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Historical “maps” of human skin temperature

23rd Conference of the Polish Association of Thermology
Extended Abstracts including

Reference standard temperature data of normal Korean extremities

Fever screening IR camera equipped with body temperature data

Inter-Rater and Intra-Rater Repeatability of the Placement of Regions of Interest Based in Anatomical Landmarks

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Organ of the UK Thermography Association (Thermology Group)

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Original article

23rd Conference of the Polish Association of Thermology

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Historical “maps” of human skin temperature

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SUMMARY

This article is a short overview on the history of clinical thermometry with a focus on measuring skin temperature. The physics of thermoelectricity, detected by Seebeck in 1821, laid the foundation for the development of thermoscopes, thermo-multipliers and finally bolometric radiometers.Skin temperature was investigated in various subjects and under various individual and ambient conditions. Examples of data on skin temperature behaviour collected by John Davy, M.S. Pembrey, F.G. Benedict, G.N. Stewart, L.B. Aldrich and R. Cobet are presented. Most problems and limitations of infrared based temperature measurements were already recognized in observations performed between 1880 and 1926.

KEY WORDS: skin temperature, historical temperature measurements, bolometer, thermopile. Differential thermometer

HISTORISCHE ”LANDKARTEN” DER MENSCHLICHEN HAUTTEMPERATUR

Dieser Artikel ist ein kurzer Überblick über die Geschichte der klinischen Thermometrie mit einem Schwerpunkt auf der Messung der Hauttemperatur. Die 1821 von Seebeck entdeckte Thermo-Elektrizität legte den Grundstein für die Entwicklung von Thermoskopen, Thermo-Multiplikatoren und schließlich für bolometrische Radiometer. Die Hauttemperatur wurde bei verschiedenen Personen und unter verschiedenen individuellen und Umgebungsbedingungen untersucht Es werden Daten über das Temperaturverhalten der Haut vorgestellt, die von John Davy, M.S. Pembrey, F.G. Benedict, G.N. Stewart, L.B. Aldrich und R. Cobet gesammelt wurden.

SCHLÜSSELWÖRTER: Hauttemperatur, historische Temperaturmessungen, Bolometer, Thermosäule, Differentialthermometer

Thermology international 2019, 29(2) 53-58

Introducton

In 1928, an article appeared in the German journal "Klinische Wochenschrift" entitled "300 years of clinical thermometry" [1]. This paper was the condensed version of a rather comprehensive monograph on the history of medical thermometry [2]. The author Erich Ebstein, a specialist in internal medicine and medical director of a geriatric care hospital in Leipzig, named Santorio as the first physician who used a thermometer at the bedside examination of patients. The principle of his thermoscope was already described by the antique philosopher Philon of Byzantium and was later improved by Heron of Alexandria [2,3]. Ebstein reports carefully the modifications of the Heron instrument performed in the first half of the 17th century. Santorio´s thermoscope was an open glass tube with a bulb on the upper end which was warmed by holding it in the hand of the patients, by contact with the chest or after placing the bulb into the mouth by breathing against it. The lower end of the tube was set into a water bath and the heated air made space for the water column which crudely indicated the temperature level. Like Hoppe, a German historian of physical science [3], Epstein raised a number of arguments that Galileo was not the inventor of the thermoscope. The debate, who invented the thermometer, is still continuing [4].

In the second half of the 17th century, closed thermometer tubes filled with mercury or alcohol, became available, often produced in Florence. The Prussian engineer and optician Gabriel Daniel Fahrenheit (1686-1736), the French scientist R. A. F. Seigneur de Reaumur (1683-1757) and Swedish physician Anders Celsius (1701-1744) made important contributions to temperature scales. The Scottish physician George Martine (1702-1741) was the first who compared the temperature measurements obtained with differently scaled thermometers by correlating two points on each of 14 different thermometers with two points on the Fahrenheit scale [2,5].

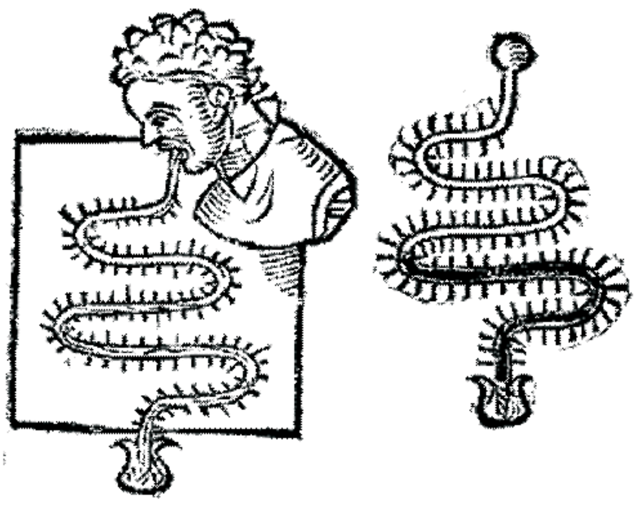
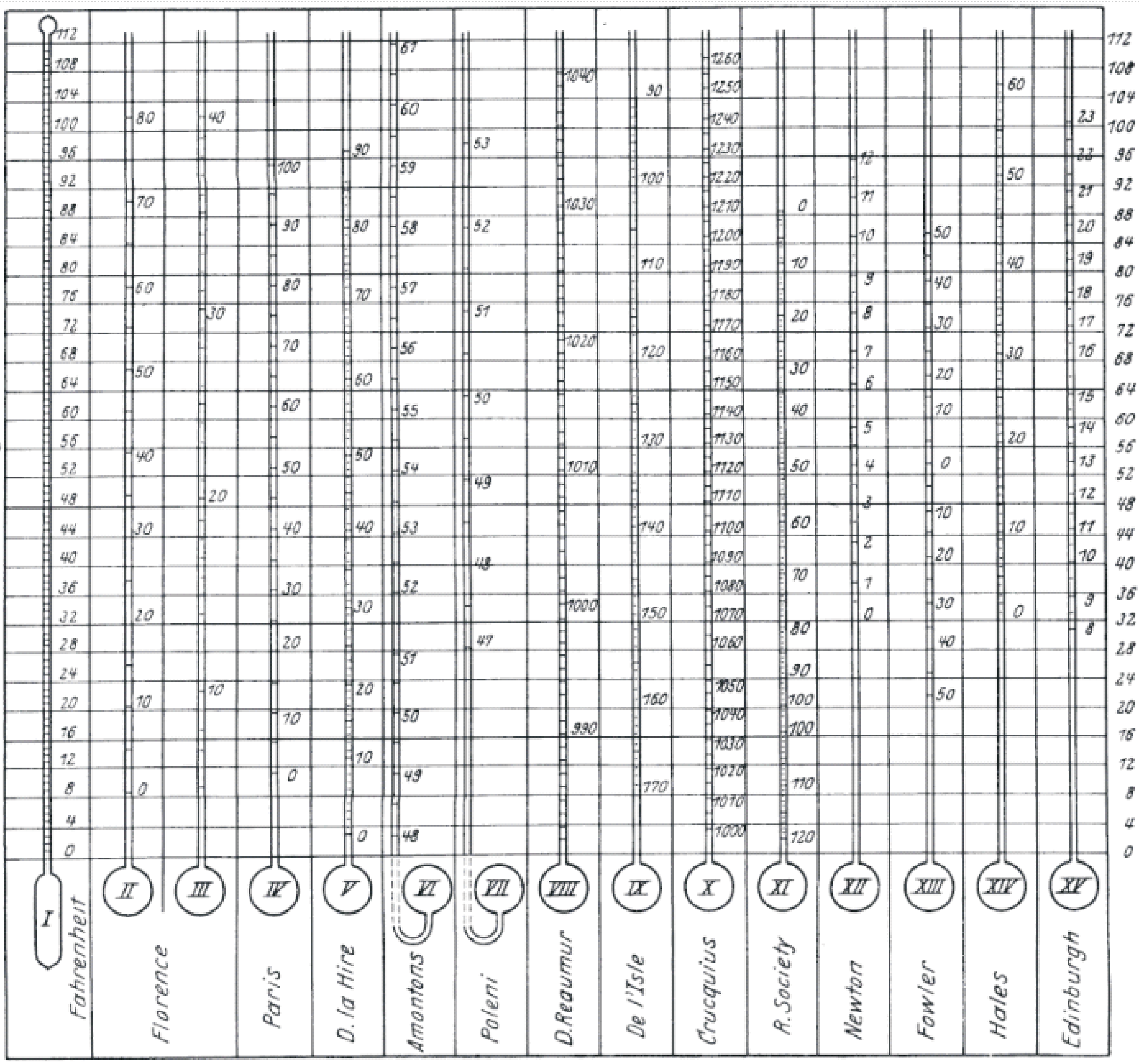


Figure 1
Santorio´s air thermometer

Figure 2
Comparison of different thermometer scales by George Martine



Ebstein´s monograph continues to report the progress in clinical thermometer achieved in Holland by Boerhave in Leyden and Schwenke in Den Haag. The use of thermometers as a diagnostic tool for fever detection was further developed by Boerhave´s pupils van Swieten and de Haen, both important physicians and founders of the first Viennese Medical school. The achievements of British physicians, particularly of Home in Edinburgh and the English surgeon Hunter, who started to investigate the temperature of inflamed tissues are also reported by Ebstein. A long chapter in Ebstein´s text is dedicated to the stimulating influence of hydrotherapy on clinical thermometry, mentioning the Irish physician C. Lucas, William Falconer from Bath in England and James Currie, who worked in Liverpool.

Skin temperature measurements

The history of measuring skin temperature started with Davy in Britain in the early 19th century. Skin temperature measurements were taken with a mercury thermometer of which half of its bulb surface could be brought into contact of various skin sites. It seems, that the naked individual was John Davy himself, who just came out the bed and was examined at 7 a.m. at an ambient temperature of 21.1°C (70°C F). The findings are shown in table 1 [7].

Between 1816 and 1820, John Davy investigated sublingual and axillar temperature of British or native individuals in South Africa, Ceylon and Mauritius. No differences in sublingual temperature was detected between Europeans and Non-Europeans. Finally, he published the profile of his sublingual temperature over 18 hours in combination with pulse and respiration rate and the ambient temperature. Mean temperatures for each month of the year, recorded at 3 times of the day were presented in the same relationship. This article is completed by tables describing the effect of various forms of exercise, mental attention or food intake on body temperature.

Table 1
Skin temperature profile obtained by John Davy in 1812 [7]

Examined body site	Celsius	Fahrenheit
At the central part of the sole of the foot	32.2°C	90°F
Between the malleolus internus, and the insertion of the tendo achillis, where the artery is felt	33.9°C	93°F
Over the middle of the tibia	33.1°C	91.5°F
Over the middle of the calf	33.9°C	93°F
Over the popliteal artery at the bend of the knee	35.0°C	95°F
Over the femoral artery in the middle of the thigh	34.4°C	94°F
Over the middle of the rectus muscle	32.8°C	91°F
Over the great vessels in the groin	35.8°C	96.5°F
About a quarter of an inch below the umbilicus	35°C	95°F
Over the sixth rib, on the left side, where the heart is felt pulsating	34.4°C	94°F
Over the same place in the right	33.9°C	93°C
Under the axilla, the whole surface of the bulb being applied	36.7°C	98°F

Wunderlich, who established clinical thermometry for the determination of deep body temperature to enable the diagnosis of fever, was not much interested in local skin temperatures. He was skeptical on the regular occurrence of local temperature changes, even in case of inflammation when the tactile sensation of warmth is not much supported by skin temperature measurements [8]. Wunderlich had also little confidence in the reliability of skin temperature measurements obtained thermo-electrically by Breschet and Becquerel.

The English physician and physiologist M.S. Pembrey became in his early career much interested in animal heat and published an overview on observations upon the deep and surface temperature of healthy men in 1898 [9]. In this article, some simultaneously measured deep and surface temperatures are reported, which have been recorded at different times of day in resting conditions or after various physical activities. Like Wunderlich, Pembrey was sceptical about the necessity of thermo-electric measurements of skin temperature, since he obtained comparable results by using a simple flat bulb mercurial thermometer. Rectal temperature was measured a small bulbed clinical thermometer which was inserted about 4 cm into the rectum and retained there for 2-3 minutes. Urine temperature was obtained by insertion of the thermometer in the stream of urine. The author was well aware of the uncertainties in measuring urine temperature. Tables 2 and 3 show some of Pembrey's results.

The American physiologist and nutritionist Francis G. Benedict studied originally chemistry and received a PhD degree cum magna laude from the University of Heidelberg in Germany in 1895 (10]. Upon his return to the United States in 1895, worked with Professor Wilbur Olin Atwater at Wesleyan University, Middletown, Connecticut, and got involved in physiology and nutrition science. In 1905, Atwater & Benedict published experiences with their respiration calorimeter, which was further developed from an apparatus designed by Max Pettenkofer in the eighteen sixties in Munich [11].

As a by-product of Benedict's interest in calorimetry, a map of skin temperatures was obtained with electric differential thermometers[12]. After the subjects arrived in the laboratory, the clothing was loosened, and temperature measure- ments were made at numerous points on the skin under the clothing (Figure 3). An example of such obtained temperature profiles is given in Figure 4. Interestingly, some of the measurement sites defined by Benedict are identical to the measurement points used in Regulation-Thermography. Like Schwamm and Rost, Benedict was also interested in the change of temperature after undressing..

Table 2
Temperature of the skin [9]

date	time	Surface temperature	Deep temperature	Remarks
31. VIII.1896	6 p.m.	32.0°C (thigh)	37.0°C (mouth)	After tennis, very hot, sweating
4. IX. 1896	noon	32.3°C (forearm) 33.6°C (palm of hand)	37.0°C (mouth)	Rest
19. X. 1898	10.45 p.m	32.2°C (forearm) 32.1°C (abdomen)	36.66°C (urine)	Rest. Temperature of air = 15.75°C
20. X. 1898	7.15 a.m.	33,5°C (forearm) 34.0°C (abdomen)	36.77"C (urine)	On getting up. Temperature of bed= 25.5°C
20. X. 1898	10.30 p.m.	32.25°C (forearm) 32,75°C (abdomen)	36.83°C (urine)	Rest
30. X. 1898	10 p.m.	34.0°C (abdomen) 33.5°C (palm of hand) 31.5°C (calf) 29.0°C (sole of foot) 26.5°C (ball of big toe)	36.83°C (urine)	Rest

Table 3
Simultaneous deep and surface temperatures [9]

Hour	Temperature of air °C	Internal temperature (rectal) °C	Surface temperature (abdomen) °C	Remarks
6.30 a.m	19.5	36.33	33.5	In bed
6.50 a.m.	19.5	36.83	31.2	After cold bath
7.30 a.m	22.5	36.44	34.5	
8.30 a.m	22.5	36.22	34.5	
10.00 a.m	22.5	36.44	33.25	Immediately after breakfast
11.00 a.m	22.5	36.56	34.4	
12.00 a.m	22.5	36.50	35.0	
1.00 p.m.	22.0	36.78	35.0	Before dinner
2.00 p.m	21.5	37.0	33.75	After dinner
2.30 p.m	21.0	36.89	34.0	Reading
4.00 p.m	21.0	36.83	34.0	Reading
4.40 p.m	21.0	37.11	35.0	After tea
5.30 p.m	21.0	37.22	35.5	Reading
6.00 p.m	21.0	37.33	35.0	Reading
6.15 p.m	21.0	37.22	35.0	Reading
7.15 p.m	21.0	37.11	35.0	Reading
8.15 p.m	21.0	37.05	34.5	Reading
9.20 p.m	20.5	36.89	34.5	Reading
10.50 p.m	20.5	36.44	34.5	Reading

In 1926, the German specialist in internal medicine Rudolf Cobet published an at that time comprehensive overview on skin temperature [14]. He discussed advantages and disadvantage of various skin thermometers including very early radiometric devices.

Infrared measurements

After Herschel´s detection of "dark heat" that is transferred by invisible infrared rays, further discoveries were necessary to disclose the relationship between thermal and electric energy. Seebeck described in 1821 of thermo-electricity that is the conversion of temperature differences directly into electricity. This laid the foundation to design thermoelectric generators which could be used also as a thermocouple to sense heat radiation. A series of thermocouples formed a thermopile. Ten years later, the Italian physicists Nobili and Melloni combined a thermopile with a galvanometer to a thermo-multiplier which was able to register human heat radiation at a 10 m distance.

