress reactions, manifested with higher internal temperatures, what was presented on Fig. 2 (E3), but it is not correlated with the dehorning region (R1), where the higher temperature was found after the dehorning procedure (hot dehorner burning the buds with simultaneous warming the nearby regions). Moreover, the dehorning areas are important regions to be monitored with the use of IRT to determine a healing process, what is the one of the aims of our future studies.

Conclusion

The animal welfare detectors, especially non-invasive tools, are still not well known. The IRT results in our study were confirmed by the blood analysis what may create conditions for the IRT use in the animal welfare assessment.

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References

Caray D, des Roches ADB, Frouja S, Andanson S, Veissier I. Hot-iron disbudding: stress responses and behavior of 1-and 4-week-old calves receiving anti-inflammatory analgesia without or with sedation using xylazine. Livestock Science 2015, 179: 22 - 28.

Cwynar P, Soroko M, Kupczynski R, Burek A, Pogoda-Sewerniak K. Pain and Stress Reactions in Neurohormonal, Thermographic and Behavioural Studies in Calves. Lecture Notes in Computational Vision and Biomechanics. Springer, VipIMAGE 2017, 27: 722 - 731.

Hall C, Kay R, Yarnell K. Assessing ridden horse behaviour: professional judgement and physiological measures. Journal of Veterinary Behavior: Clinical Applications and Research 2014, 9: 22 - 9.

Huxley JN, Whay HR. Attitudes of UK veterinary surgeons and cattle farmers to pain and the use of analgesics in cattle. Cattle Practice 2007, 15: 189 - 193.

McCafferty DJ. The value of infrared thermography for research on mammals: previous applications and future directions. Mammal Review 2007, 37: 207 - 223.

Mintline EM, Stewart M, Rogers AR, Cox NR, Verkerk GA, Stookey JM, Webster JR, Tucker CB. Play behavior as an indicator of animal welfare: Disbudding in dairy calves. Applied Animal Behaviour Science 2013, 144: 22 - 30.

Mosher RA, Wang C, Allen PS. Comparative effects of castration and dehorning in series or concurrent castration and dehorning procedures on stress responses and production in Holstein calves. Journal of Animal Science 2013, 91: 4133 - 4145.

Soroko M, Davies - Morel MCG. Equine Thermography in Practice, CABI, UK and US. ISBN 13: 9781780647876; Library of Congress 2016, 201693522.

Stock ML, Barth LA, van Engen NK, Millman ST, Gehring R, Wang C, Voris EA, Wulf LW, Labeur L, Hsu WH, Coetzee JF. Impact of carprofen administration on stress and nociception responses of calves to cautery dehorning. Journal of Animal Science 2016, 94: 542 - 555.

Stewart M, Stafford KJ, Dowling SK, Schaefer AL, Webster JR. Eye temperature and heart rate variability of calves disbudded with or without local anaesthetic. Physiological Behaviour 2008, 93: 789 - 797.

Sutherland MA, Ballou MA, Davis BL, Brooks TA. Effect of castration and dehorning singularly or combined on the behavior and physiology of Holstein calves. Journal of Animal Science 2013, 91: 935 - 942.

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ASSESSMENT OF SADDLE FIT IN RACEHORSES USING INFRARED THERMOGRAPHY (IRT)

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Introduction

Infrared thermography (IRT) examination in saddle fit indicates the temperature distribution, and thus the interaction between the saddle and the surface of the back. In a correctly fitted saddle, pressure distribution should be even on both sides of the spine and back (Turner et al. 2004). Locally warmer areas on the back can be detected by IRT with at least 10 times more sensitivity than palpation by the human hand and indicate regions of higher saddle pressure. As a result, pressure points can be easily identified and localized. The aim of the study was to assess the influence of horse, saddle and rider on saddle fit in racehorses by detecting pressure distribution using IRT.

Methods

In the study, 22 saddles used on 65 racing horses ridden by 21 riders were used. Data from horses including gender, breed, age, training intensity and level of fitness were collected. Two types of racing saddle were utilised during the study: 16 were hard with a tree at the seat and back of the saddle, and 6 were soft without a tree. The mass of the saddle was also obtained, along with information about the rider's body mass and riding skills. The protocol for thermography examination was as previously described by Van Hoogmoed et al. (2000) and Soroko et al. (2014). To minimize the effect of environmental factors, thermography was always performed within an enclosed stable (in the horse's box) to avoid sun radiation and air - draft. Thermographic images were captured of the saddle's panels immediately after untacking the horse at each thermographic examination. Thermographic measurement of the saddle was conducted on each horse in duplicate. On each thermographic image of the saddle panels, six regions of interest (ROIs) were marked, with mean temperature calculated within each ROI to indicate pressure distribution (Figure 1). Saddle fit was evaluated for right/left panel pressure, bridging/rocking pressure and front/back pressure according to horse's: gender, breed, age, training intensity, level of conditioning, rider's skills, and load (saddle plus rider mass).

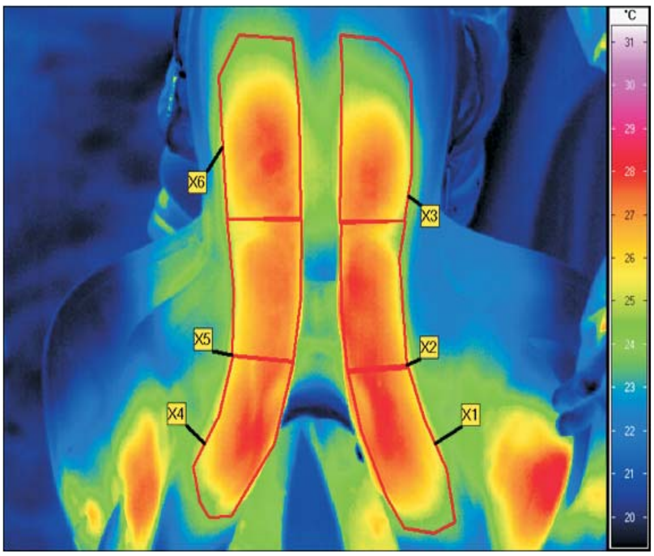

Figure 1.
Thermographic image of saddle panels taken immediately after untacking the horse, with the six regions of interest (ROIs) indicated: right front of the saddle (X1), right middle of the saddle (X2), right back of the saddle (X3), left front of the saddle (X4), left middle of the saddle (X5), left back of the saddle (X6)

Results

There were statistically significant relationships ($P<0.05$) between left/right asymmetry and age, training intensity and load. In front/back pressure there was a statistically significant relationship ($P<0.05$) for load. No statistically significant relationships were observed between bridging/rocking pressure and the rest of the above-mentioned variables.

Discussion

Key findings were that load, training intensity and horse age can influence pressure distribution. It is therefore important that the age of the horse and expected load be considered when determining correct saddle fit. In the current study, IRT was found to be useful as a non-invasive tool in the evaluation of saddle fit in racing horses by measuring surface temperature as an indirect assessment of pressure distribution. When applying IRT, consideration must be made during interpretation of findings into external factors that can influence the final results.

Conclusion

This work will contribute to easily performed and efficient evaluation of saddle fit using IRT. However, more research is required on different saddles, to confirm these initial findings.

References

Soroko M, Dudek K, Howell K, Jodkowska E, Henklewski R. Thermographic evaluation of racehorse performance. Journal of Equine Veterinary Science 2014; 34; 1076-1083.

Turner TA, Waldsmith JK, Wilson JH. How to assess saddle fit in horses. Proceedings American Association of Equine Practitioners 2004; 50; 196-201.

Van Hoogmoed LM, Snyder JR, Allen AK, Waldsmith JD. Use of infrared thermography to detect performance - enhancing techniques in horses. Equine Veterinary Journal 2000; 12; 102-107.
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USE OF THERMAL IMAGING IN ARTISTIC GYMNASTICS

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Introduction

Artistic gymnastics is a sport with a long tradition, and gymnastics today is a part of Physical Education (PE) programs and a high-performance sport activity. During the long development of the sport, we acknowledged huge development of apparatus used in gymnastics. Interaction between an apparatus and human is mostly defined by the physical contact between a gymnast and apparatus. Contacts are mostly performed with feet or palms. While the contact with feet is often not associated with even slight injuries, contact with the palms is often related with skin injuries (e.g. blisters). Therefore, the contact time and friction between apparatus and human skin is of special interest for technicians and is worth being studied. In this sense, Thermal imaging can be used to detect the level of friction, and according to the contact time, presumed consequences can be assessed. While exercising gymnastics on apparatus, gymnasts use magnesium carbonate ($MgCO_3$) to protect their palms. However, high performance gymnasts also use safety guards (leather which covers part of the palm and is fasten around the wrist). As the progress of apparatus was mostly defined by the high-performance athlete's needs, apparatus for PE and for high performance were the same for a long time. In the last few decades PE apparatus started to change slightly, more towards pupil's needs, abilities and characteristics. As new apparatus can be made of different materials with different shape or size, it is important to gain knowledge on how new apparatus influence the human grip. In this study we used thermal imaging to investigate whether the use of $MgCO_3$ affects skin temperature of the palm hands. We also investigated whether safety guards and different apparatus design influences the skin temperature of the palm.

Methods

We did different experiments with the infrared thermal camera Guide TP 8. The infrared thermal camera had a resolution of 384 by 288 pixels, operating wavelength 8 μm to 14 μm, and was calibrated with the special blackbody with an expanded uncertainty of 0.3 °C in the range from 10 °C to 70 °C. The maximum temperature of a palm was measured. The thermal camera was put on a stand at the distance of 2 meters, and skin temperature of the palm was measured before and after exercise In the analysis of thermograms the emissivity of skin was set to 0.97 and the emissivity of the wooden bar was set to 0,9. Different number of subjects participated in the experiments (students and high-class gymnasts, such as competitors at World Championships and Olympic Games), who were all adults and participated with a consent. All results of statistics (pairwise pre-exercise-post exercise t-test) were considered significant when $p<0.05$.

Results

Novices (N=7) performed three one leg circles forward on uneven bars. The palm temperature was measured after each circle before performing the next circle. The palm temperature increased from the first circle to the last one for 1.5 °C, when using $MgCO_3$, and was not raised, if $MgCO_3$ was not used. When subjects (N=18) were able to perform three one leg circles in a row (without stopping after each circle) on uneven bar without assistance, there were no differences when using $MgCO_3$ or not. In both cases the palm temperature increased for 1.5 °C.