In 1878, the German physiologists Arthur Christiani and Karl Hugo Kronecker reported in a short paper their temperature measurements that have been obtained by collecting thermal radiation from the palmar hand [15] For radiation collection, they used a hollow copper cone in which the cone´s top had been replaced by a thermopile covered

Figure 3
Benedict´s measuring sites for skin temperature measurement

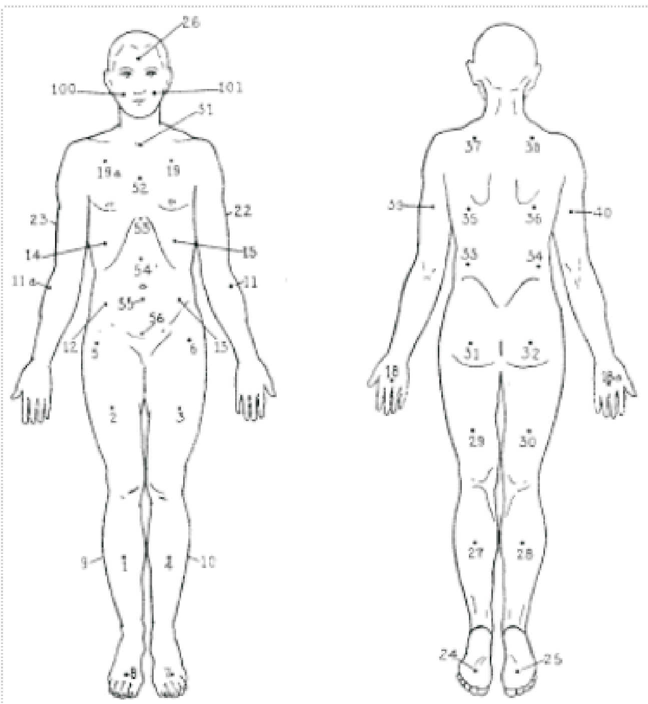
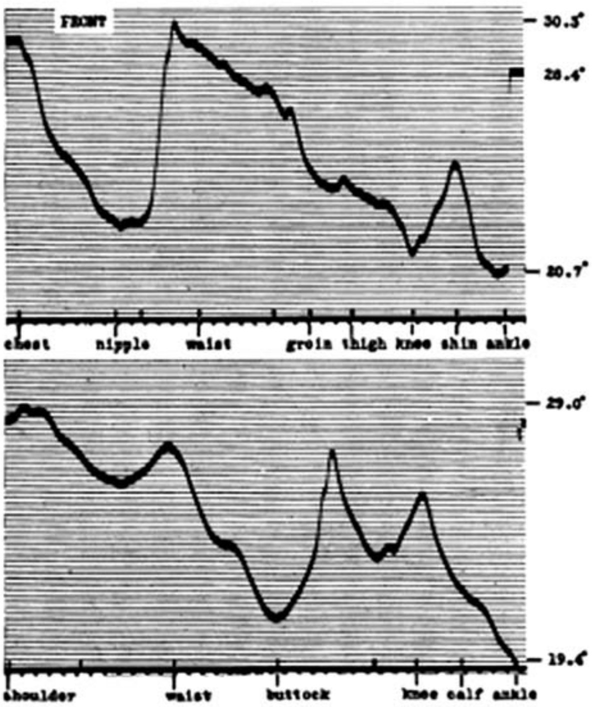


Figure 4
Temperature profile recorded in a naked female



with soot. Temperature readings were derived from the deviations of a galvanometer. Compression applied to various sites of the arm resulted in reduced blood flow and lower temperature readings.

C. Baur constructed in 1882 a simple radiometer that was based on the difference in resistance of two platelets of which one was exposed to radiant heat, but the other was not [16]. Samuel Langley developed with a similar approach between 1878 and 1880 his famous bolometer, but Baur states did he not know about Langley's invention. Baur referenced a paper by Svanberg, who described in 1851 a "galvanic differential thermometer" based on the Wheatstone's bridge principle[17].

In Zürich, the physicians A. Masje and his supervisor Professor H. Eichhorst, director of the medical clinic, regarded thermopiles as non-reliable instruments for measuring heat rays [18]. They adapted in 1885 Baur´s radiometer and used a grating of tinfoil of 20cm² area to measure skin temperature when placing their bolometer at distance of 5 cm to the skin. Masje conducted a number of experiments measuring the heat emittance of naked human skin in different anatomical regions, at various room temperature and after immersion of one arm in water of different temperatures. He found reduced heat radiation in cool skin and increased radiation from warm skin areas. However, his measurements were considered as erroneous.

George Neil Stewart, who became later Professor of Physiology and Histology at Western Reserve University School of Medicine in Cleveland, USA, started 1885 in Manchester to repeat Masje´s experiments and published the results in 1891 [19]. Different to the investigators in Zürich, Stewart was more interested in the temperature of skin covered with clothes than in the surface temperature of naked men. He measured skin temperature by a thermistor and used a grating of lead paper for measuring the amount of heat radiation. He provided data about the behaviour of skin temperatures of the undressed anterior surface of the left forearm at room temperatures of 18.4 or 20.2°C respectively. He reported a maximal decrease in temperature by 1.7 or 2.4°C occurring 27 or 20 minutes after onset of the experiment. The temperature remained constant about this minimum value for another 40 minutes when the experiment was broken off. He also measured skin temperature and heat radiation simultaneously and determined the difference between skin and room temperature. The greater the gradient from skin to air, the more heat radiation was detected.

Skin temperature in different anatomical regions varied in range of 31.9 to 35°C, although room temperature was kept stable. Heat radiation was between 190 and 232 deflections (a devision of the scale represents 0.000006 cal=6μcal.) Table 4 shows data from one of Steward's experiment.

In America, the first application of bolometers for skin temperature measurement was reported by the astrophysicist L.B. Aldrich in 1928. The study is the result of grant given by the New York Commission on Ventilation for investigating the contribution of radiated heat from pupils to

Table 4
Steward's experiment 1 [19]

Deflection read — Δ=difference of the temperature between the parts and the air of the room; T= temperature of the room

Region	Defl	Δ	T	Tr
Anterior surface of left forearm	222	16.8	34.4	17.6
Posterior surface of left forearm	218	16.4	340	17.6
Anterior surface of left forearm over belly of biceps	232	17.6	35.0	17.4
Left leg over head of tibia	190	14.4	31.9	17.5
Skin just below xiphoid cartilage	226	17.2	34.7	17.5
Skin over sternum	206	15.6	33.2	17.6
Trousers over anterior surface of left thigh (nothing between trousers and skin)	82	6.1	23.7	17.6

Def.=deflection Tr=Temperature of room

Table 5
Aldrich's experiment, Subject: Miss W, nude. March 30, 1921 [20]

Time	Position	Temperature water jacket	Observedtemperature (thermoelement)	Temperature computed from radiation	remarks
1.33	19	21.1	32.8	34.1	Pos.14 cm below 19
1.38	19	20.8	33.0	33.0	
1.45	19a	19.8	31.6	31.8	Pos.14 cm below 19a
2.05	55	19.3	32.7	40.7	
2.10	55	19.1	32.5	36.8	
2.18	55	19.1	31.9	39.6	
2.29	54	19.1	33.0	34.2	Pos.10 cm to left of 54
2.35	54		32.7	34.2	
2.45	55	19.5	31.2	36.6	
2.58	54	19.7	32.2	33.3	Pos.10 cm to left of 54
3.21	32	20.0	27.8	28.4	Standing facing window,holding iron post to steady herself
3.27	31	19.7	27.2	29.3	
3.38	30	19.2	27.7	30.6	Pos.2cm below 30
	34	18.9	30.3	33.7	Pos.6 cm above 34
3.53	45	18.7	27.6	30.2	
4.01	46	18.4	27.7	29.9	
4.12	14	18.7	32.1	34.6	

Figure 5
Radiometer by Cobet und Bramigk [14]
Bl= aperture Sp=gold plated metal mirror Th.E= thermopile
V.Kl.= movable metal plate (shutter)
W.Th=angled thermometer H.F=small wooden feet
L.H.= paint skin Q.K = mercury reservoir

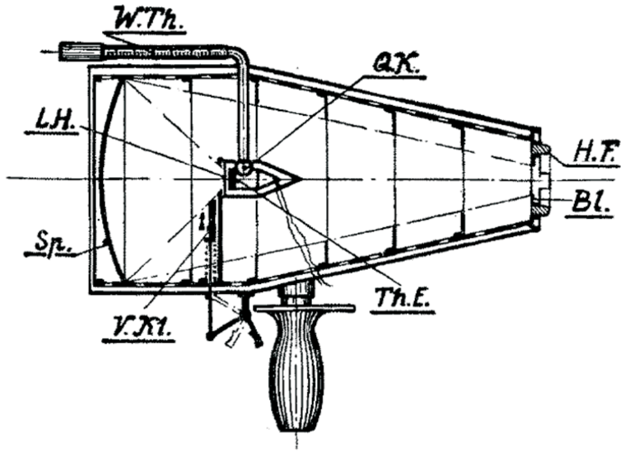
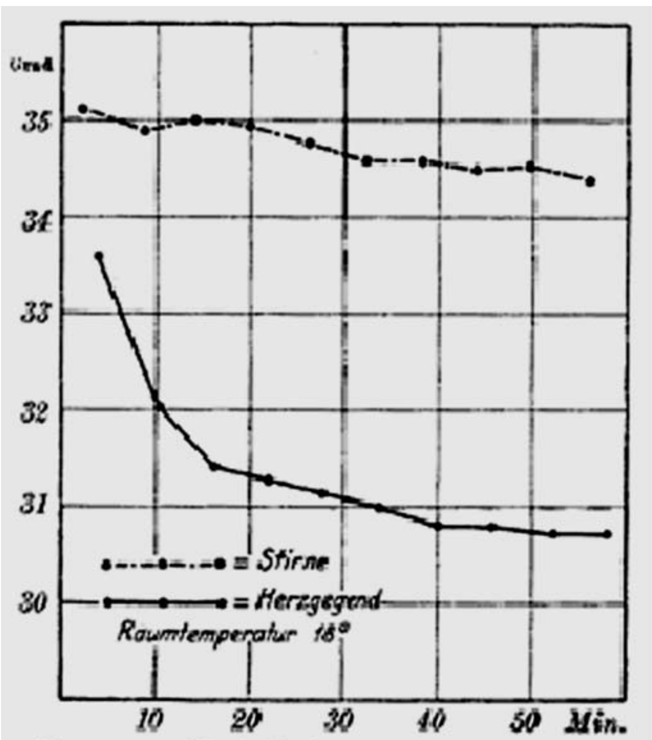


Abb. 2. (Nach Cobet und Bramigk.)
(Deutsch. Arch. f. klin. Med.)

Table 6
Cooling rate at various room temperatures [14]

Room temperature	Temperature decrease after 1 minute
20°C	0.7°C
18°C	0.9°C



Kurve 1. (Nach Cobet und Bramigk.)

Figure 6
Temperature course at the forehead ▪▪▪▪
and at the chest (above the heart) ▬▬

the temperature conditions in the classroom. Aldrich´s report starts with unpublished data from a pilot study of 1921 in which the astrophysicist and former co-worker of S. P. Langley conducted together with the physiologist F. G Benedict skin temperature measurement by a rubber- backed thermo-element and the Melikeron, a black-body like designed radiometer, in nude subjects. Their first measurements with remarkable large uncertainties of temperatures computed from radiation are provided in table 5 [20].

The final study consisted of two parts, the first investigating 3 adults and 7 children in still air, the second 2 adults and 8 children exposed to no, moderate or fast air movements. The pilot study of Aldrich found that temperature measurements based on radiometry overestimated skin temperature determine by the thermos-element on average by 1.9°C. In the final study, in which a new, improved version of the Melkerion was used, the agreement between the mean temperature obtained with both measurement devices was closer (difference 1.1°C). This study addressed also the contribution of convective cooling and radiation from the walls of the examination rooms on the accuracy of surface temperature measurements [21].

The German physicist W. Bramigk and the physician R. Cobet designed a radiometer which provided temperature values related to the heat radiation emitted from a 2.5cm² area, collected by concave mirror that reflected the heat energy to a thermopile generating thermoelectricity (14]. The deviations of the galvanometer were calibrated with empirical data derived from cadaver skin, resulting in the difference between skin temperature and temperature of the thermo-element. The later was displayed on a mercury thermometer. The sum of both temperature values are equal to the skin temperature under investigation (figure5).

Cobet showed the drop of skin temperature after undressing. The dependence of temperature drop on room temperature was a well-known fact. Table 6 presents the decrease in skin temperature in dependence to various room temperatures. Figure 6 shows the course of the skin temperature in the heart region in comparison to the forehead temperature over a period of 60 minutes. All measurements were recorded with the Bramigk-radiometer.

Cobet discussed in his monography "normal" skin temperature and stated that the skin temperature of the same individual varies over 24 hours and between days even when the measurements have been obtained at the same time of the day. A healthy, naked subject presents at an ambient temperature between 22 and 23 °C with an average skin temperature of 32 to 33°C. Subjects with skin temperatures less than 31.5°C feel themselves cold and uncomfortable.

Cobet reported the behaviour of skin temperatures after mechanical, chemical and thermal stimulation, and local temperature alterations in defined diseases. He expressed his scepticism that inflammatory processes in inner organs such as lungs, pleura or kidneys result regularly in an increase of skin temperature, although such responses can occasionally, but seldom be observed. Inflammatory disorders of peripheral joints become more often obvious by elevated temperatures. However, this is only true for acute cases irrespective of the underlying cause. Temperature differences to the contralateral joint of 4°C or more were reported as typical findings in tubercular arthritis [14].

The American physiologist Hardy used a radiometer based on the design of Cobet & Bramigk to determine the infrared emissivity of skin[22,23]. By establishing an emissivity of skin of 0.98 at wavelengths above 6 µm, he clearly identified the skin as the primary source of infrared radiation (not the clothes as Stewart argued) and rejected the idea of Masje that heat exchange with the environments affects skin emissivity.

Discussion

The early investigations in skin temperature clearly indicate the difficulties and limitations of this measurement task. In research conducted by scientists rather than physicians, comparability of temperatures scales and calibration of thermometers was the challenge for valid and reliable measurements of body temperature. Relationship of both deep and superficial body temperatures to physical activity, climate and ambient temperature, clothing and food intake was early recognised. Response time of mercury thermometers brought in contact to skin made skin temperature measurement to a time-consuming procedure.

The indication of temperature and the correct scaling became critical in the eighteen thirties with the appearance of devices such as thermoscopes that detected heat sources in a remote manner. These instruments recorded the deflection of the galvanometer and related it to calories. Bramig's radiometer was the first device that allowed a direct reading of the temperature of the captured heat rays.

Most authors in the past were aware of the uncertainties of their measurement of temperature or radiation, respectively. They also realised that "heat" is a typical, but not an obligatory clinical sign of inflammation. All researchers of the past had the intention, to raise evidence that temperature measurements can objectively contribute to the definition of health conditions. To follow a protocol for skin temperature measurements very strictly, was as mandatory required as today.

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23rd Meeting of the Polish Society of Medical Thermology Combined with the European Association of Thermology

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ZAKOPANE 12th-14nd April 2019

Conference venue:

Hotel "HYRNY" , Zakopane, Pilsudskiego str 20

Programme

Saturday, April 13th, 2017

09:00 - 10.50 Session I: **Chair:** Prof Kurt Ammer, Dr Kevin Howell

1. *Kevin Howel (United Kingdom)*
   The European Association of Thermology: Promoting the science of temperature measuremet in medicine and biology across Europe.
2. *Ho Yeol Zhang, Taemi Youk, Ho Keon Lee, Hyeon Jin Song, Kyoung Hwa Yang (South Korea)*
   Reference standard temperature data of normal korean extremities
3. *A.L. Urakov, M. Yu Alies, V. N. Nikolenko, A. A. Gadelshina (Russia)*
   Dynamics of local temperature in the hands of healthy adult volunteers under the frosty air contacting a cold metal object.
4. *M. Strakowska, B Wiecek (Poland)*
   A new method and software for skin pathologies screening using cold provocation
5. *A. Seixas, I. Pimenta, K. Ammer, R. Carvalho, J. P. Vilas-Boas, J. Mendes, R. Vardasca (Portugal/Austria)*
   Inter-Rater and intra-rater repeatability of the placement of regions of interest based in anatomical landmarks of the foot
6. *A. L. Urakov, A. A. Kasatkin, K. Ammer, K. G. Gurevich (Russia/Austria)*
   The dynamics of fingertip temperature during voluntary breath holding and its relationship to transcutaneous oximetry.

7. *Kurt Ammer (Austria)*
The most cited article from thermology international in the period 2000 to 2018.

11:00 - 13:00 Session II **Chair:** Prof. Aleksandr Urakov, Dr. Aderito Seixas

1. *Ho Yeol Zhang, Dong Wook Kim, Ho Keon Lee, Hyeon Jin Song, Kyoung Hwa Yang (South Korea)*
Fever screening IR camera equipped with body temperature data.
2. *N. A. Urakova, A. L. Urakov (Russia)*
In pregnant women with thrombophilia the fingers local temperature can indicates the status and prognosis of fetus health.
3. *B. Englisz-Jurgielewicz, J. Poletek, R. Winkler, L. Teuster, K. Sieron, A. Siemianowicz, A. Stanek, A. Cholewka (Poland)*
Side curvature spine evaluation in children by using thermal imaging and X-ray.
4. *E. Staffa, V. Can, J. Bernard, J. Pokorna, A. Zetelova, M. Farkasova, V. Mornstein, Z. Kala (Czech Republic)*
Usefulness of blood supply visualisation by infrared thermography and indocyanine green fluorescence angiography for invasive esophagectomy performed after ischemic gastric conditioning.
5. *B. Englisz-Jurgielewicz, A. Cholewka, E. Firganek, G. Knefell, M. Kawecki, J. Glik, M. Nowak, K. Sieron, A. Stanek (Poland)*
Evaluation of hyperbaric oxygen therapy effects in hard-to-heal wound using thermal imaging and planimetry.
6. *V. Bernard, J. Pokorna, E. Staffa, P. Hanakova, Z. Balintova, H. Oslejskova, V. Morstein (Czech Republic)*
Facial palsy - contactless thermographic study.
7. *J. Pokorna, Z. Balintova, V. Bernard, E. Staffa, H. Oslejskowa, V. Morstein (Czech Republic)*
Infrared thermography: a new approach for examination of brachial plexus injury.

14:15 - 15:30 Session III **Chair:** Prof. Manuel Sillero, Prof. Zofia Drzazga

1. *M. Sillero Quintana, I. Fernandez-Cuevas, D. Alba-Lopez (Spain)*
Efficiency and validity of several thermal imaging cameras using an automatic software for the selection of ROI.
2. *M. Sillero Quintana, J. G. Adamczyk, S. Karabas (Spain/Poland)*
Thermal profile of elite masters athletes and the influence of athletic competition on their skin temperature.
3. *T. Kasprzyk, A. Stanek, K. Sieron, A. Cholewka (Poland)*
Application of thermal imaging in athlete's thermoregulation mechanisms assessment after dynamic training.
4. *J. Gabrhel, Z. Popracova, H. Tauchmannova, K. Ammer (Slovakia/Austria)*
The value of thermography in the diagnosis of myofascial pathways distortions.
5. *M. Binek, Z. Drzazga, I. Pokora (Poland)*
Preliminary studies of impact of cryotherapy on thermal mapping of body during endurance treatment

16.00 - 17.00 Session IV: **Chair:** Prof. Anna Jung, Prof. Armand Cholewka

1. *D. Kiera, A. Baic, M. Stankiewicz, B. Lange, A. Stanek, K. Slosarek, A. Kowalczyk, A. Cholewka (Poland)*
Thermal imaging for monitoring chemotherapy in breast cancer patients -preliminary results
2. *D. Kiera, A. Baic, M. Stankiewicz, B. Lange, A. Stanek, K. Slosarek, A. Cholewka (Poland)*
Correlation of isotherms with isodoses for patients with breast cancer treated by radiotherapy.
3. *A. Maciejewski, A. Jung, A. Byszek, A. Pypkowska, H. Jaremek, A. Krause-Piorek, A. Szczesniak, M. Trzyna, G. Ornowski (Poland)*
A novel tool based on liquid crystal thermography for adjunctive breast cancer detection used by medical professionals.
4. *L. Kapek, A. Cholewka, M. Szlag, P. Wojcieszek, A. Stanek, S. Kellas-Sleczka, K. Slosarek, A. Cholewka (Poland)*
Thermal imaging based evaluation of skin temperature following brachytherapy of basal cell carcinomas.

Abstracts

THE MOST CITED ARTICLE FROM THERMOLOGY INTERNATIONAL IN THE PERIOD 2000 TO 2018

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INTRODUCTION:

The journal "Thermology international" started under the name "Thermologie Österreich" and has published between 1991 and 2018, 28 volumes with a total of 110 regular and 6 supplementary issues. Elsevier started in 2002 to list the journal´s content regularly in the databases Embase /Scopus. Currently Embase shows 429 papers for Thermology international, Scopus has 253 entries in the journal´s primary collection and 529 papers in its secondary database. A search in Google Scholar performed with Harzing´s Publish or Perish (PoP) identified 278 articles. Clarivate´s Web of Science (WoS) is listing 210 different articles citing Thermology international. The article "The technique of infrared thermal imaging in medicine by E.F.J. Ring and K. Ammer, published in Thermology international 2000, 10(1) 7-14." was identified as the most cited article with a total of 340 unique citations included in my private archive (315 citations in Google Scholar, 187 in Scopus and 137 in WoS).

METHOD

All 340 citing articles were analysed with respect to name and country of the first author, source, type and publication year of the citing article were collected. An analysis was also performed in all citations found in Scopus with respect to the aspect of the article that was referenced.

RESULTS

The article showed a peak of 42 citations in the year 2018 and the minimum of 3 citations in 2001. PoP reports an average of 17.4 citations/year. Francis Ring cited the article 22 times as first author (FA) and 10-times as co-author (CA). R. Vardasca cited the article 31-times (FA: 14, CA:17) followed by Armand Cholewka with 22 cites (FA: 17, CA: 5) and Kurt Ammer with 21 citations (FA: 9. CA:11). Authors from Poland cited the "technique article" 53-times. The article was referenced in 202 journal articles, in 3 books, in18 book chapters, in 65 articles of conference proceedings, in 32 theses and in 2 posters. 74% of first authors originate from Europe, 15% from Asia, 8% from South America, 2% from North America, and 1% from Australia

The content analysis revealed some papers quoting the article as general reference for the usage of thermography in medicine. Most articles understood the "technique article" as guideline which was cited to support their method for the acquisition of thermal images, irrespectively whether the recommendations were followed. The proposal for the ambient temperature in the examination room was most often misunderstood. 18 to 24° C is the range of possible room temperatures, but not the variation of ambient temperature per hour which should be equal or less than ± 0.5°C.

DISCUSSION

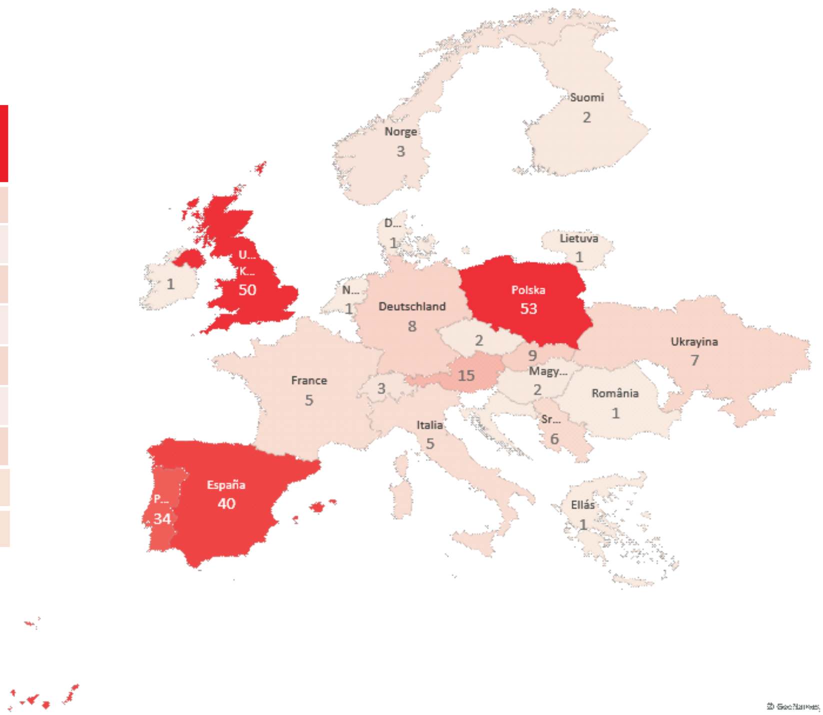
The annual literature survey on thermology and temperature measurement reports approximately 250 journal articles identified with the keyword combination "thermography" and "medicine", resulting in a total of 4500 papers published in the period 2000 to 2018. 340 citing papers represent approximately 7.5% of articles related to medical thermography. Roughly 40 % of thermography papers originate from North America, but only 2% of citations of the "technique article" were authored by Americans.

CONCLUSION

The article by Ring and Ammer is an important reference for medical thermography frequently cited by authors all around the globe, but predominantly in Europe.

253 citations from Europe

Country	% of European
Poland	20.9
United Kingdom	19.8
Spain	15,8
Portugal	13.4
Austria	5.9
Slovakia	3.6
Germany	3.2
Ukraine	2.8
Serbia	2.4



THE VALUE OF THERMOGRAPHY IN THE DIAGNOSIS OF MYOFASCIAL PATHWAYS DISTORTIONS

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4 National Institute of Rheumatic Diseases in Piešt´any

INTRODUCTION

Myofascial pain syndrome (MFP) is defined by the combined occurence of sensory, motor and autonomic symptoms that include local and referred pain, decreased range of motion and weakness . MFP is considered as a localised muscle pain disorder. Fibromyalgia (FM) is envisaged to be a pain syndrome related to dysfunctional central pain processing and is postulated as being chronic [1]. FM patients present with additional somatic symptoms such as fatigue, sleep or mood disturbances and have other co-morbidities [1,2]. Abnormal central pain processing, a characteristic of FM, is also prominent in MFP 3.. There is a considerable clinical overlap with FM and with muscle soreness.

Peripheral nociceptive input from the myofascial trigger points and other peripheral pain generators may be relevant to the contemporary understanding of myofascial pain syndrome and fibromyalgia. MTP are stiff, tender nodules that may arise from contraction of the sarcomeres in this region. Myofascial trigger points are always tender points, however, not all tender points show palpable nodules or taut bands. An active MTP is spontaneously painful i.e. no manipulation is needed to elicit pain. However, firm pressure over the taut band reproduces the patient´s spontaneous pain symptoms, as well as referred pain, motor and autonomic symptoms. A latent MTP is painful only upon palpation, which cause pain, a local twitch response and referred pain [2,3].

Delayed onset muscle soreness (DOMS) typically occurs after strenuous and unaccustomed exercise and physical activity. Tenderness of muscles is the leading sign of the disorder. Several models must be integrated to understand the physiological processes that lead to DOMS. However, radical oxygen species (ROS) play a central role in the pathomechanism [4].

The low threshold to sensory stimuli of all qualities is currently explained by altered central neural processing in nociceptive pathways. This alteration includes augmented pain and sensory processing, enhanced excitation in the central nervous system, alterations in central inhibition, psychological stress contribute to the altered central processing of pain information. Only a minority of fibromyalgia patients show alterations in the sympathetic nervous system and recently an "egg or hen" discussion was started on the origin of this changes in the autonomic nervous system. Altered immune function and alterations in nociceptors might also contribute to some of the pathology in fibromyalgia [3].

Muscle pain is caused by the activation of high-threshold mechanosensitive (HTM) muscle receptors which function as nociceptors when exposed to high mechanical forces such as squeezing or applying pressure to the muscle. They respond also to intramuscular algesic chemical stimulation by bradykinin, serotonin, histamin, potassium chloride, levoascorbic acid and hypertonic saline. They can be sensitised by chemicals such as prostaglandin E2 or serotonin leading to an enhanced response to bradykinin or mechanical stimulation. The sensitization of muscle nociceptors is the best-established peripheral mechanism for the subjective tenderness and pain during movement of a damaged muscle [5].

Trigger points can be detected by palpation (taut band, twitch response) and the underling structural alteration can be confirmed by ultrasound imaging as hyperechoic area. The only moderate interobserver reproducibility of palpatory findings [2] is not an argument against the validity of indentifying myofascial trigger points by palpation. Other methods used for confirmation of trigger points[2]are EMG for recording the electrical activity elicited by insertion of a concentric needle electrode into MTP, microdialysis - MTPs have an acidic milieu, ultrasound elastography and magnetic resonance elastography . In all of the aforementioned methods, reliabilty was not yet investigated.

INFRARED THERMOGRAPHY IN DIAGNOSIS OF MYOFASCIAL PAIN

Thermography represents an objective means to document trigger points. In 1984, Fischer described a typical thermographic image of a trigger point, that is a localized area of elevated temperature, usually 5-10 mm in diameter and often disc-shaped. These findings corroborate with local palpation and a quantitatively measured pressure threshold in the affected area. Fischer & Chang [6], and Ammer [7] proved that the pressure threshold was statistically significantly lower in hot spots. That myofascial trigger points can be detected as areas of elevated temperature. Also painful tendon strains - enthesopathies, are reliably diagnosed by measuring the skin temperature, as reported by Ring & Ammer[8]. Miranda and Robaina, who examined a large sample of patients with myofascial pain syndrome, found hot spots without pain (false positive) in 15.3% of patients only [9]. Balbinot, using thermography and algometry, demonstrated that thermography is a suitable method for diagnosing myofascial syndrome of the trapeze muscle [10]. Myofascial trigger points are typically imaged as hyperthermic area, some of them with a hypothermic area surrounding the local muscle spasm. Applying pressure on trigger points results in a change of thermal intensity in the area plus elicitation of radiating pain or referred pain respectively.

Ammer proved that determining the number of hotspots by thermography is in fibromyalgia patients a diagnostic tool of moderate to good sensitivity and specificity [11]. Counting hot spot can assist in the diagnosis of fibromyalgia but cannot replace palpation of tender points. In case of hotspot search in patients with fibromyalgia, the reproducibility by the same investigator is acceptable, when hotspots were visually identified in in a repeated evaluation of thermal images [12]. Reproducibility of visual hotspot identification is dependent on processing thermal images [13], particularly determined by contrast and brightness.

According to Barbosa [14], thermography combined with clinical examination is effective in confirmation of the diagnosis fibromyalgia and in the differentiation to other syndromes spreading from painful sites. Brioschi claimed a correlation between the clinical picture of fibromyalgia and the thermographic image [15]. In previous studies [16,17],we confirmed the coincidence between tenderness and increased skin temperature in functional disorders of the myoskeletal system.

IN OUR PRACTICE

Thermography allows us to differentiate the inflammatory etiology of pain from painful conditions which present with symptoms induced by the autonomic response to nociceptive input from several sources. However, some skin affections, such as inflammatory and allergic changes, show also a thermal image with increased temperature. Superficial varicose veins may imitate myofascial trigger points as they also appear as hot spots

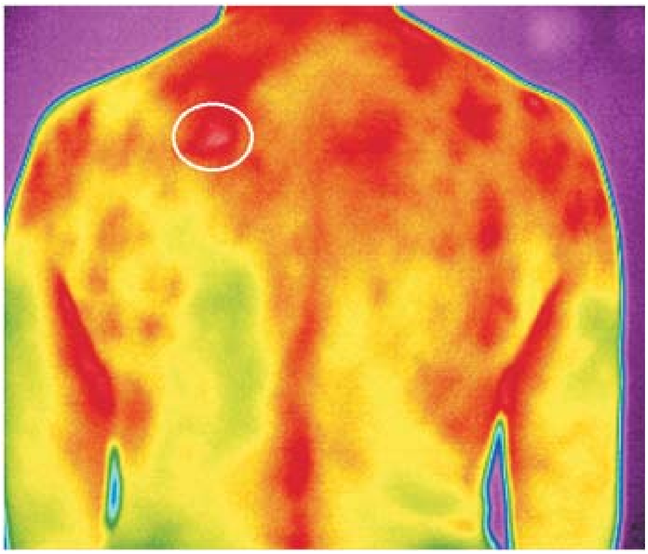

Figure 1a.
Thermal active trigger points on the left side of the thoracic back.

Figure1b
Relation of trigger points to theappropriate myofascial tracts.

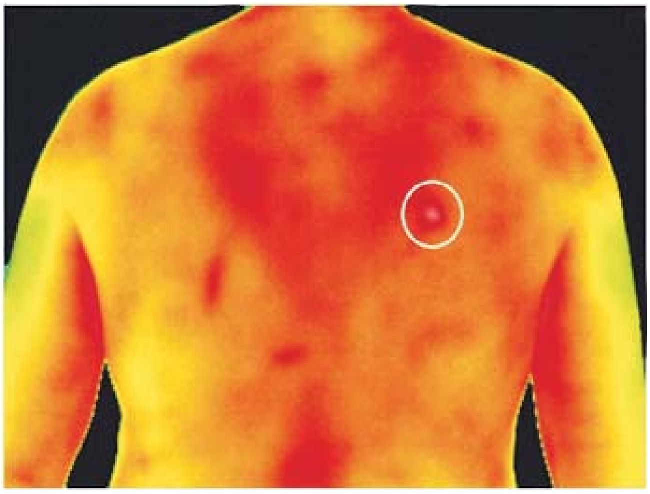

Figure 3
Furuncle on the right-sideof the thoracic back

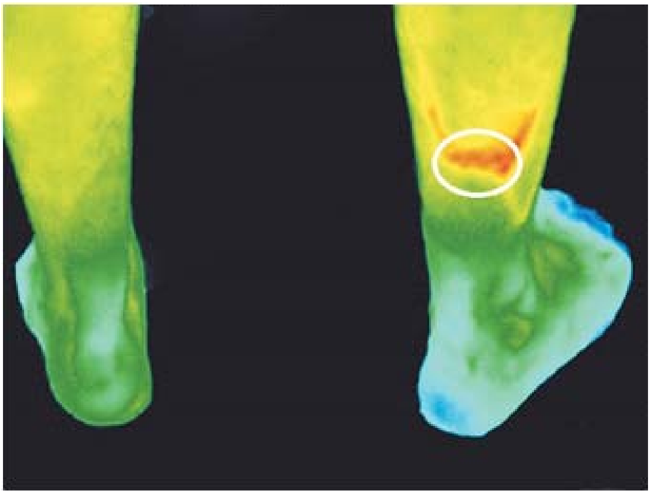

Figure 4
Varix on the distal right calf

Therefore, a clinical examination must also be part of the thermographic examination, making a note of these changes in the investigation form, so that we do not assign them to the trigger points. In clinical practice, we often find MTPs located on myofascial pathways [17] in the same position as acupuncture points. We also relate thermal active trigger points to the appropriate myofascial tracts, and we treat not only the trigger point but also all other possible disorders on the myofascial tract such as and radiating pain caused by these disorders. Thermography is an imaging modality that resolves anatomical structures badly. Therefore, it is necessary to supplement thermographic examination subsequently by myoskeletal or sonographic examination.