When high class gymnasts (N=8) performed five consecutive giant swings backwards on the high bar using safety guards the palm temperature decreased for 0.9 °C. A similar result was found with female high-class gymnasts (N=6), where palm temperature decreased for 1.3 °C. When female high-class gymnasts (N=4) used only tiny bandage in the middle of a palm, the palm temperature increased for 2.3 °C. One female high-class gymnast did not use any protection on the palm and her palm temperature increased for 10.9 °C (Figure 1.).

For testing different apparatus design the new rings were manufactured, one with the straight handle part and one with the bent inward handle part (Figure 2.). The best fit anatomic grip design showed the by our opinion best results and therefore for PE (N=18) ring design with inward handle is best choice in hang during 8 long swings, the palm temperature changed the least (lower for 0.7 °C), while with other designs the palm temperature changed much more (classic rings lower 1.5 °C, and straight rings lower 1.3 °C). The new ring designs were protected as the registered community design (RCD).

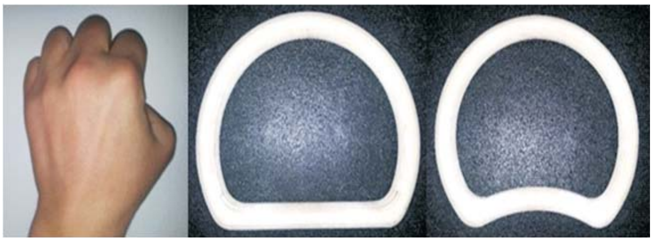

Figure 2 a b c
a - palm grasp
b - rings with the straight part
c - rings with the bent part inward

1 2

Figure 1. High class female gymnast's palms before and after 5 giant circles backward, 1 - without safety guards, 2 with safety guards

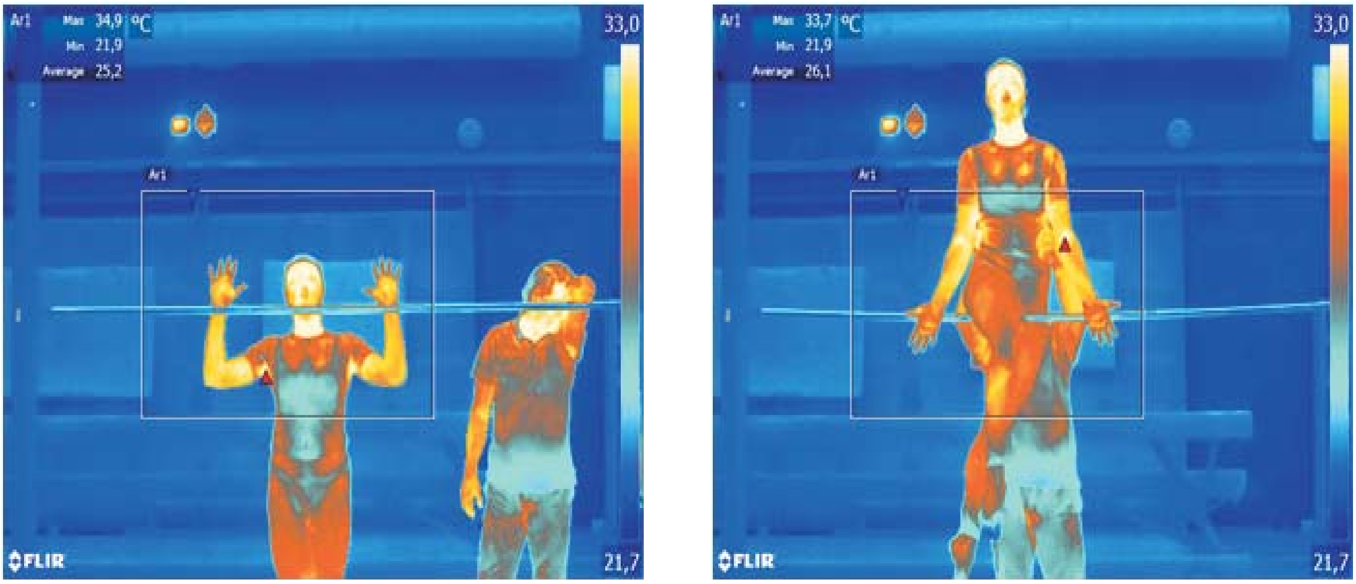

Figure 3. 1 2
Novice female gymnast's palms before (1) and after (2) exercise on a wooden bar

Conclusions

Results indicated that using $MgCO_3$ for novices on wooden bar is not necessary when training small number of repetitions. Both later is not so much important and can make training environment healthier (less dusty). It is important that new apparatus design can also protect palm skin. It should be highlighted that in hang and with the use of safety guards the palm skin temperature decreased. This raises new questions, which require answers to adjust to the actual conditions in training and competition. Thermal imaging technique is useful in gymnastics to analyze the palm grip characteristics.

References

Cuk I. Handgrip in artistic gymnastics. In: Cuk I, (ed.). Lectures and book of abstracts: International Scientific Conference Sport Health & Education "Complementary Approach to Gymnastics", Gdansk University of Physical Education and Sport, 18-20th of June 2015, (Science of Gymnastics Journal; 7(3), 2015). Ljubljana: Faculty of Sport. 2015, p. 128

Pušnik I, Cuk I, Hadžic V. Influence of new anatomic ring design on palm skin temperature. Science of gymnastics journal; 2017; 9 (1), 61-70.

Pušnik I, Cuk I. Thermal imaging of hands during simple gymnastics elements on the wooden bar with and without use of magnesium carbonate. Science of Gymnastics Journal; 2014; 6 (1); 67-72.

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. A large aperture blackbody bath for calibration of thermal imagers. Measurement Science & Technology, 2013; 2 (24), 1-8

Miklavec A, Pušnik I, Batagelj V, Drnovšek J. Calibration of thermal imagers by evaluation of the entire field-of-view. International Journal of Thermophysics, 2011; 32 (11/12), 2600-2609

Grgic G, Pušnik I. Analysis of thermal imagers. International Journal of Thermophysics, 2011; 32 (1/2) 237-247

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PRELIMINARY STUDY ON THE USE OF INFRARED THERMOGRAPHY IN DIAGNOSING CENTRAL VENOUS CATHETER INFECTIONS IN CHILDREN WITH CANCER

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Introduction

Children affected by oncological diseases are often patients fitted with central venous catheters. Catheter infection is a frequent complication, sometimes accompanied by thrombosis. Our objective is to use infrared thermography, an innocuous technique that allows us to record the distribution of body temperature, to discern whether there is infection in patients with central venous catheter, and if so, to undertake a close follow-up of its evolution, after administrating antibiotic therapy and/or removal of the catheter. [1,2].

Material and methods:

A prospective controlled pilot study and follow-up were undertaken on children with oncological diseases, fitted with a central venous catheter, at the Hospital Clínico Universitario in Valencia. The study was approved by the Hospital's Scientific Ethics Committee.

The study includes four children with suspected infection of peripherally inserted central catheter (PICC) (cases) and four children fitted with the same catheter but without infection (controls) matched by sex and age. The characteristics of the patients of each group, such as age, gender, oncological diagnosis and side of PICC are described in table 1. When we suspect catheter infection, we usually take a blood test and blood culture, before initiating antibiotic therapy, and also an ultrasound to assess the existence of thrombosis. All cases received antibiotic therapy and the catheter was removed, sending the catheter tip for bacteriological culture in the majority of cases. Cases were not temporally related to the administration of chemotherapy.

A protocol for taking the thermographic images of children by adapting that which is used for adults [3]. The images were taken in the respective rooms where the patients were admitted or in the doctor's office. The room temperature was 24 ±1ºC and humidity was 50 ±5%. The acclimatization time was 10 minutes. Thermal images were taken with the camera perpendicular to the Region of Interest (ROI), usually from a distance of 1 metre. We tried to take the images in standing or sitting position, perpendicular to the areas of interest (arms, forearms, face), but it was not possible in all cases due to the clinical situation of the children, some had to be taken in bed.

Skin temperature was measured with a IRT camera FLIR E-60, of 320x240 pixels of resolution and thermal sensitivity <0.05ºC. An emissivity factor of 0.98 was used to obtain skin surface temperatures. The mean temperature of each ROI was obtained using the thermography software FLIR Thermacam Researcher Pro 2.10 (Flir Systems Inc., Wilsonville, Oregon, USA). We compared the Thermal Difference (TD): Mean temperature of affected ROI - Mean temperature of contralateral ROI, measured in Celsius degrees at diagnosis and during the follow-up in cases and in controls.

Results

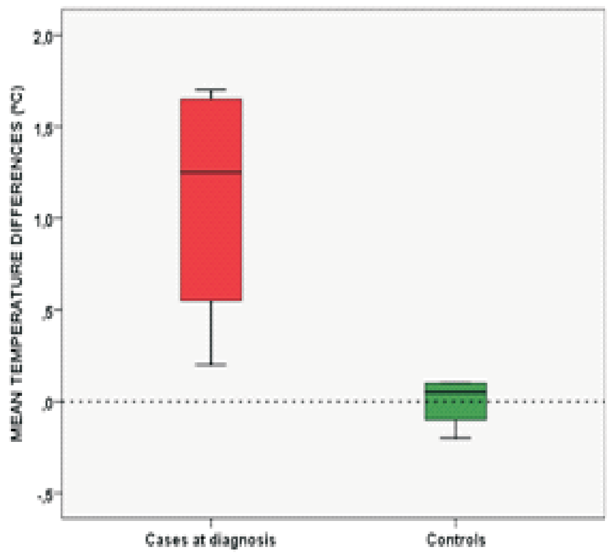
All patients with suspected catheter infection at diagnosis showed local inflammatory signs in the insertion region of the catheter (erythema, local heat, pain, edema, induration), but only one had fever and no significant case-associated increase in acute phase reactants (maximum value of C-reactive protein: 18.5 mg/L). In three cases we took microbiological culture (blood and tip catheter) before starting antibiotic therapy, and the results were negative. Additionally, in all patients we undertook an ultrasound of the catheter region, this technique showing signs of thrombosis in only two patients. In four cases the catheter was removed and intravenous antibiotic therapy was administered (Vancomycin or Teicoplanin), no case being related with recent chemotherapy administration. All cases had a good clinical outcome resolving the signs of local inflammation and thrombosis, although three cases required the insertion of another PICC.

Figure 1 shows the distribution of TD values in cases at diagnosis versus controls. Higher variability and mean in cases can be observed than in controls. The TD mean for cases was 1.1ºC in cases and 0.0ºC in controls, with p= 0.021 (Table 2). TD decreased from 1.1 ºC on diagnosis to 0.05ºC during the follow-up in line with good clinical evolution (Figure 2). Figure 3 provides an example of thermograms for one control and one case at di-

Table 1
Characteristics of cases and controls.