CONCLUSION

Diagnosis of myofascial trigger points by infrared thermography, and their assignment to the appropriate myofascial pathway, enables us a targeted use of treatment techniques. Thus, alleviating the malfunctions occurring through the course of the relevant myofascial pathway. identifying and treating any peripheral pain is a target of high priority in the management of pain disorders of complex pathomechanisms such as MP and FM.

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THE DYNAMICS OF FINGERTIP TEMPERATURE DURING VOLUNTARY BREATH HOLDING AND ITS RELATIONSHIP TO TRANSCUTANEOUS OXIMETRY

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INTRODUCTION

Voluntary breath-hold duration is affected by behavioural factors such as practice and psychology and autonomic regulatory loops based on respiratory chemoreflexes, and lung stretch. When a breath hold is performed at rest, arterial O2 levels begin to drop and arterial CO2 begins to rise (pH levels drop) as a function of metabolism 1.. Short periods of apnea either induced by voluntary breath holding or in obstructive sleep apnea (OSA) result in peripheral vasoconstriction 2, 3..

In thermal images, low finger temperature is understood as a sign of low peripheral perfusion due to vasoconstriction. Vasoconstriction can occur as a thermoregulatory response against heat loss. In case of apnea the input from central or peripheral chemoreceptors results in an increased activity in the sympathetic branch of the autonomic nerve system. While an abundance of literature exists on physiological research in breath holding divers 4., the effects of short phases of apnea on the peripheral circulation have not been much investigated 5..

Since skin temperature represents the width of peripheral vessels and transcutaneous oximetry records blood oxygen saturation, we were interested in the temporal relationship between those parameters in case of voluntary breath holding. We investigated in a very simply designed pilot study whether the response of skin temperature occurs prior, simultaneously or after a decrease in oxygen saturation was detected.

METHODS

The study was conducted in all 25 healthy volunteers: 18(72%) men and 7(38%) women, average age was 26.6±4.2, body mass index less than 20-25kg/m2. The temperature dynamics of fingertips was studied with infrared thermal images before, at the end and after BHT in twenty-five adult healthy volunteers. All participants were instructed to refrain from caffeine and alcohol for at least 12?h before study. In all volunteers BHT was performed in the morning before breakfast. The breath-holding test was carried out as follows: after maximal inspiration of atmospheric air, the participant was instructed to hold his breath for as long as possible. A stopwatch was used to record the duration of voluntary apnea. Pulse rate and oxygen saturation was continuously recorded with the electric sensor of a pulse oximeter (Mindray, China) for 5 minutes, starting 2 minutes prior to the breath holding test. Infrared monitoring was performed by using the thermal imager ThermoTracer TH9100XX (NEC, USA). Ambient temperature of the examination room was 24±0.5°C, the temperature window of the thermal camera was set to the range of 25 to 36°C. Temperature dynamics was studied in the horizontal position of volunteers. To do this, the volunteers were placed in a horizontal position lying on their backs for 10 minutes before the start of apnea. Thermal images were recorded prior to breath holding, 12 to 17 seconds after stopping breathing, and 60 and 90 seconds after starting the experiment. The dynamics of the local temperature in the fingertips was determined using a computer program. At the time, when a minimum in local temperature was detected, spot temperatures were measured on the tip of each finger.

The study plan was previously approved by the local ethics committee following the principles that are outlined by the World Medical Declaration of Helsinki. All subjects provided signed informed consent to this study.

RESULTS

Our results showed that breath holding in healthy volunteers, is followed by a fall of fingertip temperature within 12-17 seconds after the start of apnea (Fig. 1)

We found out that the duration of voluntary apnea was 43.7±7.8 (Min-Max, 30-61) seconds. The local temperature value of fingertips before BHT is 33.0±1.5° C at the end of BHT is 32.3±1.6° C and 90 seconds after BHT is restored 33.9±1.8° C. The restoration of the baseline finger tips temperature was recorded at 250.7±18.6 (Min-Max, 210-300) seconds after the recovery of breathing. At the same time, significant temperature changes in fingertips were recorded 15.5±2.8 seconds after the start of BHT.

In turn, significant changes in pulse and blood oxygen saturation were recorded 39.4±8.2 and 42±5.6 seconds (respectively) after

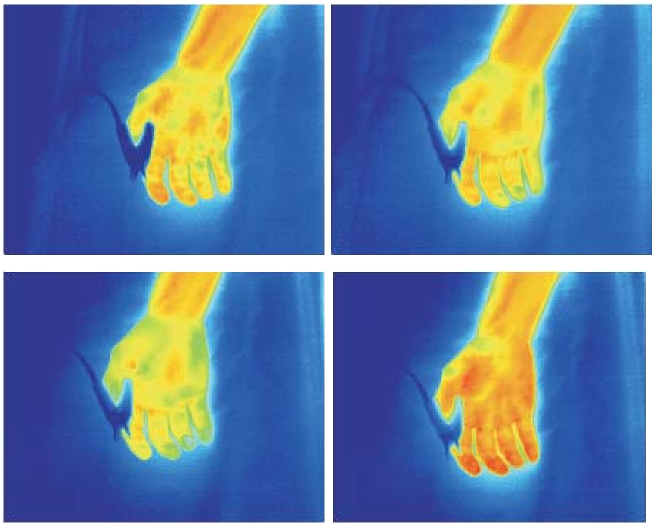

Figure 1.
Infrared image of palmar surface of the right hand (with sensor of pulse oximeter on 1 finger) of the healthy volunteer, 28 years old:
1a - prior to the apnea
(local temperature of 2-5 fingertips: 32.4, 31.8, 31.3 and 31.6 ºC),
1b - 17 seconds after of apnea
(local temperature of 2-5 fingertips: 31.8, 31.0, 30.3, 30.2 ºC),
1c - 60 seconds after of apnea
(local temperature of 2-5 fingertips: 30.8, 30.1, 29.3, 29.3 ºC) ,
1d - 90 seconds after restoration of spontaneous breathing
(local temperature of 2-5 fingertips: 33.1, 33.3, 32.9, 32.7 ºC)

the start of BHT. Baseline blood oxygen saturation was 98±1.0 %. The saturation changed not significantly to 97.9 ±1.0 % at the time point 16 sec, when a significant decrease of finger temperature was observed. 42 seconds after starting the breath hold test, the mean oxygen saturation decreased significantly to 96 ± 1.2 %.

CONCLUSION

Infrared monitoring of local temperature at the fingertips provides the earliest information about the onset of the circulatory response to short episodes of apnea. Central rather than peripheral mechanisms seem to initiate the almost immediate vasoconstriction of finger vasculature after breath holding.

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INTER-RATER AND INTRA-RATER REPEATABILITY OF THE PLACEMENT OF REGIONS OF INTEREST BASED IN ANATOMICAL LANDMARKS OF THE FOOT

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INTRODUCTION

In recent years, foot skin temperature analysis became a popular topic. It has been shown that an increase in skin temperature, when compared to the contralateral limb, predicts foot ulceration 1.. However, the definition of the regions of interest is not consensual and depends on the aims of each investigation. Previous studies have clinically validated the analysis of foot skin temperature in anatomical landmarks related to foot ulceration, such as the hallux, the metatarsal heads, midfoot and heel 2, 3.. The repeatability of the placement of regions of interest in the foot has been addressed in few studies 4, 5.and none has satisfactorily analysed the placement of regions of interest in the previously mentioned anatomical landmarks. Therefore, the aim of this study is to analyse the inter- and intra-rater reliability of the placement of regions of interest (ROI) in the foot, based in anatomical landmarks.

METHODS

Thermal images of the plantar surface of 13 diabetic patients (26 feet) were analysed by two assessors. One assessor was highly experienced in analysing thermal images (more than 6 years of experience) and the other had one year of experience analysing foot thermograms. Both assessors had strong anatomical knowledge of the foot. Both assessors evaluated the images independently and were asked to define 8 circular shaped ROI: Heel Medial, Heel Lateral, Midfoot Medial, Midfoot Lateral, 1st Metatarsal Head, 2nd-3rd Metatarsal Heads, 4th-5th Metatarsal Heads and Hallux (figure 1), all with 96 pixels. Three weeks after the first assessment one of the assessors was asked to repeat the analysis. The patient order was randomized and the fact that the patients were the same was not shared with the assessor to avoid bias. The mean temperature value was extracted using FLIR ResearchIR Max software (FLIR Systems, version 4.30.0.69). Data analysis was performed using Statistical Package for the Social Sciences (SPSS Statistics, IBM, version 25). The Intraclass Correlation Coefficient (ICC) was used to assess the inter and intrarater reliability. A two-way random-effects, absolute agreement, single measurement model was used when assessing interrater reliability and a two-way mixed-effects, absolute agreement, single measurement model was used when assessing intrarater reliability. The Standard Error of the Mean (SEM) was computed from the ICC and respective standard deviations.

RESULTS

Globally, interrater reliability measures were slightly lower than

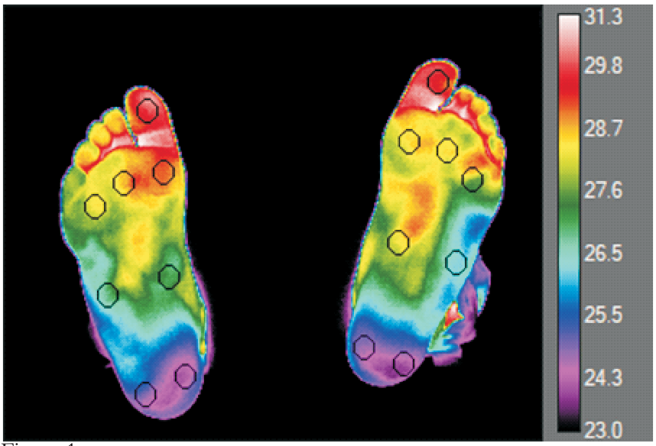

Figure 1
Regions of interest in the reliability analysis: Heel Medial, Heel Lateral, Midfoot Medial, Midfoot Lateral, 1st Metatarsal Head, 2nd-3rd Metatarsal Heads, 4th-5th Metatarsal Heads and Hallux.

intrarater reliability measures. The placement of ROI in the foot, based in the anatomical landmarks had good to excellent inter rater reliability for all regions of interest (ICC: 0.890 - 0.998) and excellent intrarater reliability (ICC: 0.918 - 0.999). The SEM varied between 0.29ºC and 0.79ºC in the interrater analysis and between 0.26ºC and 0.42ºC in the intrarater analysis.

CONCLUSION

The results suggest that the ROI based in the anatomical landmarks can be placed in the foot with excellent interrater and intrarater reliability. Although the reliability scores are excellent, they are lower than those reported in previous research analysing the reliability of the placement of ROI based in the angiosome concept 5., suggesting that smaller ROI may be more prone to measurement error.

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THE EUROPEAN ASSOCIATION OF THERMOLOGY: PROMOTING THE SCIENCE OF TEMPERATURE MEASUREMENT IN MEDICINE AND BIOLOGY ACROSS EUROPE.

Kevin Howell

President, European Association of Thermology

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REFERENCE STANDARD TEMPERATURE DATA OF NORMAL KOREAN EXTREMITIES

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INTRODUCTION

The 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 data by measuring the average temperature of each region of interest (ROI) made for each posture of infrared (IR) thermographic image of normal Koreans. The 2018 research goal was to create a reference temperature table for the normal adult's upper and lower extremities. The purpose of this study is to present the production process and results of the reference standard body temperature data of the normal Korean upper and lower limb.

MATERIALS AND METHODS

During 2017 and 2018, 935 normal adults were measured. The measurement are of the whole body is divided into 22 views. The ROI of each view were defined and measured by using the IR thermographic images of 15 among 22 views of anatomical regions corresponding to the upper and lower extremity (Figure 1ab). In 2017 years, National Health Insurance Service (NHIS) Ilsan Hospital, Yonsei University Gangnam Severance Hospital and Ajou University Hospital participated in this study, and NHIS Ilsan Hospital was participated in 2018. 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.

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 935 normal adults.

RESULTS

The average temperature of the ROIs was measured in 15 postures. Postures of upper extremity defined 9 postures, as

1) trunk anterior,

2) trunk posterior upper and mid, 3) upper extremity, right,

4) upper extremity, left,

5) hand dorsum,

6) hand palm,

7) arm and palm,

8) arm and hand dorsum, and

9) forearm ulnar side.

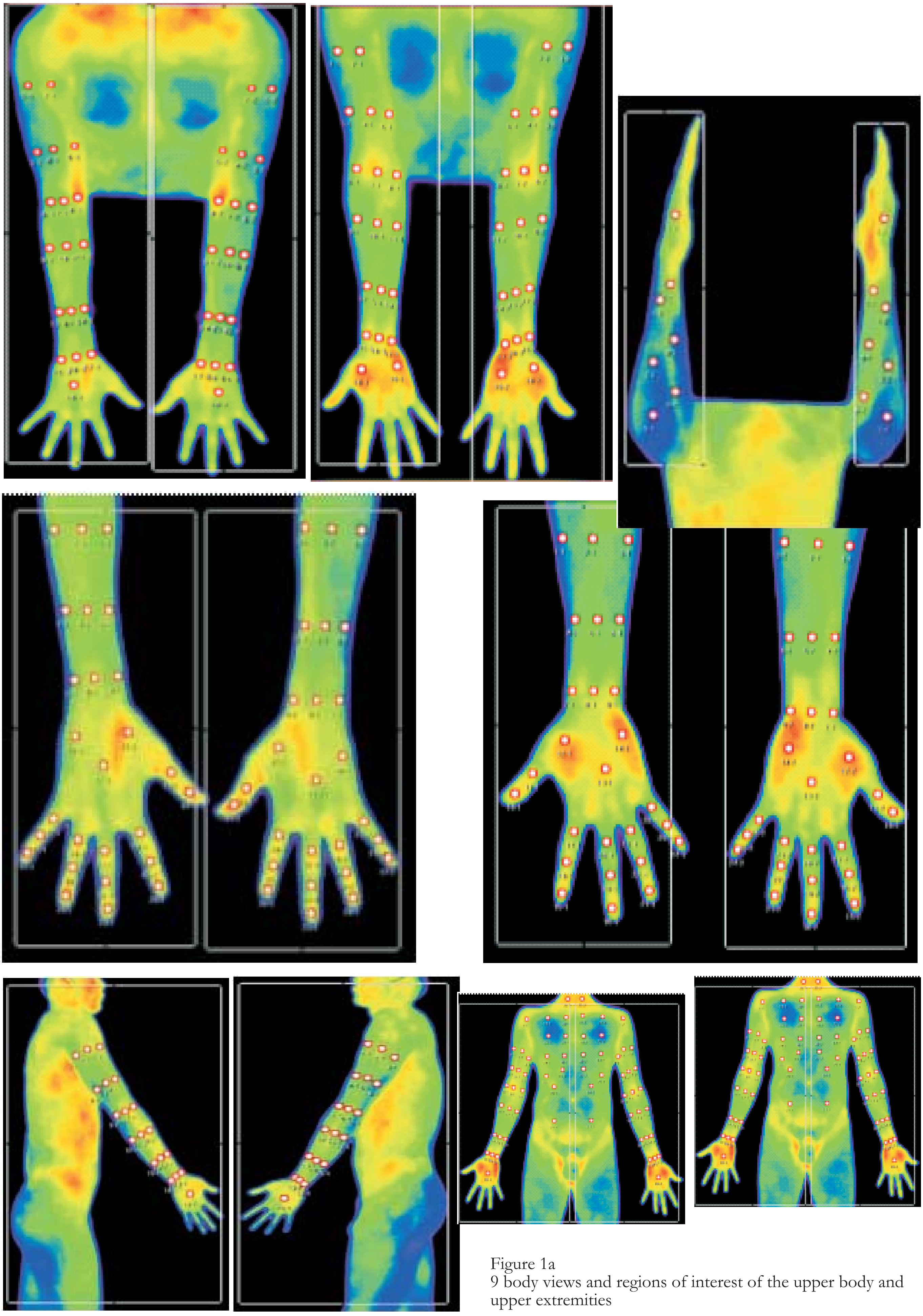

Figure 1a
9 body views and regions of interest of the upper body and upper extremities

Posture of lower back & buttocks defined 6 views, as

1) trunk posterior,

2) lower extremity posterior,

3) lower extremity, anterior,

4) lower extremity, right,

5) lower extremity, left, and

9) sole.

A reference temperature data base of normal Korean extremities was completed and divided into 20s, 30s, 40s, 50s, and 60s by age group. Total 150 reference standard data were finally obtained by dividing into male and female.

Figure 2 and Table 1 shows the reference temperature for mule, age group 40s, and the posture of arm and hand dorsum.

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 male, age group 40s in ROI 10-1 of Table 1, we have 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 expanded uncertainty of ΔT of male, age group 40s in ΔT between ROI 10-1 and 10-2.

DISCUSSION

Based on the two papers we published earlier, a reference standard temperature of at least 900 normal adults is required. We collect the data of 935 normal adults' thermographies duing last

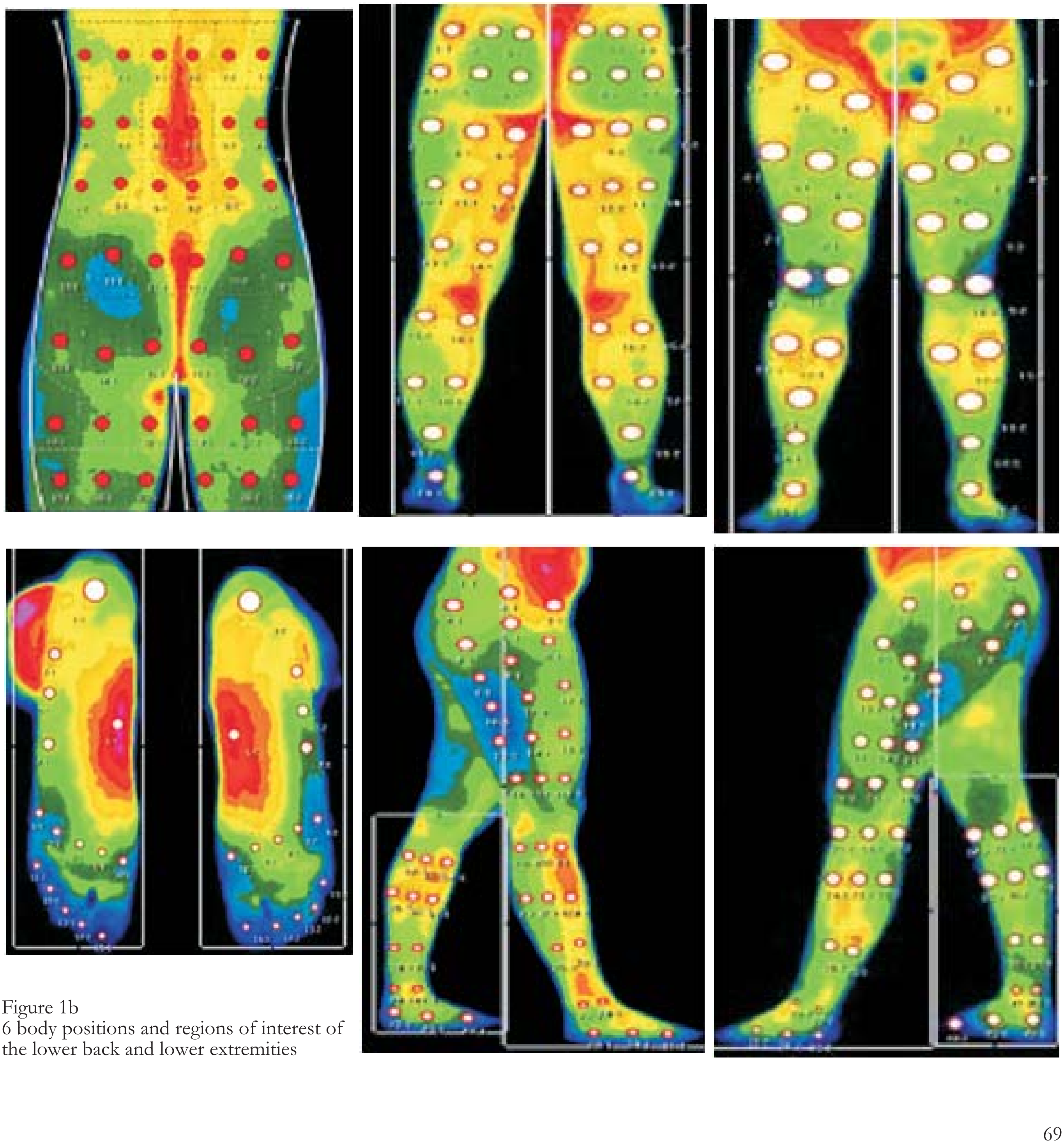

Figure 1b
6 body positions and regions of interest of the lower back and lower extremities

two year. We made the reference standard temperture data of the lower limb at 2017, and we add new development of upper extremity and revision of lower extremity at 2018. We noticed the uncertainty of average temperature of each ROI is very wide after research of 2017. But average ΔT of each opposite ROI was stable and smaller than average temperature in the study of 2018. We will have reference standard temperature data of all 22 posture of normal Koreans at the end of 2019. We 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 2018, reference standard temperature data of the normal Korean extremities were made using temperature data of 934 normal adult subjects with 15 views 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 normal Korean adults in 2019.

Figure 2
Average temperature and standard deviation of each ROIs and 95, 99% confidence interval of thermal differences of each opposite ROIs, age 40s, male, view: arm and dorsal hand

Average temperature (°C) (S.D)	ΔT (°C) (lower, upper) 95% confidence interval 99% confidence interval

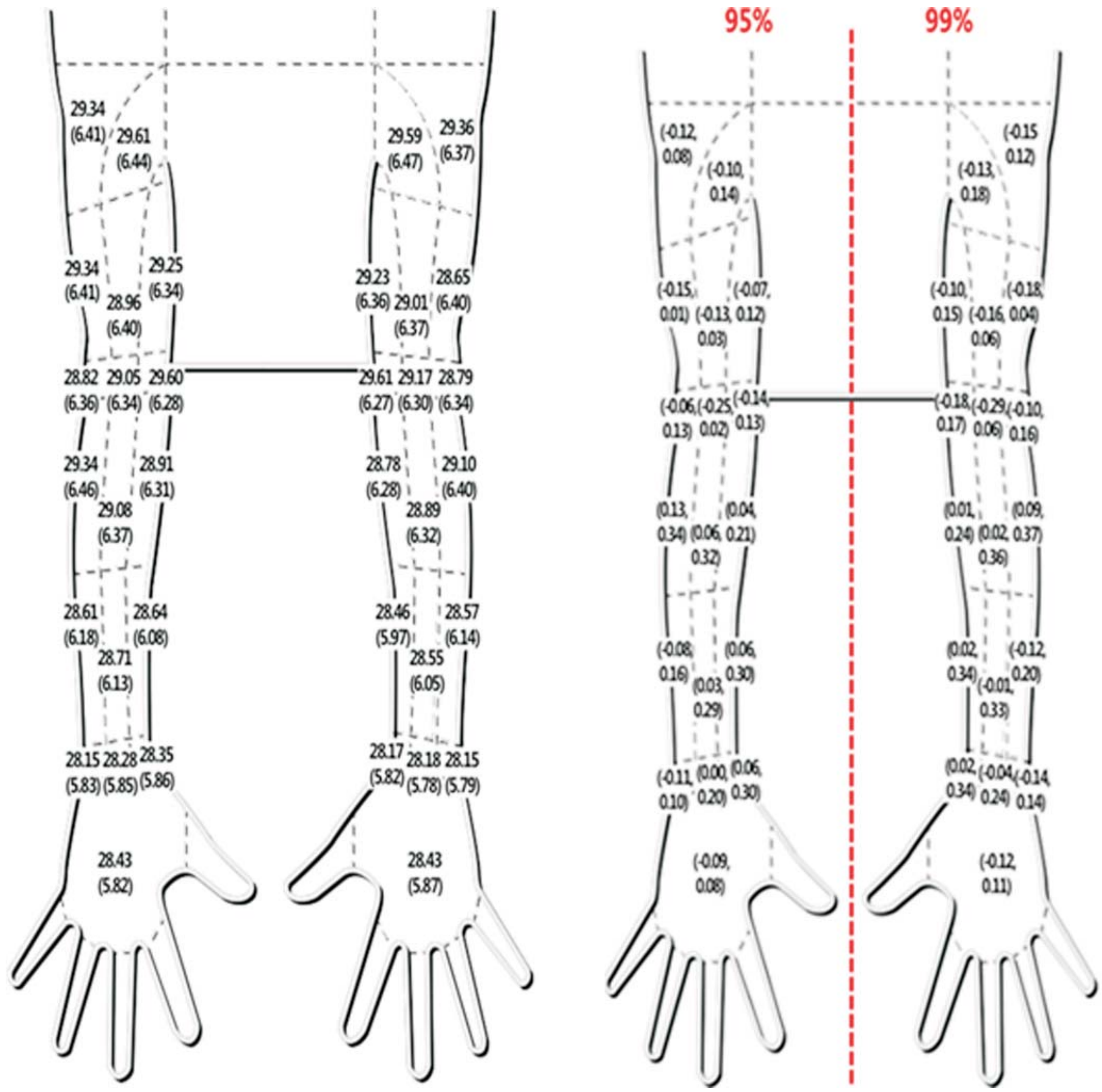

Table 1.
Example of reference standard temperature of normal Korean. Age group: 40years, View: dorsal arm and hand

(Unit:°C)

Age group	Sex	ROI	N	Mean	Std. deviation (SD)	expanded uncertainty	Left(1) - right(2)			
							Mean	Std. error (SE)	95% C.I. for mean	
									Lower	Upper
40-49	male	01.1_1	56	29.34	6.41	12.84				
40-49	male	01.1_2	56	29.36	6.37	12.76	-0.02	0.05	-0.12	0.08
40-49	male	02.2_1	56	29.61	6.44	12.90				
40-49	male	02.2_2	56	29.59	6.47	12.96	0.02	0.06	-0.10	0.14
40-49	male	03.3_1	56	28.58	6.40	12.82				
40-49	male	03.3_2	56	28.65	6.40	12.82	-0.07	0.04	-0.15	0.01
40-49	male	04.4_1	56	28.96	6.40	12.82				
40-49	male	04.4_2	56	29.01	6.37	12.76	-0.05	0.04	-0.13	0.03
40-49	male	05.5_1	56	29.25	6.34	12.70				
40-49	male	05.5_2	56	29.23	6.36	12.74	0.03	0.05	-0.07	0.12
40-49	male	06.6_1	56	28.82	6.36	12.74				
40-49	male	06.6_2	56	28.79	6.34	12.70	0.03	0.05	-0.06	0.13
40-49	male	07.7_1	56	29.05	6.34	12.70				
40-49	Male	07.7_2	56	29.17	6.30	12.62	-0.12	0.07	-0.25	0.02
40-49	Male	08.8_1	56	29.60	6.28	12.58				
40-49	Male	08.8_2	56	29.61	6.27	12.56	-0.01	0.07	-0.14	0.13
40-49	Male	09.9_1	56	29.34	6.46	12.94				
40-49	Male	09.9_2	56	29.10	6.40	12.82	0.23	0.05	0.13	0.34
40-49	Mal;e	10.10_1	56	29.08	6.37	12.76				
40-49	Male	10.10_2	56	28.89	6.32	12.66	0.19	0.06	0.06	0.32
40-49	Male	11.11_1	56	28.91	6.31	12.64				
40-49	male	11.11_2	56	28.78	6.28	12.58	0.13	0.04	0.04	0.21
40-49	nale	12.12_1	56	28.61	6.18	12.38				
40-49	Male	12.12_2	56	28.57	6.14	12.30	0.04	0.06	-0.08	0.16
40-49	Male	13.13_1	56	28.71	6.13	12.28				
40-49	Male	13.13_2	56	28.55	6.05	12.12	0.16	0.06	0.03	0.29
40-49	Male	14.14_1	56	28.64	6.08	12.18				
40-49	Male	14.14_2	56	28.46	5.97	11.96	0.18	0.06	0.06	0.30
40-49	Male	15.15_1	56	28.15	5.83	11.68				
40-49	Male	15.15_2	56	28.15	5.79	11.60	0.00	0.05	-0.11	0.10
40-49	Male	16.16_1	56	28.28	5.85	11.72				
40-49	Male	16.16_2	56	28.18	5.78	11.58	0.10	0.05	0.00	0.20
40-49	Male	17.17_1	56	28.35	5.86	11.74				
40-49	Male	17.17_2	56	28.17	5.82	11.66	0.18	0.06	0.06	0.30
40-49	Male	18.18_1	56	28.43	5.82	11.66				
40-49	male	18.18_2	56	28.43	5.87	11.76	0.00	0.04	-0.09	0.08

Table 2.
Summarized table of components of various uncertainties in this study. Age group: 40 years, Sex: male, View: dorsal arm and hand, ROI 10-1, Average Temperature

Name of uncertainty		Definition	Value
$u(T_{m,s})$		Standard deviation of measured value	6.41
$u(T_{m,rep})$		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
	$u(\delta Tr_{ef3})$	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 $u_c(T) = \sqrt{u^2(T_{m,s}) + u^2(T_{m,rep}) + u^2(T_{m,res}) + u^2(\delta T_{ref}) + u^2(T_{env})}$			6.42
Expanded Uncertainty, $U = k \cdot u_c(T)$ (95%, $k=2$)			12.84

Table 3.
Summarized table of components of various uncertainties in this study. Age group: 40s, Sex: male, View: dorsal arm and hand [(ROI 1-1) - (ROI 10-2)], ΔT

Name of uncertainty		Definition	Value
$u(T_{m,s})$		Standard deviation of measured value	0.46
$u(T_{m,rep})$		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
	$u(\delta Tr_{ef3})$	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 $u_c(T) = \sqrt{u^2(T_{m,s}) + u^2(T_{m,rep}) + u^2(T_{m,res}) + u^2(\delta T_{ref}) + u^2(T_{env})}$			0.72
Expanded Uncertainty, $U = k \cdot u_c(T)$ (95%, $k=2$)			1.45

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DYNAMICS OF LOCAL TEMPERATURE IN THE HANDS OF HEALTHY ADULT VOLUNTEERS UNDER THE INFLUENCE OF FROSTY AIR CONTACTING A COLD METAL OBJECT

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INTRODUCTION

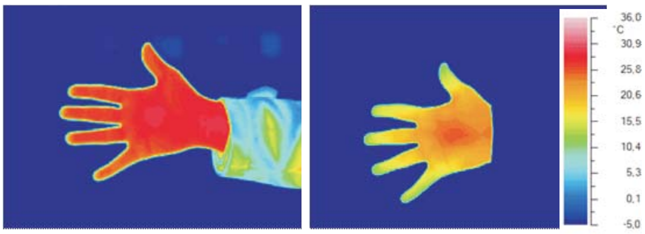
We have suggested that the use of a thermal imager camera can help in the modernization of winter mittens and winter gloves, which are used for contact with iron objects of large size, such as scrap and a wrench designed to remove the car wheels. Such products are very necessary for drivers of heavy vehicles and workers serving railway tracks in the Northern latitudes, because they have to use iron hand tools in the cold when unscrewing nuts and bolts when changing wheels in heavy vehicles and when replacing sleepers and rails. The fact is that in winter, use the usual, that is, "summer" wrenches. These keys are made of metal and are not covered with thermal insulation. Also, there are no special mittens to work with iron wrenches and scrap in the cold. So in the cold, modern wrenches turn into "refrigerators for hands" and when you take the wrenches in your hands, with mittens on, they take the heat out of your fingers and palms. Under these conditions, the fingers and palm can quickly cool down, which can cause frostbite. In this regard, to avoid frostbite fingers in the cold driver forced to repeatedly interrupt the work in order to timely warm frozen hands. However, it is still not known how modern winter gloves and winter mittens protect hands from freezing during prolonged contact with metal hand tools in frost weather. In particular, the dynamics of the local temperature in the fingers and palms of the hands of drivers in winter gloves and mittens with long-term holding of metal hand tools, for example, large wrenches, scrap, car towing cable during repair in the field in the cold was not studied. It is possible that information about the influence of cold hand tools on the dynamics of the local temperature in the hands will indicate us to the part of the mitt, which should be made warmer.

METHODS

On frosty days in January 2019, in Izhevsk and in Moscow studied the dynamics of local temperature of fingers in traditional mittens in 10 healthy adult volunteers (men aged 22 - 45 years). Standard fur mittens and double-layer wool mittens were used. As a model of an iron hand tool, a segment of an iron pipe with length 50 cm and outer diameter of 30 mm was used. The temperature was recorded first for 15 minutes in the cold without a hand tool and then after 30 minutes of finding a volunteer in a warm room, the temperature studies in the cold were carried out again for 15 minutes, but after the volunteer held a pipe in his hand. To register the temperature in the fingers, the mitt was removed from the hand for 5 seconds. In the first series of observations was invested the dynamics local temperature of the fingers of the hand in mitten in the cold without a pipe. In the second series of observations was invested the dynamics of the local temperature of the fingers of the hand in the mitt when taking a pipe in the cold. Infrared temperature monitoring of the fingers of the hand was performed using a thermo-Tracer TH9100XX (NEC, USA) imager. The air temperature during the study was -9 - 11°C and it was snowing and blowing a moderate cold wind. The temperature window of the thermal chamber was set in the range from +36- -5°C.