	Cases				Controls			
Patients	1	2	3	4	1	2	3	4
Age (years)	15	6	8	12	15	5	8	11
Gender	F	F	M	M	F	F	M	M
Oncological diagnosis	HL	ALL	BL	ALL	HL	ALL	BL	LL
Side of PICC	Left	Right	Left	Left	Left	Left	Right	Right

F: Female. M: Male. HL: Hodgkin Lymphoma.
ALL: Acute Lymphoblastic Leukemia. LL: Lymphoblastic Lymphoma.
BL: Burkitt Lymphoma



agnosis (B) and during follow-up, and their respective TD values, the latter patient being the same, but at different moments.

Conclusions

Infrared thermography is of special interest in oncological children because it is a harmless, accessible and quick technique, allowing us to reduce the use of ionizing radiation, avoid moving patients from their rooms, as most of them are immuno-suppressed, or having to separate them from their parents or relatives.

All the cases presented in this preliminary study, with suspicion of catheter infection, showed signs of local inflammation, without associated high fever or significant increase of acute phase reactants. Infrared thermography provides added value in this pathology, as it allows us to quantify the clinical signs of inflammation (erythema, edema, local heat ...), which are otherwise only qualitatively detectable in the clinical examination.

In cases with PICC infection, TD values were higher than in controls without infection, allowing us to assess improvement after starting the treatment. Therefore, as the results shown, TD provides a good parameter for quantifying the inflammatory changes produced by pathologies that alter peripheral circulation, given that it shows the asymmetry of temperature between the affected and healthy areas.

Table 2
Table showing differences from mean in cases and controls, their standard deviation and p value.

	Difference from mean	Standard deviation	
Cases	1.1	0.69	P= 0.021
Controls	0.0	0.14	

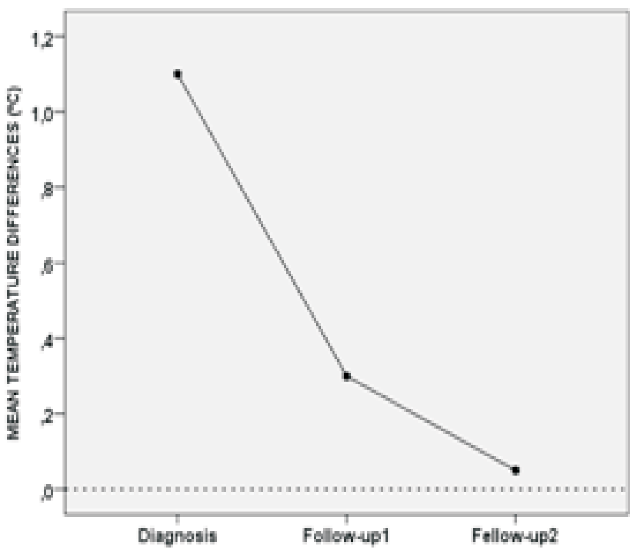


Figure 2:
Line graphic of differences from mean in cases at diagnosis, during the first follow-up (24 hours after treatment) and during the second

Table
Analysis to thermogram and EMG, symptom in schwannoma patients

These preliminary results are satisfactory, but more studies need to be undertaken with an extensive paediatric population to establish reference values. By doing so, it may be possible to anticipate infection, and provide early treatment, so avoiding the removal of the catheter, and, moreover, to observe whether there is any complication after starting antibiotic therapy and/or removal of the catheter

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References

1.Silvah JE et al. Termometria infravermelha da superfície corporal em pacientes com infecção relacionada a cateter venoso central, Einstein 2015; 13(3): 364-9.

2.Oya M, et al. Low-temperature infiltration identified using infrared thermography in patients with subcutanesous edema revealed ultrasonographically: a case report, Drug Discov 2016; Ther. 10 (2), 117e122

3.Sillero-Quintana M et al. Group: Protocol for thermographic assessment in humans, TERMOINEF 2015.

4.Benavent Casanova O et al. Infrared Thermography Versus Conventional Image Techniques in Pediatrics: Cases Study. In: Tavares J., Natal Jorge R. (eds) VipIMAGE 2017. ECCOMAS 2017. Lecture Notes in Computational Vision and Biomechanics, vol 27; Springer, Cham 2018. p. 970-7.

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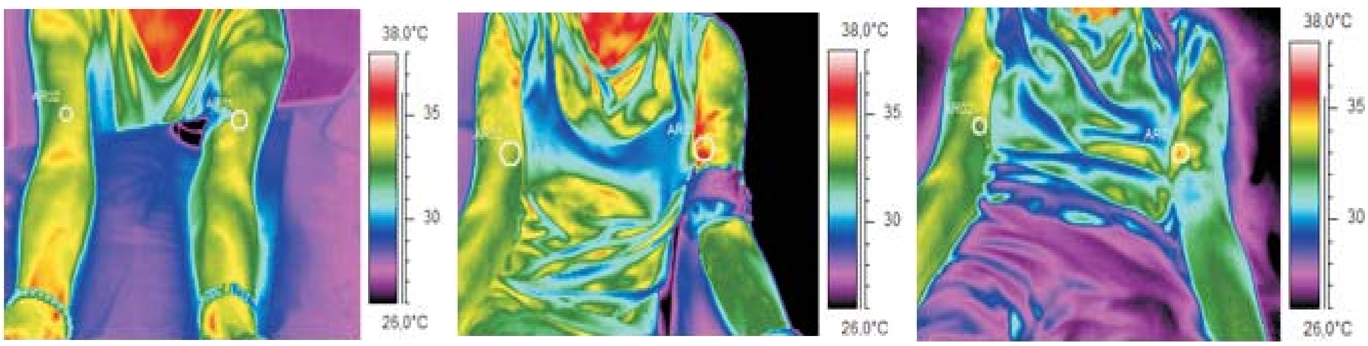

Figure

Figure 3
Infrared thermographic images of one control (A), and one case at diagnosis (B) and during follow-up (C). This example corresponds to number 1 of cases and controls. Thermal Difference (TD) in a control (A), in a case at diagnosis (B) and during the follow-up, 24 h after a treatment (C).

COMPARISON TO ELETROPHYSIOLOGIC FINDING AND IR THEMOGRAPHY FINDING IN IDEM SCHWANNOMA

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Objective

Schwannomas account for 16-30% of all intra spinal tumours. Schwannoma is a neurogenic tumour which originates from nerve sheath. It is a relatively well marginated tumour with little attachment or adhesion to the surrounding tissue [1]. Pain is the most common and usually the first symptom produced by intradural extramedullary spinal tumour. Particularly in schwannomas affecting single nerve roots, the pain has radicular character.

The purpose of the study is to analyses thermographic and electrophysiologic findings of schwannoma of intradural extramedullary spinal cord tumour [2].

Materials and methods

Total 23cases of pathologically proved only intradural extramedullary schwannomas with MR imaging at our hospital were retrospectively reviewed. We excluded patients with severe neuropathic symptoms (eg spinal degenerative disease, herpes disease and so on). The male to female was 11:12 and their ages were ranging in age from 23 to 77 years. All patients admitted and did surgical treatment. We evaluated routinely the EMG, SEP and IR thermogram for relation lesion on admission before surgery. In relation to the tumour lesion, we evaluated thermal pattern by infrared thermography (DITI, DOREX, USA, IRIS-XP Medicore, KOREA) and electrophysiologic findings (EMG, CADWELL, Sierra USA). IR thermogram was performed without light and heat and the room temperature was maintained at 23-25°C (recorded by the thermometer installed the room or the thermometer of the heating system). The patients kept for about 15-20 minutes without garments so that they could accommodate the room temperature. We captured routinely standard regions for imaging. The data was analysed statistically (by Fisher´s exact test on chi-square).

Results

The tumor location was cervical in 6 cases, thoracic in 5 cases, lumbar in 12 cases. The symptom of radiculopathy was about 16 cases and the myelopathy in 7 cases. The thermographic finding of tumour lesion was thermal asymmetry (thermal difference above 0.5 degree) and hypothermic thermatomal lesion. Thermatome means the skin area linked with the autonomic nerves and has some patterns like dermatome. Abnormality or asymmetry can be diagnosed with left and right skin temperature differences. The dermatomal symptom of the radicular pain was consistent with thermatomal lesion (15cases) and electro- physiologic finding (9 cases) (Table), but myelopathic symptom was not typical thermatomal lesion. The dermatomal symptom of the schwannoma in eight cases were consistent with electrophysiologic finding and thermatomal lesion. (P<0.005) (Figure)

Conclusion

The thermography, which is neither an invasive nor uncomfortable method, has the potential for an easy to perform assessment in patients with intradural extramedullary spinal cord schwannoma.

Table
Analysis to thermogram and EMG, symptom in schwannoma patients

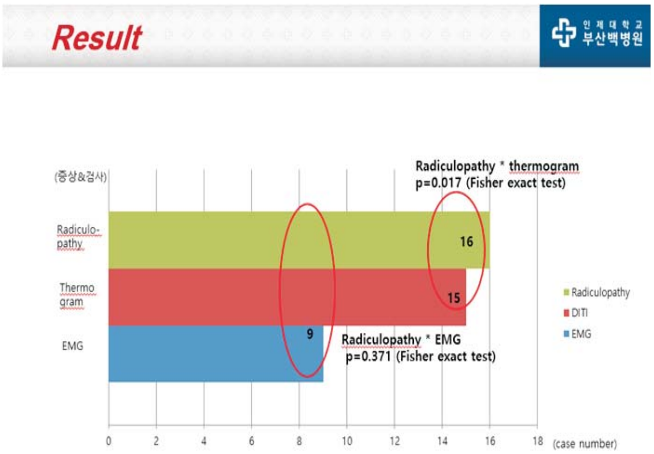

Figure
Comparison thermogram with EMG in symptom of schwannomas

Result

Radiculopathy	Thermogram	EMG	Case No.
O	O	O	8
O	X	O	1
O	O	X	7
O	X	X	0
X	O	O	2
X	X	O	0
X	O	X	1
X	X	X	4

O : Positive
X : Negative

References

1. Parsa AT at al. Spinal cord and intradural-extra-parenchymal spinal tumors: current best care practices and strategies. Journal of Neuro-Oncology 2004; 69: 291-318.

2. Ishigaki T., Sakuma S. Infrared imaging of spinal cord lesion: relation between thermal abnormalities and extent of the lesion. Thermology 1987; 2: 578-583.

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Poster Session 2

REGISTRATION OF THERMAL IMAGES USING GLOBAL AND NON-PARAMETRIC MODELS FOR ANALYSES IN MEDICAL THERMOGRAPHY

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Background

The challenge to evaluate images captured in distinct moments and under varying conditions is inherent in medical imaging. The problem arises from distortions occurring during multiple image acquisitions including varying target orientations, shape changes, sensor positioning and setup, ambient irregularities, and signal noise. In this context, image registration has been extensively used in biomedical applications for superimposing images of the same target or system onto a mutual coordinate framework to facilitate change detection and other image-based analyses. Registration has been a crucial step not only in medical imaging, but also in remote sensing, cartography, and many computer vision problems employing different image modalities. Apart from its popularity, only a small number of thermography-based research and clinical studies benefit from image registration. Specifically, in infrared thermography where pixels represent both qualitative and quantitative features, registration meets increased complexity as it must preserve the original temperature measurements and cause minimal radiometric alterations.

Objective

To explore different image-registration approaches using global and non-parametric mapping models. Then, to select a thermal image registration method to analyze images from a dataset of 349 thermograms from a biomedical application portraying the lower body of human subjects.

Method

A registration process generally uses two images at a time - the source S and target T images. The goal is to compute a spatial transformation between corresponding structures in S and T. If u is a function that represents a geometric deformation or displacement field to be performed on image S towards T, then the transformation function h at pixel p is $h(p) = p + u(p)$. Therefore, (S ? h)(?) = T(?). Here, h is modeled as a mapping function. Both global and non-parametric approaches were investigated. For global models, (a) the similarity transform (rigid), (b) the affine transform (partially rigid plus a translation), and (c) the perspective projection were examined. Under non-parametric mapping, (d) deformable registration was selected. Figure (1) portrays an example grid representing each transformation model. For the scope of this work, images were considered bidimensional. Experiments were conducted on pairs of thermal images from the same subject for assessing the main features and the accuracy of a specific approach.

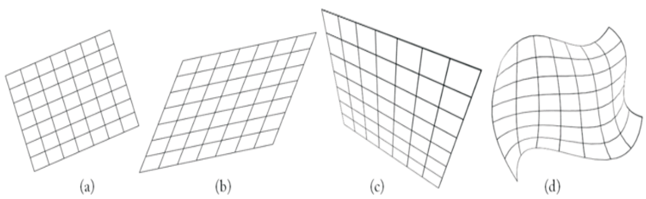

Figure 1
Transformation models: (a) the similarity transform, (b) the affine transform, (c) the perspective projection, and (d) the deformable transform.

Results

All transformation models presented characteristics that are beneficial for thermography-based analysis. Global methods require less computational cost and have simpler implementations. Pairs of matching points on both S and T images can be automatically identified using feature-matching methods (e.g., SIFT) or manually selected, assuring expert supervision. These methods are most viable for the thermal analyses of rigid targets where no intrinsic shape deformations occur throughout the image sampling period. On the other hand, deformable registration is preferred for the advanced analysis of thermograms of living subjects where arbitrary distortions arise due to different positioning, displacement, growth, and changed acquisition parameters, for example. Figure (2) shows several iterations of our registration process of 2 thermograms of the same subject using a non-parametric mapping model.

Discussion

Because of the diversity of imaging conditions and types of degradation on a dataset of thermal images, a universal registration

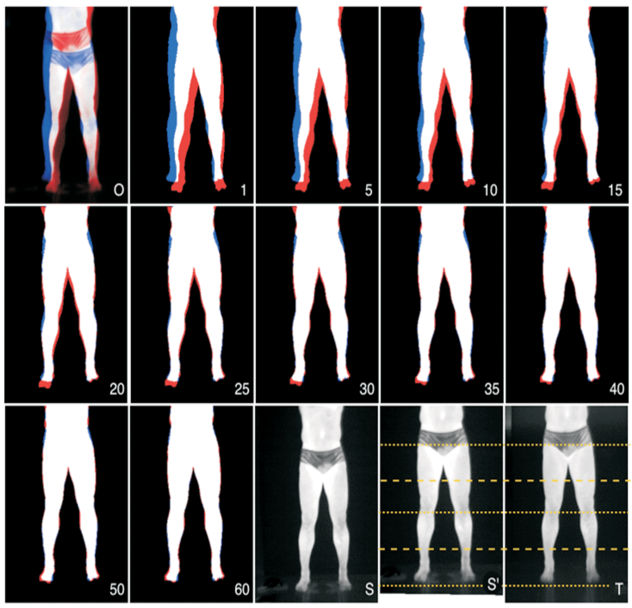

Figure 2
The registration of 2 thermograms of the lower-body of a human subject. Images are misaligned due to varying positioning and camera perspectives. From left to right, top to bottom: (O) Overlay of the original source and target images, respectively portrayed in the red and blue channels; Following, snapshots of body masks in red (source only), blue (target only), and white (intersection) depicting the progression of the registration process in iterations 1, 5, 10, 15, 20, 25, 30, 35, 40, 50, and 60. Finally, the (S) original source, (S') aligned source, and (T) target images are presented side-by-side. Five lines along images S' and T are shown for visualization purposes of the resulting registration.

method is rather impractical. After analyzing the application requirements and the images on the given dataset, our deformable registration approach modeled the transformation between corresponding images with high accuracy under 100 iterations. Computation performance was not in the scope of this investigation and was not measured. Considering the dynamic state of human organisms and the simplification that occurs when representing real targets onto bi-dimensional thermal images, registration cannot guarantee exact overlaying due to the dimensionality (and therefore, the information) loss. Nonetheless, image registration successfully superimposed pairs of thermograms onto a consistent coordinate framework allowing for a precise and progressive thermal evaluation through the extraction of normalized temperature data from overlaying regions of interest, the symmetrical comparison of isotherm regions, and the tracking of hot spots.

References

Zitová B, Flusser J. Image registration methods: a survey. Image and Vision Computing, 2003; volume 21, number 11; p. 977-1000.

Hill DL, Batchelor PG, Holden M, Hawkes DJ. Medical image registration. Physics in Medicine and Biology, 2001; R1-45.

Barcelos EZ, Caminhas WM, Ribeiro E, Pimenta EM, Palhares RM. A combined method for segmentation and registration for an advanced and progressive evaluation of thermal images. Sensors, 2014; 14(11). 21950-21967.

Vardasca R, Gabriel J, Jones CD, Plassmann P, Ring EFJ. A template-based method for normalizing thermal images of the human body. In Proceedings of the 12th International Conference on Quantitative Infrared Thermography, 2014; Bordeaux, France.

Jones CD, Plassmann P, Ring EFJ. Optimised registration of infrared images for comparison of standard views. In Proceedings of the 9th European Congress of Medical Thermology, 2003; Krakow, Poland.

Brown M., Lowe D.G. Automatic Panoramic Image Stitching using Invariant Features. International Journal of Computer Vision, 2007; 74(1) 59-73.

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DYNAMIC INFRARED THERMOGRAPHY AS A TOOL FOR IMAGING ISCHEMIA DURING ABDOMINAL SURGERY

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Introduction

Two important issues during intestinal surgery are: (1) the determination of the location of an ischemic area and, (2) the determination of the precise location for an anastomotic procedure after surgical removal of the damaged tissue. Anastomosis leakage due to poor blood perfusion is one of the worst postoperative complications in intestine surgery. Thus, the determination of the ideal resection line during a surgical procedure is crucial both during and after surgery. An ischemic part of intestine can subjectively be determined by the surgeon macroscopically. This is not always adequate since areas where micro-perfusion are not fully adequate may be overlooked. Indocyanine green (ICG) enhanced fluorescent angiography is often used as an objective imaging method to visualize intestinal blood supply although the ICG technique has some disadvantage such as being an invasive technique with low fluorescence. Infrared thermography (IRT) is a well-established non-contact, non-invasive technique for indirectly visualizing blood perfusion. The main objective of this study was to see whether infrared thermal imaging can be used for the accurate detection of an intestinal area with poor blood perfusion following ligation of its vascular supply and could therefore, also be a suitable method to determine the best location for anastomotic procedures.

Methods

To test this a pilot study comparing ICG angiography and IRT was carried out in a porcine model. The infrared camera used was a Workswell WIC 640. An ischemic state was created in ten parts of the lower intestine by resection of its blood supply. To determine the best location for the anastomotic procedure the resection line was observed macroscopically by the surgeon, as well as by IRT and ICG angiography.

Results

Table 1 shows agreement or disagreement of surgeon determination of the ischemic part of intestine compared to images from ICG and IRT determination. Positive sign (+) indicates agreement of the place of resection lines with surgeons decision on each of the ischemic proximal and distal part of the intestine. The full or partial agreement of surgeon decision was seen 10 times in the case of ICG and 11 times in case of IRT. In most cases both of the image methods indicated that a shorter resected part of the intestine may have been necessary.

Discussion

Based on the data evaluated by an experienced surgical team in this pilot study, it is evident that the dynamic infrared thermal imaging provides an easy to use non-invasive method for determination of the optimal intestinal resection plane and may contribute to the lowering of anastomotic complications after the surgery of intestine.

Acknowledgements

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Table 1
Agreement between the surgeon and the imaging modalities.

No. of ischemic state (proximal/distal)	1	2	3	4	5	6	7	8	9	10	Partial agreement	Full agreement
ICG	+/+	+/+	-/-	-/+	+/-	+/-	+/+	+/-	-/-	-/-	4 times	3 times
IRT	-/+	+/-	+/+	+/-	+/-	+/+	-/-	+/+	+/-	-/-	5 times	3 times

Figure 1
ICG (left) and IRT (right) image of ischemic part of intestine after removal of blood supply. Tweezers show the place for anastomosis based on macroscopical evaluation by surgeon

SKIN TEMPERATURE AND NEUROPATHY: COMPARING DIABETIC FOOT AND FAMILIAL AMYLOID POLYNEUROPATHY

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Introduction

Peripheral neuropathy is a condition affecting nerves at various levels, impairing motor, sensory and autonomic systems. Several pathologies have peripheral neuropathy as a common denominator, such as Diabetic Foot (DF) and Transthyretin Familial Amyloid Polyneuropathy (TTR-FAP), both being disabling and life-threatening conditions. Because of loss of feeling, foot deformities, impaired coordination and impaired functioning of sweat and sebaceous glands, the foot becomes vulnerable to infection and ulcer formation [1-3]. Skin temperature can reflect the presence of clinical abnormalities [4] and, although not a consensual idea [5-7], skin temperature may be altered in neuro- pathic patients. The relevance of skin temperature monitoring in patients with DF has been identified [8] but reports on the assessment of skin temperature in patients with TTR-FAP are yet to be published. Therefore, the aim of this research is to assess and compare skin temperature in the dorsal and plantar aspects of the foot in DF and TTR-FAP patients.