RESULTS

We investigated the ability of traditional mittens to protect from hypothermia the hands of adult healthy volunteers in the cold and confirmed that the mittens are still do not provide effective protection the thumb, index, middle, ring fingers and little finger from the effects of frosty air and cold hand tools. In our opinion, the thing is that the mitten is traditionally made of heat-insulating material, which has the same thickness in all elements of mitten. Therefore, all parts of modern mittens have the same thermal protection properties. However, the fingers, palm and wrist, even at room temperature have a different temperature. Moreover, in many situations the fingertips are colder than the palm and wrist. This is due largely to the fact that arterial blood, which is the main coolant in the hand, cools as it flows from the wrist to the fingertips. Therefore, fingers require more protection from hypothermia in the cold than the palm and wrist. Therefore, when the same intensity of taking heat from the entire area of the surface of the mitten the fingers is smaller than the palm of the hand and wrist are opposed to lowering the temperature inside the mittens. And that is why the frosty air and cold hand tools are a threat primarily to the fingers. As shown by our results, the blowing frosty air on the mitten with hand and/or contact of the hands, wearing mittens, with cold metal object comparable in size begins to cool hands from the fingertips. Moreover, if in cold and snowy weather to take a cold hand tool hand, dressed in a mitten and then hold the tool for several minutes in his hand, the fingers will cool faster and stronger, than without the tool. Results of our investigations showed that heavy snow and strong wind when the air temperature is -9 - -11° C to reduced the local temperature in fingertip in all phalanges of volunteers from level of +31 - +34º C to level of +11 +13º C after 5 minutes and to level of +9 - +10º C after 15 minutes (Fig.1).

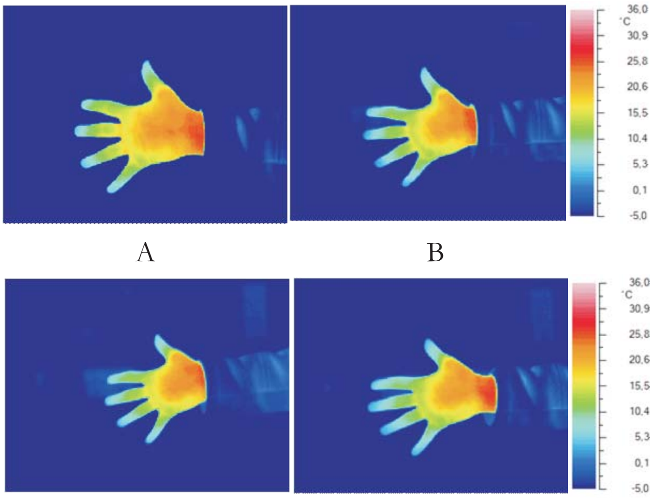


A B

Figure 1.
Infrared image of a hand (male at age of 22 years) indoor before going to the frost (A) and after 15 minutes of being in the frost in the double-layer wool mitten (B) when the air temperature is -9º C.

On the same day, at the same air temperature we investigated the local temperature in the fingers under influence the cold iron pipe. Results showed that cold iron pipe reduced temperature in fingertips from level of +30 - +34º C to level of +9 - +10º C after 2 minutes, and then to level of +4 - +6º C and to level of +1.5 - +2.5º C after 5 and 10 minutes of contact with the hand clad in the mitten. And after 15 minutes of contact with the cold iron pipe the temperature in the fingertips in 7 out of 10 volunteers dropped to level +0.5 - +1.5º C and in 3 volunteers local temperature in some fingertips dropped to level of -0,5 - 0º C. It was found that at the same time the local temperature decreased in all fingers along the entire length of the phalanges and even in the distal part of the palm. Zone of local hypothermia in the palm was located perpendicular to its length and had a width of about 2.0 - 2.5 cm. At the same time, after 5, 10 and 15 minutes of holding the iron pipe with the hand in the mitt in this part of the palm, the temperature decreased to an average of +16.2 ± 0.3º C, +14.1 ± 0.2º C and 12.4 ± 0.2º C (respectively) (P ? 0.05, n = 10) (Fig.2).

It was found that at 3 out of 10 volunteers had severe pain in the fingertips of the hand simultaneously with a decrease in local temperature to 0º C. Therefore, they released the iron pipe from their hands after 12 to 14 minutes from the beginning of its re-



A B

C D

Figure 2.
Infrared image of a hand (male at age of 22 years) in the presence in a hand in a double-layer wool mitten of an cold iron pipe lasting 5 minutes (A), 10 minutes (B), 12 minutes (C) and 15 minutes (D) when the air temperature is -9° C.

tention, since longer to keep this cold object was prevented by severe pain in the fingers due to their overcooling. In addition to this, we conducted a similar study of the dynamics of the local temperature in one of the co-authors of this report at an air temperature was of -27° C in conjunction with the North wind. It turned out that it is impossible to hold an iron pipe in the hand, dressed in a fur mitt, for longer than 15 minutes due to a decrease in the local temperature in the pads of the index, middle, ring fingers and in the little finger to 0° C and due to severe pain in them.

CONCLUSION

Modern winter mittens are produced with the probability of contact in the cold with cold objects and hand tools made of metal. However, the results of our studies have shown that in the field in frosty weather standard fur mittens and double-layer woolen mittens provide long-term heat preservation only in the palm of your hand. Mittens do not protect fingers from rapid hypothermia in the cold, regardless of contact with metal objects. Infrared thermography allows real-time to evaluate, as a mitten protects fingers and palms from hypothermia, when frost, snowfall and strong cold wind. Therefore, imager may be suitable for designers when upgrading winter mittens and winter gloves. For example, our results show that it is necessary to increase the thermal insulation of the mittens where the fingers are located.

FEVER SCREENING IR CAMERA EQUIPPED WITH BODY TEMPERATURE DATA

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INTRODUCTION

Many persons 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 infections 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 medial canthus temperature is the most suitable place to replace the tympanic membrane temperature, but there are no accurate measurements and no reference values. We conducted a study to construct a model that predicts tympanic membrane temperature from the temperature of the medial canthus or interbrow. We are also adding the data of febrile and non-febrile person's temperature of tympanic membrane, medial canthus, and ambient temperature. Now we want to introduce the devleoping state of fever screenign IR camera equipped with the body temperature data.

MATERIAL AND METHOD

Data were collected from NHIS Ilsan Hospital between 2017 and 2018. A total of 2,204 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. 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 the IR thermography. Finally, left and right tympanic temperature was measured. 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. Region of interest (ROI) of each thermography was measured at both medial canthus and interbrow with 4X4 pixel size (Figure 1). Existing statistical methods and various machine learing methods were used for the identification of febrile patients (≥37.5°C). The IR camera was 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.

We are willing to make the reference standard data of tympanic-medial canthus-ambient temperature, and to make the algorythm of febrile person detection using the results of various statistical and machine leraning methods

On the other hands, an IR camera company of Korea is involving the development of IR camera. The company is constructing the IR camera of autonomic focusing and measuring the temperature of both medial canthus and interbrow and considering the the efficient IR camera booth at the international airport .

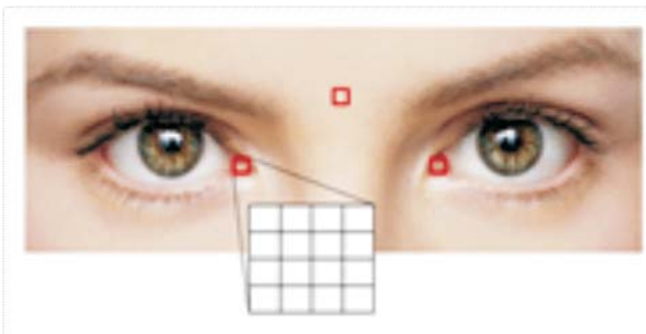

Figure 1.
Three ROIs (two medial canthi and interbrow) of temperature measurement of the face. The size of each ROI was 4X4 pixels.

Table 1
An example of reference standard of age between 40 and 59, ambient temperature between 26.1 and 27 °C and each gender.

≤25 ≤26 ≤27 >27

0-19 20-39 40-59 ≥60

Ambient T (26.1 ℃ ~ 27 ℃)		male				female			
Tympanic m. T	Variables	N	Avr.T	SD.	U	N	Avr. T	SD.	U
hypothermia (≤ 36.4 ℃)	Lt MC	6	34.92	0.54	2.1	0			
	Rt MC	6	35.0	0.38	1.94	0			
	Interbrow	6	34.13	0.28	1.88	0			
Normal (36.5 ℃ ~ 37.1 ℃)	Lt MC	84	35.68	0.47	2.02	45	35.65	0.48	2.04
	Rt MC	84	35.65	0.53	2.08	45	35.73	0.46	2.02
	Interbrow	84	34.9	0.6	2.16	45	34.78	0.58	2.14
Mild fever (37.2 ℃ ~ 37.9 ℃)	Lt MC	43	36.18	0.5	2.06	26	35.86	0.49	2.04
	Rt MC	43	36.11	0.5	2.06	26	35.87	0.59	2.14
	Interbrow	43	35.26	0.82	2.42	26	34.96	0.67	2.24
High fever (≥ 38.0 ℃)	Lt MC	7	37.0	0.56	2.12	2	37.4	0.42	1.98
	Rt MC	7	37.1	0.55	2.1	2	37.25	0.21	1.84
	Interbrow	7	36.33	0.46	2.02	2	36.75	0.07	1.8

RESULTS

Thirty two (32) kinds of reference standard temperature of tympanic membrane were developed with the collected data of the study population. Table 1 shows an example of reference standard of age between 40 and 59, ambient temperature between 26.1 and 27 °C and each gender.

Two kinds of statistical methods and 8 kinds of machine learning methods were used to predict the tympanic membrane temperature. The results of those methods was summarized at Table. 2.

DISCUSSION

We measured three ROIs of the facial IRT and estimated the similarity to the temperature of the eardrum. The results of reference standard temperature data shows resonable standard deviation(S.D.) and uncertainty. The accuracy of detecting febrile person (≥37.5 °C) is about 80 %. It is not suitable to satisfy the safety from contagious infectious disease.

And we noticed the exact area of medial canthus of ISO criteria from Professor Ring at the EAT 2018, London. His area of medial canthus is the skin area of the medial canthus. But our measured area was the medial canthus of cornea. This study was based on the temperature from the corneal medial canthus. Now, we are remeasuring the ROI of medical canthus from corneal medial canthus to skin medial canthus. We will revise the reference temperature data with the ROIs of exact ISO criteria (skin medial canthus) and adding more patients data of this year.

Statistical analyses and machine learning methods will use continuously until to get the satisfactory accuracy rate. An IR camera company is also devoting to make the autofocusing and measuring the three ROIs. Our algorithm will be equipped to this costructing IR camera.

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. Fever screenign IR camera equipped with body temperature data will be developed.

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Table 2
Summrized results of prediction rates of febrile person of various methods

	Name of method	Accuracy	Sensitivity	Specificity	PPV	NPV
Statistical Methods	**Logistic**	0.8134	0.8341	0.6967	0.94	0.423
	Linear Discriminant Model	0.8105	0.8239	0.7199	0.953	0.3714
Machine Learning Methods	**Neural Network Model**	0.8091	0.6738	0.8348	0.4309	0.9318
	Deep Learning (h2o)	0.7994	0.6348	0.832	0.4258	0.9203
	SVM(linear)	0.8135	0.8244	0.7461	0.9577	0.3701
	SVM(polynomial)	0.8033	0.8119	0.7361	0.9628	0.3116
	SVM(RBF)	0.8094	0.8231	0.7248	0.953	0.3676
	Tree Model	0.8118	0.8303	0.7186	0.9448	0.4026
	Random Forest Model	0.816	0.8382	0.697	0.9375	0.4414
	Adaptive Boosting	0.8155	0.7193	0.8322	0.4106	0.9469

IN PREGNANT WOMEN WITH THROMBOPHILIA THE FINGERS LOCAL TEMPERATURE MAY INDICATE THE STATUS AND PROGNOSIS OF FETUS´ HEALTH

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INTRODUCTION

Thrombophilia in women often leads to termination of pregnancy and miscarriage of the fetus. The fact that pregnancy in women with thrombophilia contributes to the development of hypercoagulation, which increases the likelihood of clogging blood vessels in the placenta. This can cause premature placental abruption, fetal hypoxia, fetal death and abortion. Therefore, to prevent miscarriage, anticoagulants of direct action, namely heparin and its derivatives, are everywhere introduced into the body of a pregnant woman. However, practice shows that their use in women with thrombophilia does not exclude abortion and fetal death. However, treatment of pregnant women with heparin is considered to be correct, and the low efficiency of heparin is explained by the complexity of its individual dosing.

The fact is that the true cause of fetal death is intrauterine hypoxia, not hypercoagulation of blood plasma in a pregnant woman. In this case, the body of a pregnant woman can very accurately feel the appearance of intrauterine fetal hypoxia and the degree of hypoxic disorders in it. In our opinion, there are markers of hypoxia in the body of the fetus that can get into the mother's blood. When a substance of hypoxia markers from the fetus appears in the mother's blood, the mother's body can react to them as markers of its own hypoxia, since these markers are universal. It is most likely that the mother's body will react to markers of hypoxia from fetus by the activation of the mechanisms of adaptation to its own hypoxia. Previously, we have shown that the mechanisms of adaptation to hypoxia in women and mans are detected by infrared thermography on the specific dynamics of local temperature in the fingers 1..

At the same time, it may well be that the elimination of hypoxia in the fetus is able to eliminate the mechanisms of adaptation to hypoxia in his mother. Therefore, we suggested that the use of a thermal imaging camera can improve the accuracy of assessment of the health status of the fetus in the mother with thrombophilia. Such safe control over the health of fetus with thrombophilia is especially necessary in the second half of pregnancy and immediately before childbirth. The fact is that during this period the life of the fetus becomes more and more dependent on oxygen. However, it is still unknown how the dynamics of the local temperature of the fingers and toes in women with thrombophilia during pregnancy and during treatment with heparin. It is possible that information about the dynamics of local temperature in the hands and/or in the feet will help us to identify pregnant women whose fetal life needs to be urgently saved with the aid of oxygen and/or Caesarean section.

METHODS

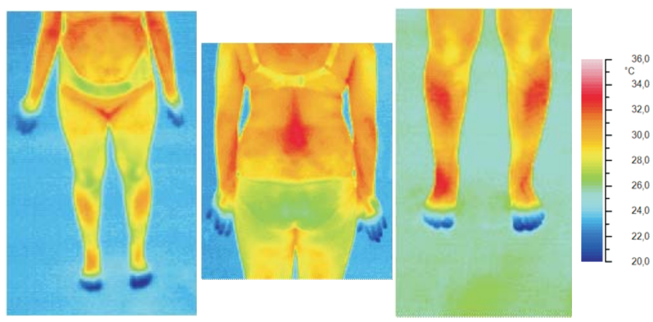
The dynamics of finger temperature using infrared thermal imager was studied in 8 pregnant women with thrombophilia and in 5 pregnant women without pathology. Pregnant women with thrombophilia were 26-43 years old. The average age of pregnant women was 34.4 ± 7 years. Before our study, pregnant women with thrombophilia lost 1 to 4 pregnancies without fetuses. Each sick woman lost an average of 2.14 ± 0.07 pregnancies. The study included pregnant women with diagnosed trombophilia who was invited to the women's consultation office during pregnancy 9 - 28 weeks in January-February 2019. Prior to our study, all women with thrombophilia were given low molecular weight heparins. The drugs were administered under the traditional control of plasma coagulation system activity. Previously, before this study, all these women had 1 to 6 pregnancies, which did not end with the birth of the fetus, because they were prematurely interrupted. Therefore, none of them could give birth to a living child. The control group consisted of 5 pregnant women at the age of 28 -32 years of age, without any pathology. Infrared monitoring of hands and foots temperature was performed by the use of Thermo Tracer TH9100XX thermal imager (NEC, USA). Ambient temperature of the examination room was 23 - 26°C, the temperature window of the thermal camera was set to the range of 20 to 36°C. Infrared thermography was performed 30 minutes after the beginning of adaptation of stripped women to room conditions. 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 results of our study showed that the local temperature in the fingers and toes of all 8 pregnant women with thrombophilia differed from the temperature in the fingers of the corresponding limbs in 5 pregnant women from the control group. All 5 women in the control group had warm hands and feet both immediately after undressing and after 30 minutes of their adaptation to room temperature. It turned out that all pregnant women with thrombophilia had areas of local hypothermia in the phalanges of the toes and/or feet and hands simultaneously in the right and left extremities both immediately after undressing and after 30 minutes of staying without clothes in room conditions at air temperature +23 - +26º C (Fig. 1).

We found that the local temperature in all fingers and toes of all pregnant women with thrombophilia was 7 to 8º ? lower than the temperatu re in the middle of hand and middle of foot areas (respectively). In addition, some pregnant women with thrombophilia had fingertips of hands and toes 1.5-2.0 degrees colder than room temperature. Zones of local hypothermia occupied areas from 1/3 to 3/3 of the length of the phalanges. It was discovered that women with smaller areas of local hypothermia, are located only at the tips of the fingers, coagulograms of venous blood was evidence of slight hypercoagulable of plasma. On the other hand, it has been shown that women with the large size of the zones local hypothermia, are located throughout the length of fingers in the hands and feet, coagulograms of venous blood indicated a significant hypercoagulable state in plasma.

The coldest were the fingertips in the hands and feet. The values of local temperature were in the range +20,5 - +23,7ºC in the fingertips of the hands and in the range +20.0 - +21.4ºC in the fingertips of the feet. At the same time, the local temperature values



A B C

Figure 1.
Infrared image of pregnant women with thrombophilia after 20 minutes of staying without clothes in room conditions at a temperature of +24 - +26º C. A -front view of the torso with arms and legs, B - rear view of the torso with arms, C - front view of the legs

in the middle of the palms were in the range +28.3 - +29.2ºC and in the middle of the foot were in the range +28.0 - +33.0ºC.