Methods

This cross-sectional study was approved by the local ethical committee all participants read and signed the informed consent form for this study. Adults with established diagnosis of DF and TTR-FAP were recruited and all enrolled subjects were neuropathic, without peripheral artery disease. The sample consisted of twelve patients (7 males, 24 feet), aged 38-76 years, six with DF and 6 with TTR-FAP. DF patients (5 males) had a median age of 64.5 years and median disease duration of 21.5 years. TTR-FAP patients (2 males) had a median age of 45.0 years and a median disease duration of 11.3 years. Data collection was conducted in a room with controlled ambient temperature and relative humidity (21.5 ± 0.7ºC; 45.1 ± 8.7%), in the same period of the day, away from airflow and infrared radiation sources, after a 10-minute acclimation period. Thermal images of the plantar and dorsal aspects of the feet were recorded with an infrared camera (FLIR Systems, E60, Wilsonville, OR, USA) with a sensor array size of 320x240, noise equivalent temperature difference (NETD) of 50mK at 30ºC and ±2% of traceability of the overall reading and with emissivity set to 0.98. The camera was positioned perpendicular to the feet, and from a distance of 1 metre. All images were analysed with FLIR ResearchIR Max software (FLIR Systems, version 4.30.0.69). regions of interest were defined in the plantar and dorsal views of the foot and mean temperature values were extracted and further analysed. Data analysis was performed using Statistical Package for the Social Sciences (SPSS Statistics, IBM, version 25) and STATISTICA (Dell, version 13). The distribution of the study variables was assessed with the Shapiro-Wilk test. Continuous variables were compared with the independent samples Mann-Whitney test and to test for independence of categorical variables, exact tests were used (Monte Carlo approach). The correlation between skin temperature, age and disease duration. Thermal symmetry was computed and the agreement between skin temperature of the right and left foot was analysed using the Bland-Altman approach, assessing agreement and limits of agreement (LOA). Statistical significance was admitted if the $p \leq 0.05$ and confidence intervals (CI) were reported.

Results

The patient groups were similar in respect of BMI, general health status, room temperature and relative humidity during the assessment but significant differences were found for age (p=0.006; 95% CI=[0.005, 0.008]) and disease duration (p=0.020; 95% CI=[0.017, 0.023]). Skin temperature of the plantar and dorsal surfaces of the foot were significantly associated in DF (rho=0.878; $p \leq 0.001$) and TTR-FAP (rho=0.935; $p \leq 0.001$). Skin temperature was significantly higher in the dorsal (p=0.004; 95% CI=[0.002, 0.005]) and plantar surface (p=0.002; 95% CI=[0.001, 0.003]) of DF patients. Thermal symmetry was above 0.5ºC in both groups but no significant differences were found between DF and TTR-FAP patients. The Bland-Altman analyses between the right and left (R - L) foot revealed that the bias between the feet was -0.517ºC (LOA: -3.862, 2.829ºC) in the dorsal surface and -0.600ºC (LOA: -5.042, 3.842ºC in the plantar surface in DF patients. In TTR-FAP the analysis evidenced a smaller bias and narrower LOA, 0.100ºC (LOA: -2.567, 2.767ºC) in the dorsal surface and 0.050ºC (LOA: -2.071, 2.171ºC) in the plantar surface.

Conclusion

The results suggest that, apart from neuropathy, other determinants may influence skin temperature. Skin temperature was significantly higher in DF patients in all regions of interest. Thermal

Table 1.
Skin temperature differences between DF and TTR-FAP patients. Median, interquartile range (IQR) Mann-Whitney (U) test and significance (p) value.

Variables	Group	n	Median	IQR	U	p
Dorsal TSk (ºC)	DF	12	29.65	3.6	23.0	0.004
Dorsal TSk (ºC)	TTR-FAP	12	24.75	4.2		
Plantar TSk (ºC)	DF	12	28.85	4.1	21.5	0.002
Plantar TSk (ºC)	TTR-FAP	12	24.30	4.5		

symmetry was high but not significantly different between the two groups. In TTR-FAP patients the bias between the feet was smaller and the LOA were narrower. Additional research is required in both populations to understand the determinants of skin temperature.

References:

1. Adams D, Suhr OB, Hund E, Obici L, Tournev I, Campistol JM, et al. First European consensus for diagnosis, management, and treatment of transthyretin familial amyloid polyneuropathy. Current opinion in neurology. 2016;29:S14-S26.

2. Frykberg RG, Zgonis T, Armstrong DG, Driver VR, Giurini JM, Kravitz SR, et al. Diabetic foot disorders: a clinical practice guideline (2006 revision). The journal of Foot and Ankle Surgery. 2006; 45(5): S1-S66.

3. Schaper NC, Van Netten JJ, Apelqvist J, Lipsky BA, Bakker K, on behalf of the International Working Group on the Diabetic F. Prevention and management of foot problems in diabetes: a Summary Guidance for Daily Practice 2015, based on the IWGDF Guidance Documents. Diabetes/Metabolism Research and Reviews. 2016;32:7-15.

4. Ring E, Ammer K. Infrared thermal imaging in medicine. Physiological measurement. 2012;33(3):R33.

5. Archer A, Roberts V, Watkins P. Blood flow patterns in painful diabetic neuropathy. Diabetologia. 1984;27(6):563-7.

6. Bagavathiappan S, Philip J, Jayakumar T, Raj B, Rao PNS, Varalakshmi M, et al. Correlation between plantar foot temperature and diabetic neuropathy: a case study by using an infrared thermal imaging technique. Journal of Diabetes Science and Technology. 2010;4(6):1386-92.

7. Boyko EJ, Ahroni JH, Stensel VL. Skin temperature in the neuropathic diabetic foot. Journal of Diabetes and its Complications. 2001;1 5(5):260-4.

8. Ring E. Thermal imaging today and its relevance to diabetes. J Diabetes Sci Technol. 2010;4(4):857-62.

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INFRARED INVESTIGATION OF SKIN TEMPERATURE RANGE FOR THERMO-OPTIC LAYER TO POLYURETHANE FOIL WITH NANOCOMPOSITES

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Introduction

Antibiotic resistance against potentially threatening human health and life bacteria, represents a serious problem for nowadays medicine. This study is a part of a project aimed at a new vascular access security model development. Now, when the era of antibiotics is coming to an end this model could be a solution for protection from bacteria and/or fungal infections potentially leading to sepsis. The model of vascular access security is based on thin biocompatible polyurethane foil (Suprasorb F) with a modified surface which contains biocidal nanocomposites: graphene oxide (GO) and silver nanoparticles (Ag-NPs). The foil with nanocomposites toxicity against bacteria and fungal was tested. Effectiveness of antibacterial and antifungal effect has been demonstrated on the level of: 88,6% for the Escherichia coli (gram-negative bacteria), 79,6% for the Staphylococcus aureus (gram-positive bacteria), 76,5% for the Staphylococcus epidermidis (gram-positive bacteria) and 77,5% for the Candida albicans (pathogenic yeast) [1].

Aim

The aim of the study was to determine the temperature of the human body skin surface around hypothetical coniulated area where medication are directly applied to a blood vessels. The range of the temperature was a basis for the selection of liquid crystal which could be work as thermo-indicator. Additionally, the prototype of polyurethane foil covered by liquid crystal (thermo-optic layer) for early detection of a skin inflammation was made.

Material and method

The methodological flow followed three steps:

1)Infrared studies of a skin temperature

The study was performed in 29 healthy women (average Body Mass Index = 24 to 28), aged 22 to 63 years (average age = 34), who has routine breast control using BRASTER Tester in the diagnostic laboratory. Accordingly, before study every female was asked about agreement for thermal imaging of the skin of the selected body areas. Next, each women was asked to undress from the waist up and remain calm in sitting position during 10 minutes. The ambient room temperature was in the range of 22-24 degrees Celsius and the humidity was 35-45%. For the monitoring of the temperature distribution of the interesting skin area, infrared studies using the Thermovision Camera FLIR T650 SC, calibrated by black body (object temperature range -40°C to 150°C, spectral range 7,5-13,0μm, NETD <20mK, accuracy of +/- 1°C) has been carried out. During the examination subject was in standing position (facing forward to the camera) at the distance of 1 meter from the camera. Thermal imaging was performed according to Glamorgan Protocol [2,3]. Researchers selected three regions of interest (ROI) - Figure 1: ROI 1 - the area of subclavian vessels, ROI 2 - the area of the left elbow and ROI 3 - the area of the right elbow, where the skin temperature was registered by infrared thermography. Tests were analyzed using dedicated thermal analysis software (FLIR ResearchIR Max 4). The software specified the minimum, maximum and average temperature value of the region of interest manually determined by researchers.

2)A design and manufacture the thermo-optic indicator prototype

Prototype of thermo-optic indicator was based on thin polyurethane foil (100μm) covered by appropriately selected liquid crystal layer (30μm) with absorption material (PET, 125μm) underneath and with protective and polyvinyl layer (110μm) on the top and underneath. Each layer was applied by CLCF (Continuous Liquid Crystals Film) method. An adhesive layer was placed on the other side of the foil.

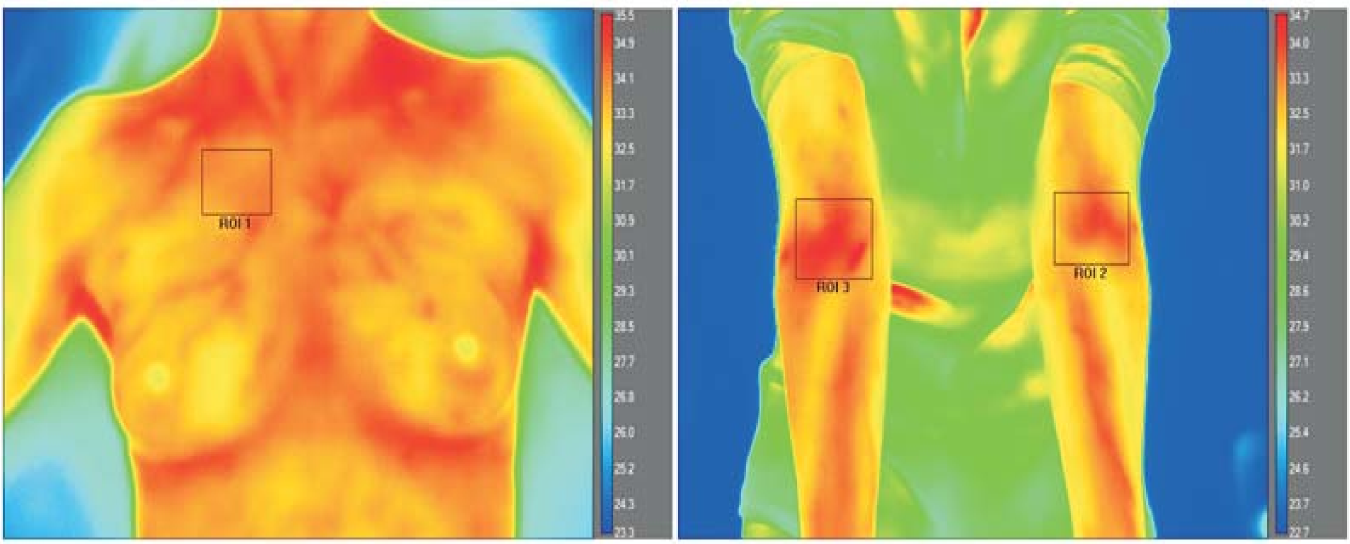

Figure 1
Exemplary result of infrared studies of body surface areas (woman, age of 34) - ROI 1-3 where: ROI 1- the area of subclavian vessels, ROI 2 - the area of left elbow, ROI 3 - the area of right elbow

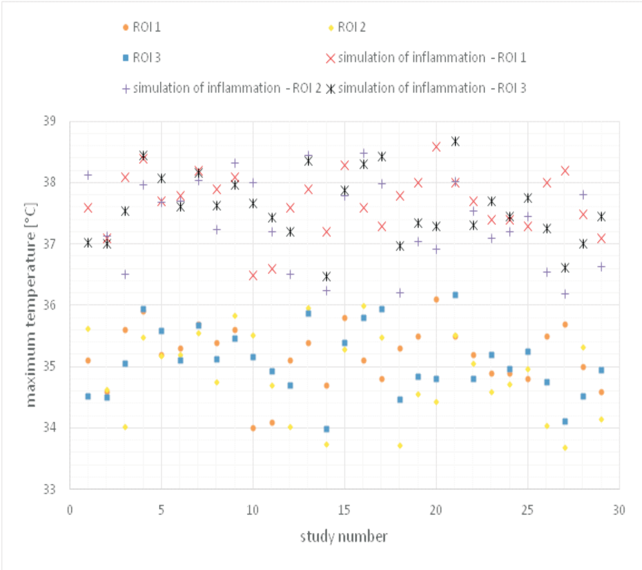

Figure 2
Distribution of maximum temperature values for the surveyed body

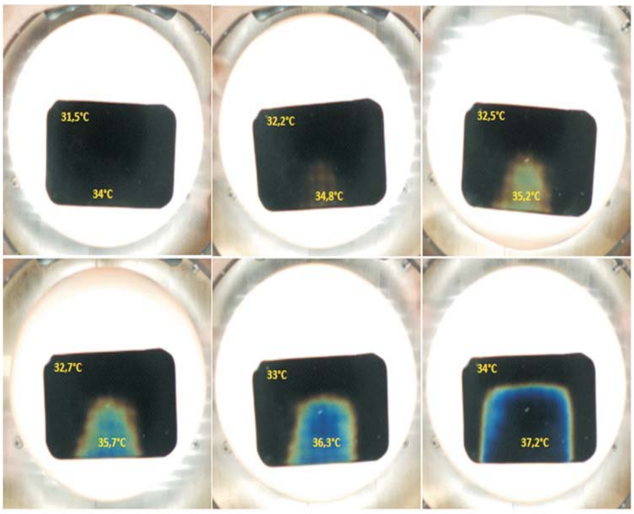

Figure 3
Functional test of the prototype results.

3)Functional tests of the prototype

The functional tests of the prototype based on placing the prototype on the surface of a phantom (heat generator with adjustable heating power) and then recording a value of temperature as well as thermo-indicator response.

Results and Discussion

The infrared studies revealed that elbow of the upper limb temperature is between 31°C to 36,2°C whereas maximum temperatures are in the range of 33,7°C to 36,2°C (Figure 2). Area of subclavian vessels is characterized by temperature between 31,6°C to 36,1°C while the maximum temperatures are in the range of 34°C to 36,1°C (Figure 2). We suppose the maximum temperature is better value as basis of liquid thermal reactivity in our prototype than average temperature. More studies are needed to confirm our findings.

Based on infrared studies results and due to the fact that an inflamed body surface area is characterized by temperature of about 2,5°C higher than a healthy skin areas do, liquid crystal thermal reactivity was proposed in a range of 34,5°C to 36,5°C. Functionality of the prototype has been proved (Figure 3): under 34,5°C the foil is black (no thermo-trace of the foil), in the temperature range from 34,5°C to 36,5°C the foil changed colour from red through yellow and green to blue, above 37,2°C the foil is black again.

Conclusions

Infrared imaging is a useful and effective evaluation method of body surface temperature ranges, required for determination the appropriate thermal reactivity of thermo-indicator - the part of polyurethane foil with nanocomposites. Ensuring proper thermo-indicator functionality requires the design of a stable liquid crystal film with a wider range than 34,5°C to 36,5°C what is the main aim of further research.

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References

1.Jaworski S, Wierzbicki M, Sawosz E, Jung A et al. The graphene oxide-based nanocomposites decorated with silver nanoparticles as an antibacterial agent. Nanoscale Research Letters 2018; in press

2.Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body. Thermology International, 2008, 18(4), 125-129

3.Ring EFJ, Ammer K. The technique of infrared imaging of medicine. Thermology International, 2000,.10(1), 7-14

4.Huh AJ, Kwon YJ. Nanoantibiotics: a new paradigm for treating infectious diseases using nanomaterials in the antibiotics resistant era, Journal of Controlled Release?: Official Journal of the Controlled Release Society, 2011, 156, 128-145.

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DESIGN OF A THERMOGRAPHIC PROTOCOL TO EVALUATE MATTRESSES

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Introduction

An adequate thermal exchange between a human and a mattress during sleeping is an important factor to improve sleep efficiency (Bischof et al. 1993). In addition, this characteristic of a mattress is more important for bedridden patients in a clinical environment with the aim to increase comfort and reduce the likelihood of injuries and pathologies such as ulcers or hypothermia (Robinson and Benton 2002, Aléx et al. 2014).

Thermal manikins are the most used method to assess the thermal characteristics of mattresses (Huang 2008). However, mattress manufacturers need easier, cheaper and quicker methods to measure its characteristics. In this sense, infrared thermography is a not very expensive, non-contact and non-invasive technique which allows to measure surface temperature (Priego Quesada et al. 2017). The aim of the study was therefore to validate a new thermographic protocol to evaluate the back skin temperature and sheet temperature after the use of the different mattresses. The protocol was designed prioritizing an easy methodology in a single day.

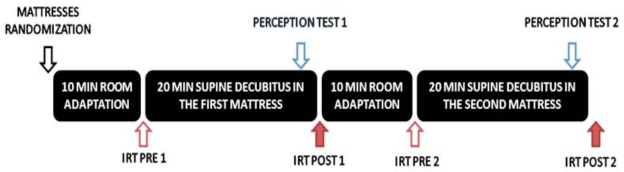

Figure 1
Protocol design.

Methods

To determine the capacity of the new thermographic protocol to evaluate mattresses, 2 mattresses with the same appearance and design were assessed. The difference between both was that one of them had incorporated phase change materials (PCMs) in the outer textile layer of the mattress and in the bottom sheet. The PCMs consisted of microencapsulated paraffin. It was hypothesized that the mattress with PCMs could be very different to the other because PCMs have a high heat storage capacity (Hyun et al. 2014).

10 males and 10 females, (Age: 24 ±3 years; Body mass: 68.4 ±13 Kg; Height: 1.70 ±0.09 m) volunteered to take part in this study. They followed instructions regarding hydration, nutrition, and other aspects to reduce the variability of skin temperature between participants.

The two mattresses were evaluated in the same test. The environmental conditions were 24 ±10ºC and 38 ±7% relative humidity. Protocol is showed in Figure 1. Measurements were made with the trunk of the participants undressed. The order of evaluation of the mattresses was randomized. Firstly, participants remained in a standing position at rest for 10 minutes to adapt their body temperature to the room temperature. Then, participants lay down for 20 minutes in a supine decubitus position without moving on one of the mattresses chosen at random. Thermal comfort and thermal perception using a 150-mm visual analogue scale (VAS) were reported during the last minute of the lying test on each mattress. Skin temperature of the back of the participant and surface temperature of sheet on the mattress was measured before and immediately after lying on each mattress.

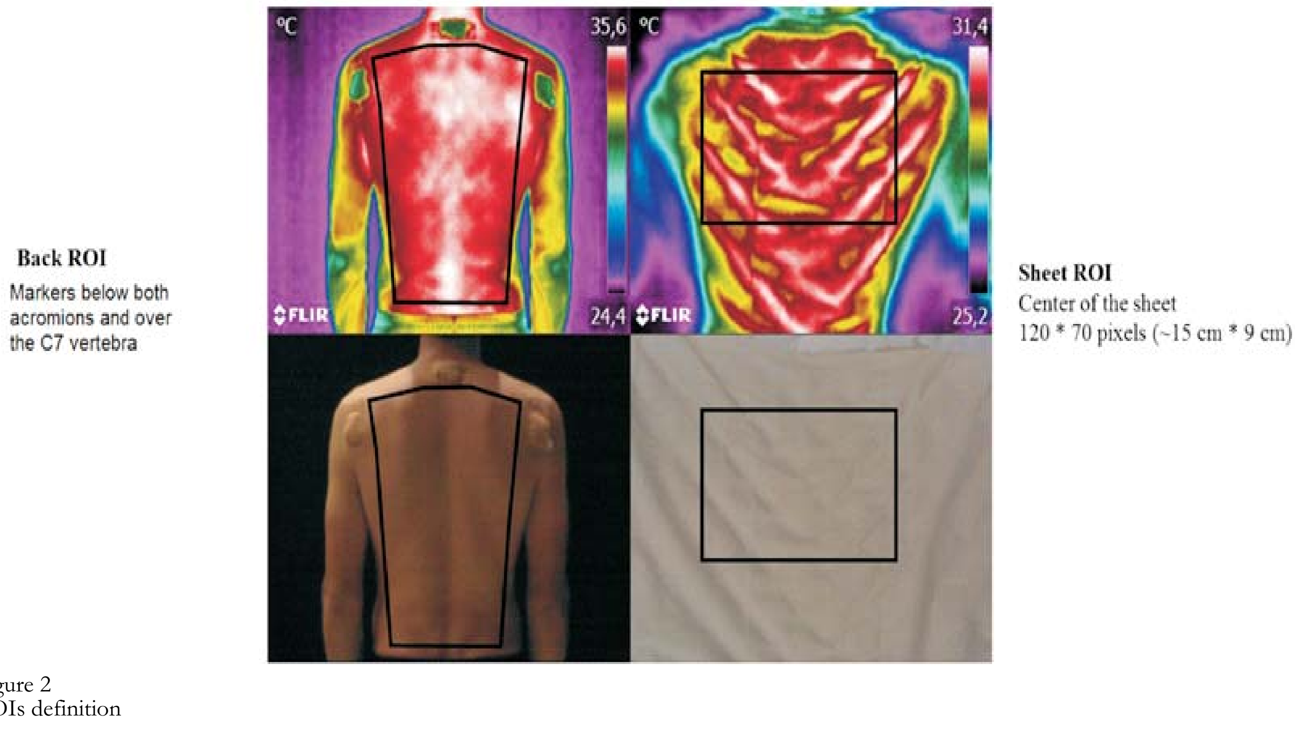

Figure 2
ROIs definition

Table 1
Results of the thermographic analysis.