Thus, the pregnancy for more than 9 weeks in women with thrombophilia for reduces the blood supply to her fingers and toes. This occurs due to reflex spasm of blood vessels and is a universal reaction to the lack of oxygen. Since there was no hypoxia in the body of a pregnant woman, we assume that the mother's body reacts in response to hypoxia of her fetus. Moreover, the results of our study show that in women with thrombophilia, in which the areas of local hypothermia occupy more space in the hands and even capture the distal part of the palms, the coagulogram shows the presence of very pronounced hyperncoa gulation of blood plasma.

The results show that during pregnancy in a pregnant woman with thrombophilia can be found a symptom of universal adaptive response to hypoxia in the absence of hypoxia in her body.

CONCLUSION

Thus, pregnancy in a woman with thrombophilia can force her body to rebuild and include universal compensatory mechanisms to protect her from hypoxia, which indicate a complicated pregnancy. The beginning of the mother's adaptation to hypoxia may indicate the possibility of hypoxia in the fetus. In all probability, one of the first symptoms of the beginning of adaptation to hypoxia in a pregnant woman with thrombophilia is local hypothermia in the fingertipss of her hands and feet 2..

Infrared thermography reveals the early adaptive reaction of the body of a pregnant woman to a complicated pregnancy. This adaptation reaction is similar to the reaction of adaptation to ischemia, hypoxia and blood loss, that is, it is universal. We assume that the body activates it not only during apnea and ischemia, but also in any other acute critical conditions. Therefore, we hope that the findings may provide the basis for developing a method to assess the stability of the pregnancy at women with thrombophilia.

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A NEW METHOD AND SOFTWARE FOR SCREENING OF SKIN PATHOLOGIES USING COLD PROVOCATION AND THERMAL IMPEDANCE ANALYSIS

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IR thermography becomes more and more popular and useful in medical quantitative screening and diagnosis. It is due to the progress in IR techniques, new developed algorithms of data processing, methodologies and protocols. In parallel, there is enormous step ahead in electronic and computer science technologies. All these developments make possible to improve thermal measurements, especially of biomedical subjects in dynamic states. Recently, IR thermography has become more accurate, stable and faster. In consequence it allows the quantitative temperature measurements to be more repetitive and reliable, especially in active medical thermography experiments [1,16-20].

One of the possible methods of advance data analysis after cold provocation and registration long sequence of thermal images is presented in this abstract. It is based on the concept of thermal impedance presented in frequency domain [2-13]. Thermal impedance is known and effectively used in many applications [1-4,15].By using Laplace transform, the analysis is shifted to frequency domain. It leads to treat the results of thermography measurements in terms of a transfer function (thermal impedance). Such transfer function, well known in automation, electronics and mathematics is often used to characterize the dynamic objects. In case of medicine, a tissue is a multilayer object. Delivered power excites the object and induces the thermal process with varying temperature. By detailed analysis of the thermal response and thermal impedance, it is possible to differentiate the pathological and physiological states of a tissue [2-4,15-20].

As a result of the proposed methodology, the large sequence of thermal images is compressed to a few quantitative parameters. The most used are the thermal time constants, thermal capacitances and resistances [14,22]. It has to be underlined that tissue is a multilayer, nonhomogeneous, non-stationary structure, where blood flows and perfusion occurs. All these facts make the analysis more difficult, especially in applications of quantitative classification of different medical cases [16-20].

The proposed method was implemented in Matlab 21.and in parallel in Java software and is offered to the researchers under freeware license. Selected images for a patient suffering from psoriasis are in fig. 1. The thermal impedances as well as the time constants for healthy and unhealthy skin are presented in fig. 3 and 4. Finally, in fig 5 the distributions of time constants are presented for the giver regions of interest.

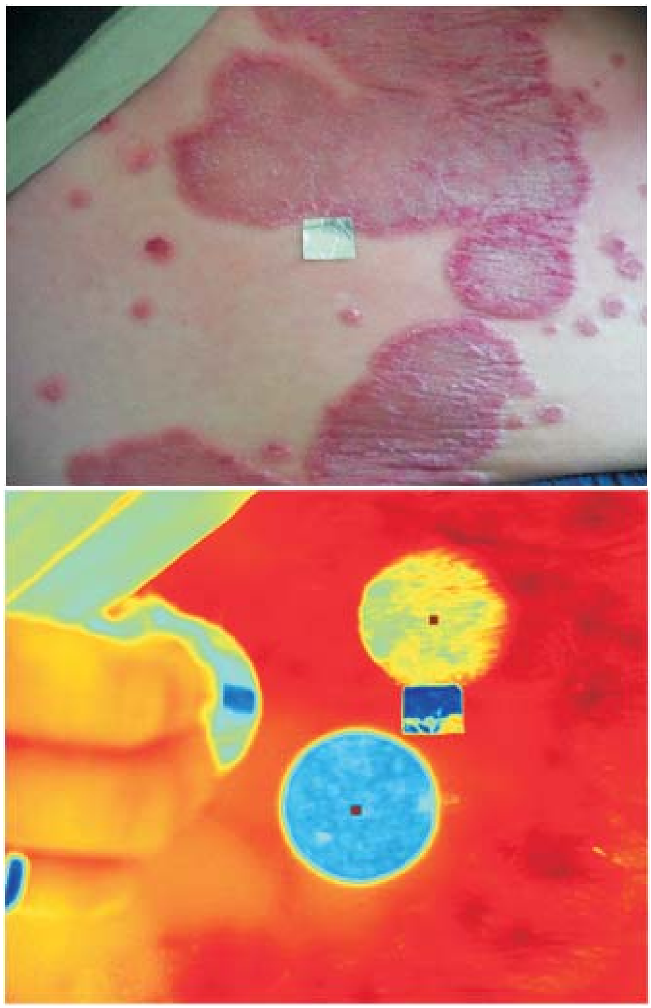

Figure. 1.
Thermal provocation for a patient suffering from psoriasis using a cold metal block

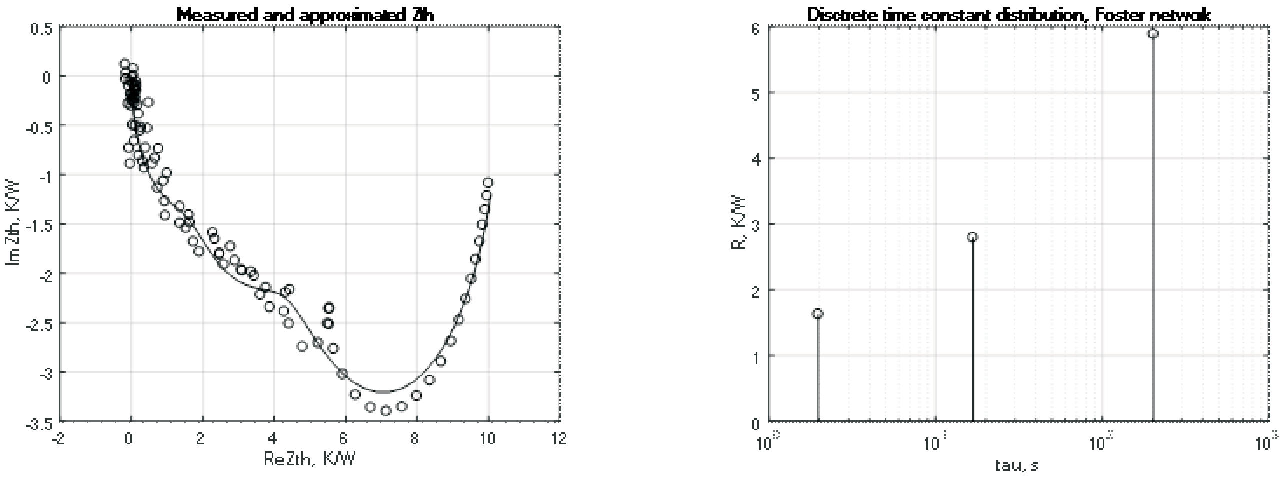

Figure 2
Thermal impedance and time constants distribution of the unhealthy parts of the skin

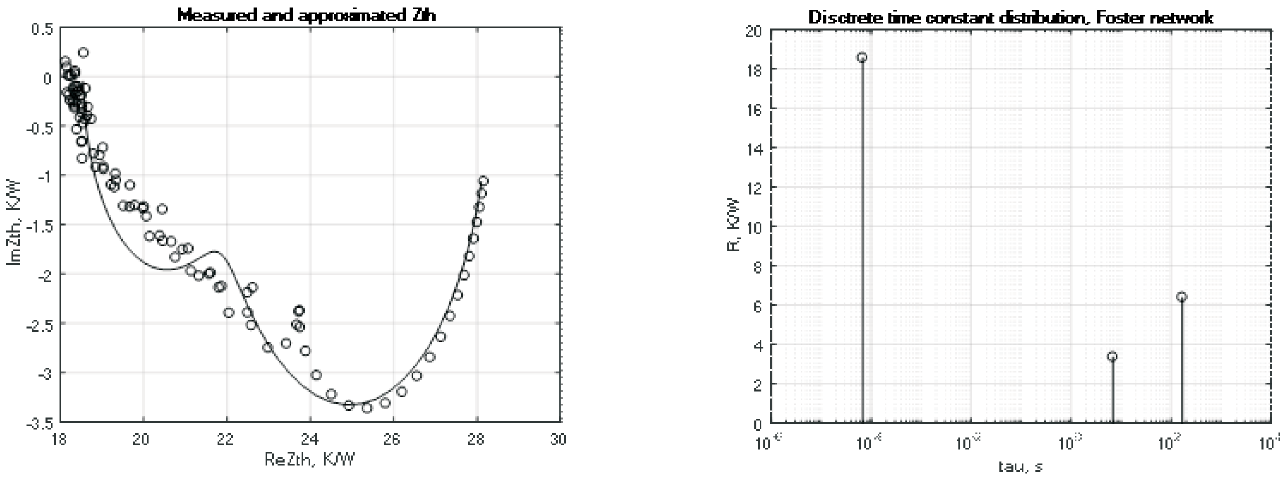

Figure 3
Thermal impedance and time constants distribution of the healthy parts of the skin

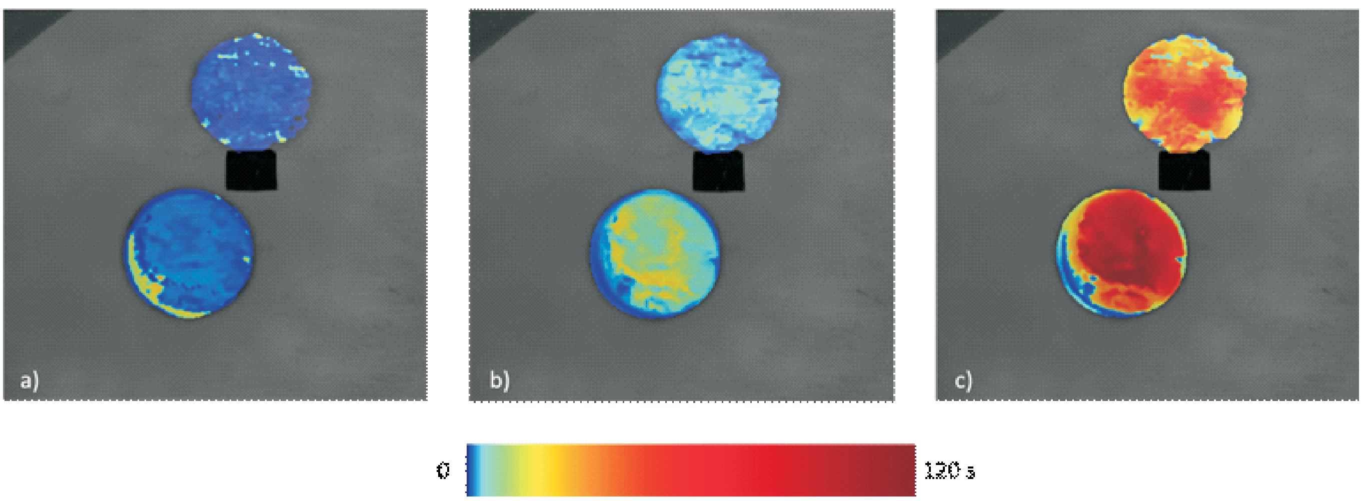

Figure 4
Distribution of thermal time constants for the healthy and unhealthy parts of the skin using Foster network approximation of 3-layer skin tissue model

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SIDE CURVATURE SPINE EVALUATION IN CHILDREN BY USING THERMAL IMAGING AND X-RAY

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Diagnosis of curvature of the spine, in particular lateral curvatures, is still one of the more complicated tasks of orthopedics. It is related to the complex structure and complexity of the functions performed by the axis of our body - the spine. In addition, the difficulty in diagnosing the spine is additionally associated with little characteristic clinical symptomatology, which is particularly evident in lateral scoliosis.

The aim of this research is to assess the suitability and development of a research methodology based on the use of infrared thermography as a non-invasive screening test for spinal curvatures in children and adults. The developed method will allow to observe changes in the curvature of the spine at an early stage of abnormality, which will contribute to a faster decision on the need for rehabilitation, and consequently will lead to a faster recovery of the patient.

It is worth noting that currently, an X-ray is used as a screening test in spine diseases in children and adults

This type of test is invasive due to the presence of ionizing radiation. The children and adolescents who are in developmental age are particularly vulnerable to harmful ionizing radiation necessary for the diagnosis of spinal curvatures.

The research was carried out at the Health Center in Mikolów in the trauma and orthopedic surgery clinic under the supervision of Dr..med. Lukasz Teister. The study involved 80 children (girls: 51, boys: 29) aged 4-17 years with diagnosed lateral scoliosis of the spine with different values of the determined Cobb angle.

Parameters obtained from thermographic studies were additionally subjected to analysis, aimed at establishing a statistically significant correlation with the size of the curvature of the spine, so-called Cobb angle determined on the basis of X-ray results.

Preliminary results obtained from the conducted research may indicate the justified use of infrared thermography as a non-invasive method of early detection of lateral spinal curvatures in children and adolescents. The obtained correlation of selected temperature parameters with the Cobb angle value may suggest that thermal imaging of the back in children can be used as a screening technique for lateral spinal curvatures.

The use of a non-invasive technique that is thermal imaging in monitoring and diagnosing lateral spinal curvatures in developmental age, can be an alternative method to currently used diagnostic tests, using ionizing radiation, not indifferent to our health. However, deeper research and development of guidelines and a general protocol for this type of research are necessary.

USEFULNESS OF BLOOD SUPPLY VISUALIZATION BY INFRARED THERMOGRAPHY AND INDOCYANINE GREEN FLUORESCENCE ANGIOGRAPHY FOR INVASIVE ESOPHAGECTOMY PERFORMED AFTER ISCHEMIC GASTRIC CONDITIONING

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INTRODUCTION: One of the most common reasons for esophagectomy is a malignant tumor. Resection of the esophagus is an extensive procedure with frequent and serious postoperative complications. One of them is anastomotic leakage. The visualization of proper blood microcirculation gastric conduit used as esophageal replacement might potentially reduce occurrence of anastomotic leakage. Visualization od blood flow can be managed by indocyanine green (ICG) fluorescence angiography (ICG-FA). This imaging method is based on the fluorescing effect of intravenously administered indocyanine green (ICG) at near infrared wavelength when absorbed a light with specific wavelength. Other possibility for assessing blood flow in gastric conduit is using Infrared thermography (IRT). This imaging method works in a different wavelength specter and provides a thermal image. Aim of the study is to compare both imaging techniques for visualization of blood supply of gastric conduit used for esophageal replacement.

METHODS: Presented study shows first results of using both imaging methods in esophagectomy. The infrared camera used was a Workswell WIC 640. IRT and ICG-FA (Novadaq Technologies) were performed during esophagus tumor resection surgery. Using both of the imaging methods we assessed ischemic part of gastric conduit which could not be used for anastomosis

RESULTS: Comparing both imaging methods was done subjectively during surgery. The mean temperature difference between ischemic and well perfused part of gastric conduit was 1.7°C. The region of interest (ROI) was selected by polygon tool for warm and cold area (Figure A shows line between areas). A temperature profile by line fitted from end to end of part of gastric conduit shows graph on Figure B. Figure C show visualization of blood perfusion by ICG-FA on same part of the esophagus. Data of both imaging methods were recorded in same time.