	Absolute temperatures (ºC)						Temperature variation (ºC		
	Before laying down for 20 min			After laying down for 20 min					
	PCMs mattress	Control mattress	PCMs vs Control p and ES	PCMs mattress	Control mattress	PCMs vs Control P and ES	PCMs mattress	Control mattress	PCMs vs Control p and ES
Human back	33.8 ±0.6	33.5 ±0.8	p>0.05 ES<0.8	34.7 ±0.5	35.0 ±0.6	**P<0.01** ES<0.8	0.8 ±0.6	1.5 ±0.4	**P<0.01 ES=1.4**
Sheet surface	24.5 ±0.9	24.4 ±0.8	p>0.05 ES<0.8	30.7 ±0.9	29.8 ±1.1	**P=0.01 ES=0.9**	6.2 ±0.9	5.3 ±1.3	**P=0.02 ES=0.8**

The camera (FLIR E-60, FLIR, Wilsonville, Oregon, USA; resolution of 320x240 pixels, thermal sensitivity < 0.05°C, and accuracy of ± 2ºC or 2%) was positioned perpendicular to the regions of interest (ROIs). Air temperature relative humidity and reflected temperature (measured according to the standard method ISO 18434-1:2008) were introduced into the camera set up for every thermographic measurement. Definition of the ROIs is showed in Figure 2. Emissivity of 0.98 for the skin (Steketee 1973) in the ROI of the back, and an emissivity of 0.95 for the cotton fabric (Carr et al. 1997) in the ROI of the sheet were used in computing mean temperature of each ROI (Thermacam Researcher Pro 2.10 software, FLIR, Wilsonville, Oregon, USA).

The temperature variations (post-pre) of the back and the sheet were analyzed. Differences between mattresses in the variables of interest were evaluated using repeated measures ANOVAs. Bonferroni test with Cohen effect size (ES) were used for the pairwise comparisons. Statistical significance was established at $p<0.05$ and $ES>0.8$. 95% confidence intervals (95%CI) of the differences between mattresses were provided.

Results and Discussion

Results were independent of gender ($p>0.05$), and in the further treatment of the data the 2 sexes were combined. Because mattresses were randomized, the order did not influence the variables ($p>0.05$).

The PCMs mattress resulted in a lower increase in skin temperature (95%CI 0.3 - 1.0ºC, $p=0.002$ and $ES=1.4$) and a greater increase of the sheet temperature (95%CI 0.2 - 1.6ºC, $p=0.02$ and $ES=0.8$) (Table 1). These findings could be explained by the idea that the heat was transferred better between the skin and the mattress through conduction (by the increase of the thermal gradient between the skin and the sheet), which is in agreement with the greater heat storage ability of PCMs (Hyun et al. 2014). However, it is pure speculation because heat transfer by conduction was not measured in this study.

No differences in thermal comfort and thermal perception were observed between mattresses ($p>0.05$ and $ES<0.8$). This finding may indicate that thermal differences should be greater to be perceived by the participants.

Conclusions

The methodology used was adequate to assess the thermo-regulatory differences of two mattresses, although these differences were not related to the perception of participants. The thermographic protocol presented a number of positive aspects: 1) the use of thermography provides a non-contact, low cost and a fast method to register skin and mattresses temperatures, 2) the protocol can be carried out in one day resulting in a reduction of the skin temperature variability between days, and 3) the protocol is quick because two mattresses can be assessed within a one-hour period per participant.

Acknowledgements

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References

Aléx J, Karlsson S, Saveman B-I. Effect evaluation of a heated ambulance mattress-prototype on body temperatures and thermal comfort--an experimental study.. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2014, 22, 43.

Bischof W, Madsen TL, Clausen J, Madsen PL, WildschiØdtz G. Sleep and the temperature field of the bed. Journal of Thermal Biology 1993, 18(5-6), 393-398.

Carr W.W., Sarma D.S., Johnson M.R., Do B.T., Williamson V.A., Perkins W.A. Infrared Absorption Studies of Fabrics. Textile research journal 1997, 67(10) 725-738.

Huang J. Prediction of air temperature for thermal comfort of people using sleeping bags: a review. International Journal of Biometeorology 2008, 52 (8) 717-723.

Hyun DC, Levinson NS, Jeong U, Xia Y. Emerging applications of phase-change materials (PCMs): teaching an old dog new tricks. Angewandte Chemie (International Ed. in English) 2014, 53 (15) 3780-3795.

Priego Quesada JI, Cibrián Ortiz de Anda RM, Pérez-Soriano P, Salvador Palmer R. Introduction: Historical Perspective of Infrared Thermography and Its Application in Sport Science. In: Application of Infrared Thermography in Sports Science. Cham, Switzerland: Springer International Publishing 2017, 1-23.

Robinson S, Benton G. Warmed blankets: an intervention to promote comfort for elderly hospitalized patients.. Geriatric Nursing (New York, N.Y.) 2002, 23 (6) 320-323.

Steketee J. Spectral emissivity of skin and pericardium.. Physics in medicine and biology 1973, 18 (5), 686.

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CORRELATION BETWEEN ARTERIAL BLOOD GASES INDICES AND THE TEMPERATURE OF FINGERS AFTER CUFF OCCLUSION TEST IN PATIENTS WITH ACUTE BLOOD LOSS

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Introduction

Previous studies showed, that cuff occlusion test (COT) combined with the infrared monitoring of patients' fingers might be useful for evaluating their adaptation to blood loss and forecasts estimation [1,2]. The limitation of the previous study was that COT results were not compared to other indices of blood quality or quantity or hypoxia assessment. This study evaluates the correlation between patients' arterial blood indices and their fingertip temperature change after two-minutes cuff occlusion test (COT).

Methods

The dynamics of fingers temperature was studied with infrared thermal imager before, during and after two-minutes COT in 20 patients with blood loss of II-III class according to Advanced Trauma Life Support system (ATLS) before other action (prior to treatment). The study included patients admitted to the hospital in 3-12 hours after bleeding had begun. The blood sampling for study was carried out from patients' femoral artery 1-2 minutes after COT. Infrared monitoring of hands temperature was performed by the use of ThermoTracer TH9100XX thermal imager (NEC, USA). Ambient temperature of the examination room was 24±25°C, the temperature window of the thermal camera was set to the range of 25 to 36°C. The study plan was previously approved by the Ethics Committee of the Izhevsk State Medical Academy following the principles that are outlined by the World Medical Declaration of Helsinki.

Results

The study group consisted of 20 patients: 12(60 %) men and 8(40%) women, average age of patients was 48.6±8.5. After COT patients were subdivided into 2 groups. Group N 1 included 11 patients with post-occlusion reactive hyperthermia of fingers which was recorded during 5 minutes after COT (patients with normal reaction). Group N 2 included 9 patients without finger hyperthermia during 5 minutes after COT (patients with abnormal reaction). Studies have shown that the gas composition of arterial blood in patients in group N 2 was worse than in patients in group N 1. The arterial blood indices for patients from both groups are presented in Table 1.

Table 1 - Arterial blood indices for patients from both groups.

	Group 1	**Group 2**
	Mean ± standart deviation	
Hemoglobin, g/l*	70.62±16.84	59.40±17.63
pH	7.44±0.07	7.42±0.02
Base Deficit (BD) mmol/l*	-0.25±2.26	-4.66±2.72
pO_2, mmHg	82.83±14.78	81.03±8.80
pCO_2, mmHg*	35.00±6.40	25.66±7.23

*p<0.05

Conclusion

Infrared diagnosis of the post-occlusion reactive hyperthermia of fingers during 5 minutes after cuff occlusion test allows to draw a conclusion about preservation of patient of adaptation reserves of regional blood circulation to blood loss. The absence of post-occlusion reactive hyperthermia in a patient with acute blood loss may indicate a pathological deficit of buffer bases and about excessively low pressure of carbon dioxide in the arterial blood. Additional prospective studies are required to confirm the results.

References

1.Urakov A, Kasatkin A, Urakova N, Ammer K. Infrared thermographic investigation of fingers and palms during and after application of cuff occlusion test in patients with haemorrhagic shock. Thermology international 2014; 24(1); 5-10.

2.Urakov A, Urakova N, Kasatkin A, Dementyev V. Temperature and blood rheology in fingertips as signs of adaptation to acute hypoxia, 2017 J. Phys.: Conf. Ser. 790 012034.

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2018

24th - 29th June 2018
QIRT 2018 in Berlin, Germany

14th Quantitative Infrared Thermography Conference
Venue Conference
H4 Hotel Berlin Alexanderplatz
Karl-Liebknecht-Straße 32
10178 Berlin

Topics

Biomedical Applications I & II (Tu, 26 June), Posters P1-P17

Calibration and Metrology I (Tu, 26 June), Calibration and Metrology II (Th, 28 June), Posters P18-P21

Fluid Dynamics and Energetics I & II (Tu, 26 June), Poster P28

Additive Manufacturing I & II (Tu, 26 June)

Modelling I (Tu, 26 June), Modelling II (We, 27 June), Poster P43

Monitoring and Maintenance (Tu, 26 June), Poster P44-P46

Thermophysics (Tu, 26 June)

NDT I (Tu, 26 June), NDT II & III (Th, 28 June) NDT IV(Fr, 29 June), Poster P47-P56

Civil Engineering & Buildings I (Tu, 26 June). Civil Engineering & Buildings II & III (Fr, 29 June)

Image and Data Processing I & II (We, 27 June), Image and Data Processing III (Fr, 29 June), Poster P29-P35

Industrial Applications I & II (We, 27 June) & Industrial Applications III (Th, 28 June), Poster P37-P41

Induction Thermography I & II (Th, 28 June), Poster P36

Thermomechanics I & II (Th, 28 June)

Vibrothermography (Th, 28 June)

Material Properties (Fr, 29 June)

Photothermal Technique (Fr, 29 June)

PROGRAMME

ORAL PRESENTATIONS - Biomedical Applications I

Towards the Diabetic Foot Ulcers Classification with Infrared Thermal Images
Ricardo Vardasca, Lucia Vaz, Carolina Magalhaes, Adérito Seixas, Joaquim Mendes (Portugal)

TSR method for burns investigation approach
Mariusz Kaczmarek (Poland)

Cryotherapy effects measured by infrared thermography in elderly people with rheumatoid arthritis
Vjeran Svaic, Nikolino Zura (Croatia)

Evaluation of patch tests results - development of technique based on infrared thermography
Barbara Tomaka, Mariusz Szwedo, Jan Targosz (Poland)

Biomedical Applications II

Simulation of skin properties by a low pass filter for thermal waves: application to thermography-based real-time blood flow imaging
Andrey Sagaidachnyi, Andrey Fomin, Dmitry Usanov, Anatoly Skripal (Russia)

Classifying Skin Neoplasms with Infrared Thermal Images
Ricardo Vardasca, Carolina Magalhaes, Joaquim Mendes (Portugal)

Measurement by infrared thermography of skin temperature variations in mice undergoing a surgery event
Veronica Redaelli, Alice Bosi, Gerardo Marsella, Laura Calvillo, Giuliano Grignaschi, Nicola Ludwig, Fabio Luzi (Italy)

Biomedical Applications Posters P1 - P17

P1 Demonstration of the evolution of the mechanical properties of orthodontic archewires by stimulated infrared thermography
Nafez Chahine, Kamel Mouhoubi, Jean-Luc Bodnar, Pierre Millet, Steve Harakeh (France/ Saudi Arabia)

P2 The analysis of thermoregulatory processes in girls and boys in thermal imaging tests
Agnieszka Debiec-Bak, Tomasz Kuligowski, Anna Skrzek (Poland)

P3 How Infrared Thermography Helps Women Deliver a Healthy Child
Albina Gadelshina (Russia)

P4 Thermal profile of broilers infected by Eimeria tenella
Ivana Knížková, Petr Kunc, Iva Langrová, Jaroslav Vadlejch, Ivana Jankovská (Czech Republic)

P5 Teat traumatization in conventional and automatic milking system
Petr Kunc, Ivana Knížková, Jana Hanusová (Czech Republic/Slovakia)

P6 Thermographic analysis and numerical modeling of time-dependent skin temperature during whole-body cryotherapy (WBC)
Herve Pron, Anthony Marreiro, Francois Boyer, Fabien Beaumont, Philippe Estocq, Redha Taiar, Guillaume Polidori (France)

P7 Development of a software algorithm working with infrared images and useful for the early detection of mastitis in dairy cows
Mauro Zaninelli, Veronica Redaelli, Fabio Luzi, Valerio Bronzo, Vittorio Dell'Orto, Donata Cattaneo, Giovanni Savoini (Italy)

P9 Thermomechanical analysis of the surface vascular system - Application to the diabetic foot
Vincent Serantoni, Franck Jourdan, Hervé Louche, Ariane Sultan (France)

P10 Application of passive infrared thermography for DIEP flap breast reconstruction
Gunther Steenackers, Jeroen Peeters, Paul Parizel, Wiebren Tjalma (Belgium)

P11 Infrared thermography monitoring of the face skin temperature as indicator of the cognitive state of a person
Anna Stoynova (Bulgaria)

P12 Review of Inventions that Formed the Basis of the Original Method of Infrared Venography
Aleksandr Urakov, Natalia Urakova, Alexey Reshetnikov, Maxim Kopylov (Russia)

P13 Infrared Imaging Device for Measuring Living Objects in Total Darkness
Aleksandr Urakov, Anton Kasatkin, Olga Shikhova, Vyacheslav Dement'ev (Russia)

P14 Basis of the Original Method of Infrared Diagnosis Signs of Patient's Life in Critical Conditions
Natalia Urakova (Russia)

P15 Dynamic Infrared Mapping of Human Skin
Mikhail Volovik, Sofia Polevaia (Russia)

P16 Dynamic Infrared Mapping of Exposed Human Cortex During Removal of Brain Tumors
Mikhail Volovik, Sofia Polevaia, Anatoly Sheludyakov, Igor Medyanik (Russia)

P17 Thermography-based remote detection of psycho-emotional states
Irina Znamenskaya, Ekaterina Koroteeva Koroteeva, Alexander Chernorizov (Russia)

Contact:

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QIRT Conferences http://qirt.gel.ilaval.ca
QIRT 2018: www.qirt2018.de

European Association of Thermology

Short Course on Medical Thermography

Wednesday 4^{th} July 2018, National Physical Laboratory, Teddington, UK

Following on from successful courses in Porto and Madrid, the next EAT Short Course on Medical Thermography will take place immediately prior to the EAT 2018 Congress at the National Physical Laboratory. The course aims to deliver a thorough introduction over one full teaching day to basic thermal physiology and the principles of infrared thermography for human body surface temperature measurement. It will be taught by an experienced faculty of EAT clinicians, biomedical researchers and imaging scientists, along with metrology experts from NPL. Aspects of reliable thermogram capture will be demonstrated in a laboratory session, and students will have the opportunity to practice thermal image analysis in a supervised "hands-on" session.

Syllabus

- Physical principles of heat transfer
- Principles of thermal physiology/skin blood perfusion
- Standardisation of thermal imaging, recording and analysis
- Quality assurance for thermal imaging systems
- Producing a thermographic report
- Provocation tests
- Image analysis
- Hands-on supervised practice
- Educational resources

Registration

The course fee (inclusive of lunch and coffee breaks) is €200

Register online from 17^{th} August 2017 at www.eurothermology.org/congress2018/course

Questions? Contact Dr. Kevin Howell at k.howell@ucl.ac.uk

LONDON 2018

XIV EAT CONGRESS 4^{th} – 7^{th} July 2018, NPL.

XIV European Association of Thermology Congress

"Thermology in Medicine: Clinical Thermometry and Thermal Imaging"

4th – 7th July 2018

National Physical Laboratory, Teddington, London

United Kingdom

LONDON 2018

XIV E.A.T. Congress, 4-7 July

Co-sponsored by:

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The 2018 AAT Annual Scientific Session Will Be Held October 13th and 14th

AAT welcomes you to our 2018 Medical Thermal Imaging Scientific Session in beautiful Greenville, South Carolina! The 2018 AAT Annual Scientific Session will be held on October 13th and 14th.

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the South Carolina Medical Association and the American Academy of Thermology. The South Carolina Medical Association is accredited by the ACCME to provide continuing medical education for physicians.

The South Carolina Medical Association designates this "enduring material" for a maximum of 6.5 AMA PRA Category 1 Credit(s)TM. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

A Pre-Meeting Physician Thermography Interpretation Course will occur on October 12th.

Annual Meeting proceedings and the Physicians Member Certification Course will be held on the Bon Secours St. Francis Hospital campus at the Bernadine Center.

Conference Schedule

Day 1

8:30**Pre-Meeting Physician Member Certification Course: Friday, October 12th, 2018**.

Day 2

General Sessions: Saturday, October 13th, 2018

8:00 Registration

8:30 Welcoming Remarks by Jeff Lefko, MHA AAT Exec. Director, Greenville, SC

8:45 **Keynote Address**: Past President Lecture on Medical Thermology by Phillip Getson, DO AAT Past President, Marlton, NJ

9:30 Diabetic Neuropathy Assessed by Medical Thermography by Luciane Balbinot, MD, PhD Porto Alegre, Brazil

10:15 Panel Discussion

10:30 Break

10:50 AAT Professional Development: Revised AAT Neuromusculoskeletal Guidelines and Revised AAT Breast Guidelines by Robert Schwartz, MD AAT COB, Greenville, SC

11:20Healthcare Policy on the Use of Medical Thermology by Jeff Lefko, MHA AAT Exec. Director, Greenville, SC

11:40 Camera Resolution and Microbolometer Sensitivity by Gaye Walden, CHC AAT Member, Charlotte, NC

12:00 Lunch (provided)

13:00 **Clinicians Corner 1: Thermology Validated: AAT Atlas of Abnormals Case Presentations**

13:00 Neuromusculoskeletal Cases by Tashof Bernton, MD AAT Board, Denver, CO

13:20 Neuromusculoskeletal Cases by George Schakaraschwili, MD AAT Board, Denver, CO

13:40 Neuromusculoskeletal Cases by Matthew Terzella, MD AAT Member, Greenville, SC

14:00 Neuromusculoskeletal Cases by Tracy Turner, DVM President, AAT, Elk River, MN

14:20 Neuromusculoskeletal Cases by Ronald Riegel, DVM AAT Member, Marysville, OH

14:40 Break

15:00 **Clinicians Corner 2: Thermology Validated: AAT Atlas of Abnormals Case Presentations**

15:00 Breast Cases by Jan Crawford, RN, BSN AAT Board, Scaly Mt, NC

15:20 Breast Cases by Anthony Piana, DC AAT Member, Burlington, CT

15:40 Breast Cases by Alexander Sepper, MD, PhD AAT Member, Forest Hills, NY

16:00 Oral/Systemic & Other Cases by Alex Mustovoy, ND AAT Member, Thornhill, ON

16:20 Oral/Systemic & Other Cases by James Campbell, MD AAT Board, Clemmons, NC

16:40 Oral/Systemic & Other Cases by Bryan O'Young, MD AAT Past President, Danville, PA

17:00 **Annual Scientific Session Wrap Up and Remarks**

17:30 pm Session Ends

8:30 pm Meet and Mingle Reception with the Leadership at the Crowne Plaza Hotel

Day 3
Committee Meetings: Sunday October 14, 2018

07:30 Shuttle from Crowne Plaza Hotel

8:00 SPECIAL MORNING THERMOGRAPHERS WORKSHOP: Ambassadors to Thermography: a Guide to Help You Find A Physician Audience and Interpreter

9:30 Open General Session (for all attendees)

10:30 General Session Ends

10:30 Shuttle returns to Crowne Plaza Hotel

10:45 Board of Directors Meeting (Board Members Only)