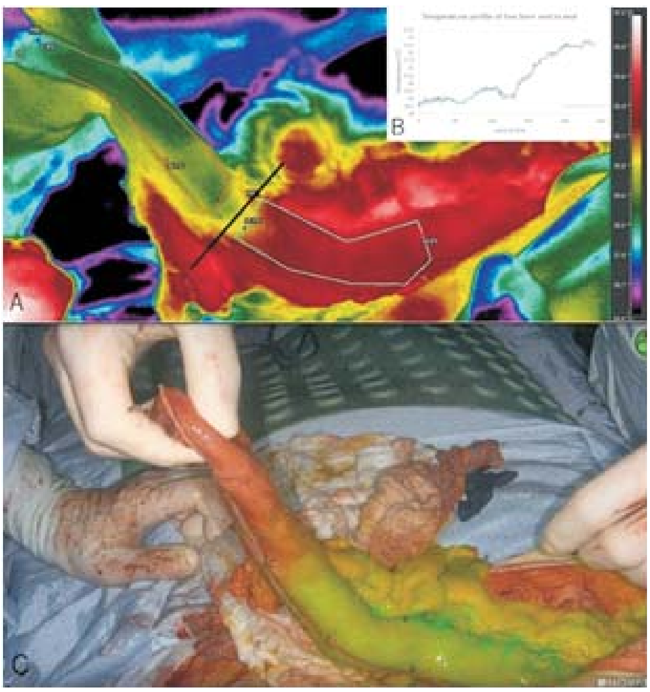

Figure
Images recorded by IRT and ICG-FA techniques

DISCUSSION: Both of the imaging methods determined ischemic part of gastric conduit very well. By subjective comparing these methods (IRT - Figure A and ICG-FA - Figure C) we observed similarity in assessing of borders between ischemic and well perfused area of gasric conduit. It is evident that the IRT provides an easy to use and non-invasive method for determination of good blood microcirculation with same result as the ICG-FA technique. Benefits of IRT technique when compared to ICG-FA technique are non-invasivity and lower operational costs. On the other hand the ICG-FA technique is more simple due to fast real time evaluation because of green visualization of circulation.

ACKNOWLEDGEMENTS: Study was supported by grants MUNI/A/0996/2018 and MCR-RVO (FNBr, 65269705)

EVALUATION OF HYPERBARIC OXYGEN THERAPY EFFECTS IN HARD-TO-HEAL WOUNDS USING THERMAL IMAGING AND PLANIMETRY

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Hyperbaric oxygen therapy (HBOT) uses higher than atmospheric pressure air or pure oxygen on the human body to facilitate wound healing.

Usually planimetry and oximetry are used in the quantitative evaluation of hyperbaric oxygen therapy effects. However, a non-invasive, quick and easy to perform method of evaluation is still required. Thus, the main aim of our study was to assess the usefulness of thermal imaging in evaluating the effects of hyperbaric oxygen therapy on hard-to-heal wounds and to compare these results with that of parameters obtained from planimetry.

The studies were performed at the Burn Treatment Center in Siemianowice Slaskie. The study included 60 patients (28 women and 32 men) aged between 48 and 82 who had hard-to-heal wounds localized on their lower extremities. Thermal images were carried out during three stages (I: 0-10 sessions, II: 10 to 20 and III: more than 20 sessions of HBOT) of the treatment cycle, before entering and after leaving the hyperbaric chamber, respectively. Simultaneously with thermal imaging the plannimetry parameters were measured. The distribution of the skin surface temperature was monitored by using of a Thermovision Camera E60 calibrated by black body.

The results showed that the temperature of the regions of interest decreased with the number of completed treatments, which suggests an improvement in microcirculation through neovascularization. Moreover, temperature differences between the regions of interest surrounding the wound decreased with the duration of treatment.

It is important to continually monitor the progress of wound healing, as this allows for proper modification of treatment and a rapid response to clinical deterioration. In addition, routine evaluation during treatment should play a key role in the diagnosis, monitoring and prognosis of chronic wounds. It seems reasonable to combine both thermovision and planimetry techniques, because these two techniques allow skin to be evaluated in terms of structural changes and functional parameters respectively.

FACIAL PALSY - CONTACTLESS THERMOGRAPHIC STUDY

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INTRODUCTION: The n. intermediofacialis palsy is a neurological disease that binds to the head region. The manifestations of this disease are mainly facial paralysis, motor impairments in the face and bulbar musculature, reduced tongue taste and reduced tear formation. The quantity and type of disease manifestations depend on the type of palsy (e.g. central or peripheral); symptoms are asymmetrical and lateral. The etiology of this disease is the partial or complete lesion of the seventh cranial nerve - n. intermediofacialis. The causes of this palsy are several - it may be especially Bell's palsy (non-specific coldness, wakefulness), infectious inflammation, tumor, mechanical trauma, and others less common. Diagnosis of the disease is based on a patient's history, neurological examination including EEG and EMG, CT and MRI, biochemical examination1.

The AIM of the study is to evaluate the possibility of use of the infrared thermal camera as a supplementary diagnostic/imaging tool for this type of disease. Authors want to find and describe the change of surface facial temperature depending on the type and degree of the palsy.

METHODS: The study included 7 pediatric patients at the age of 5 to 17. All of them were diagnosed with palsy of n. intermediofacialis with no apparent cause ('lesion e frigore'). All patients were hospitalized, and vitamin B and corticosteroids were applied as the treatment.

The thermographic measurement was performed (by) using a Workswell WIC640 infrared thermal camera at standard room conditions from a distance of one meter. The images were evaluated by QuickReport and CorePlayer software. Lateral face temperature symmetry was compared; facial areas with maximal temperature changes were searched.

RESULTS: The result of the research consists of 7 sets of patients thermoimages. Same patients were monitored repeatedly, at least twice within two weeks. Six patients showed a difference in the temperature of the sick and healthy half faces. One patient did not show the temperature difference. The measured temperature differences between the half face are not uniform in the patient´s group. Four patients showed a warmer healthy face; two patients showed a warmer sick face. The observed maximum difference of average temperature between sick and healthy half face was 1.4 °C.

DISCUSSION AND CONCLUSION: It is impossible to draw a final conclusion because of the small number of obtained data at the present time. It is necessary to collect more data from a larger group of patients. There are still a lot of factors to be cleared. It is impossible to distinguish the influence of lumbar puncture and corresponding immobility of a patient on face temperature at this moment, for example. The different degree of palsy is also necessary to take into account when evaluating. However, the thermal effect of n. intermediofacialis palsy is visible using the infrared camera. This indicates the promise of the possible use of infrared camera imaging for the following studies.

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INFRARED THERMOGRAPHY: A NEW APPROACH FOR EXAMINATION OF BRACHIAL PLEXUS INJURY

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INTRODUCTION: Brachial plexus injury is a peripheral paresis with the incidence that varies from one to two cases for every 1000 live births [1]. It involves injury to any nerve of the brachial plexus during a birth. The consequence of this complication can usually be the reduced mobility of the upper limb or its part when the rehabilitation process is not done properly.

Muscle action is the most important source of metabolic heat. Long-lasting injuries appear on thermogram as hypothermic areas which may be caused by reduced muscle contraction, and therefore reduced heat production [2], which should be possible to observe using the Infrared Thermography Imaging (IRT).

METHODS: The IRT examinations were performed on three male patients at 3 months, 7 years and 13 years. All three patients have been suffering from the birth brachial plexus injury of upper type. The IRT monitoring, using the Workswell WIC 640 thermal camera, was always accompanied by neurological examination and electromyography (EMG) measurement afterward.

The IRT examination of upper limbs was always realized before the standard EMG examination of a patient in order to prevent the stress from an inconvenient EMG. The region of measurement interest (ROI) was patients' arms and the fossa cubitalis region. To be able to compare results between left and right arm, patients were monitored from a distance of 1 m in order to capture both arms on one image. The IRT examination was done in standard room condition.

RESULTS: With validity for all 3 measurements, it was found that the hand affected by plexus brachialis injury was always colder in the fossa cubitalis region. The difference between the ROIs average temperatures of healthy and injured fossa cubitalis region varied from 0.8°C to 1.3°C. Further, it was confirmed that the average surface temperature of the injured arms along musculus biceps brachii and musculus brachioradialis were also colder than of the healthy arm.

Another interesting finding is that the difference between the average temperatures of healthy and injured arms was quite similar (+- 0.5°C) for all three patients even if they were of different age.

CONCLUSION: The IRT technique, used for this application, can serve as a supplementary examination technique to EMG method since it can be very convenient and safe even for small children.

First results, that were obtained from the measurements, confirmed the fact that the difference of ROIs average temperatures (arms and the fossa cubitalis region) were high enough to confirm that the surface temperature of the injured arm is lower.

Further, in the continuing study if should be answered, if there exists a relation between the temperature difference and the severity degree of brachial plexus injury as well as between the temperature difference and assumption of future brachial plexus injury development.

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EFFICIENCY AND VALIDITY OF SEVERAL THERMAL IMAGING CAMERAS USING AN AUTOMATIC SOFTWARE FOR THE SELECTION OF ROI.

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INTRODUCTION. One of the technical factors that can influence the thermographic results in humans is the type of camera that is used for recording the thermograms. Nowadays, the use of automatic data acquisition tools reduces the subjectivity during data collection when selecting the regions of interest (ROI).

AIM. The main objective of the present study is to compare and analyse the skin temperature (Tsk) results obtained by three different cameras, being all the thermograms analysed by a software that automatically select the considered ROIs.

MATERIAL AND METHODS. 26 volunteer students of the Faculty of Physical Activity and Sports Sciences - INEF (age: 22.3 ± 2.71 years; body mass: 70.55 ± 8.58 kg; height: 175.9 ± 8.34 cm) were assessed under the same ambient conditions and in a random way with three thermal cameras with different technical characteristics (FLIR, Sweden): FLIR ONE Pro (160x120 pixels), FLIR T335 (320x240 pixels, produced in 2009) and FLIR T530 (320x240 pixels, produced in 2018). Later, 80 ROIs from the whole body were obtained automatically by the software Thermohuman (Thermohuman, Spain) to obtain average Tsk, number of pixels and asymmetries of contralateral ROIs. Additionally, the results of the three cameras were compared using as a reference a surface with known temperature, that was inserted in the background.

RESULTS. The mean Tsk values obtained by Thermohuman software from FLIR ONE Pro camera are were not significantly different from those obtained with higher performance cameras (FLIR 335 and FLIR 530). In fact, the camera with worse performance (validity) was the FLIR 335. Surprisingly, the number of pixels obtained by the Thermohuman software from the thermograms of the FLIR ONE was between 3 and 4 times higher than those obtained from the T335 and T530 cameras. Finally, the calculation of the asymmetries neutralized the influence of the quality of the camera in the evaluation of the considered ROIs.

CONCLUSIONS. Using a software for automatic selection of the ROI, the mean Tsk results obtained from the thermograms of the FLIR ONE Pro camera are comparable those obtained with cameras of a higher resolution. Considering the lower resolution and the higher number of pixels of the thermogram, the FLIR ONE Pro imager must interpolate the registered pixels to increase the final number of pixels of the thermogram. Doing a periodical calibration of the cameras is an important factor for the validity of thermographic results.

THERMAL PROFILE OF ELITE MASTERS ATHLETES AND THE INFLUENCE OF ATHLETIC COMPETITION ON THEIR SKIN TEMPERATURE

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INTRODUCTION. Masters Athletes are considered as an example of successful aging, even when their ability to perform physical effort and recovery is changing. That is why Masters Athletes health screening should be assessed by a variety of tools with a multidisciplinary approach to maximize their potential and minimize risk of injuries.

Aim. The aim of the study was to define the thermal profile of the European Masters Athletes and looking for possible differences depending on the specific variables of each subject (eg. gender, event, age).

MATERIAL AND METHODS. Study enrolled 143 European Masters Athletes (101 men and 42 women), aged 49.99 ± 27 years. During the data collection, six images of the lower limb of the athletes were recorded (3 in anterior view and 3 in posterior view of each subject: 2 photographs before the warm-up, 2 photographs after the warm-up and 2 more photographs at the end of the competition).

RESULTS. After warming-up, the Tsk of the master athletes significantly fell an average of -0,99ºC in the anterior view and -0,67ºC in the posterior view, which suggest a correct adaptation to exercise. Immediately after competition, the Tsk of the master athletes slightly decrease by -0,08ºC on the anterior view and -0,17ºC on the posterior view. Those reductions were not significant for all the regions of interest.

CONCLUSIONS. The practice of athletic competition affects the skin temperature of the European Elite Masters Athletes. The condition of the lower limbs of the athletes participating in the EMACi were quite good; in general, much better than other for people of the same age.

APPLICATION OF THERMAL IMAGING IN ATHLETE'S THERMOREGULATION MECHANISMS ASSESSMENT AFTER DYNAMIC TRAINING

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Nowadays thermal imaging in sports is becoming more and more popular. It is a non-invasive and easy to perform method, which may find use in sportsman training evaluation and thermoregulation mechanisms monitoring.

Aim of this research was to find if infrared thermography may help in sportsmen efficiency monitoring. The cyclists body average surface temperature was analysed after short and dynamic training - the 3-minute test on rowing machine.

The imaging was performed before and directly after the test and also in 10 minutes' intervals till 50 minutes after the training. Moreover, the athletes were imaging two times - before and after

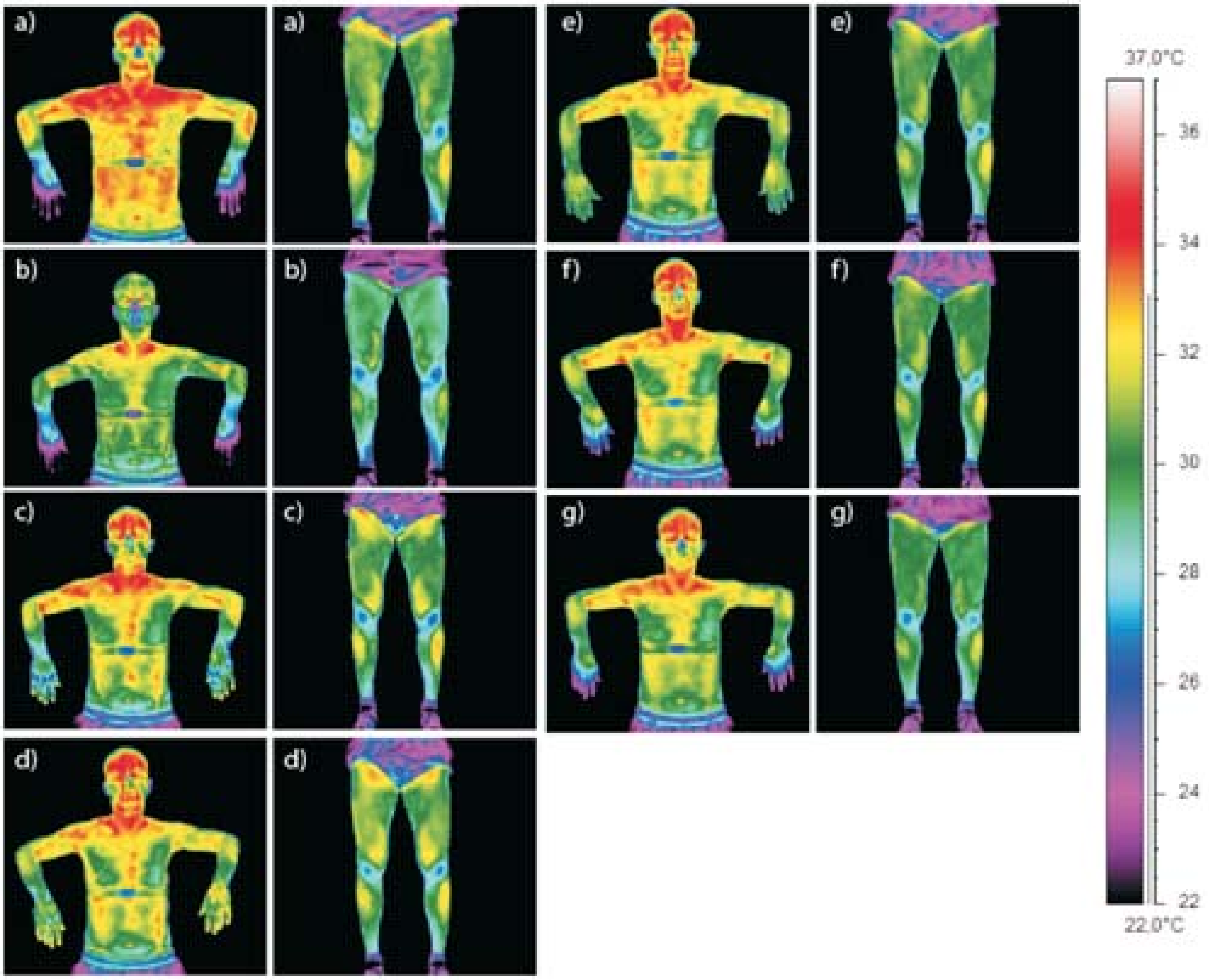

Figure 1.
Thermal images of representative subject made a) before, b) directly after, c) 10 minutes, d) 20 minutes, e) 30 minutes, f) 40 minutes and g) 50 minutes after training.

one-year training season. Research group include a 9 subjects, male cyclists. Moreover, aside from temperature distribution the heart rate, body pressure, weight and height are measured too.

The representative subject's thermal images are shown in Figure 1.

It is easy to see that immediately after the exercising the temperature in decreasing and 10 minutes after the training it start to increasing. The thermal images made between 20 to 50 minutes after the training indicate some temperature changes in specific regions. However, the overall changes of body surface temperature are not clearly visible.

For deeper analysis the average surface temperature was calculated and the trends of temperature changing are visible.

The temperature is increasing from the directly after measurements till 20 minutes after the training. The next results (for 30, 40 and 50 minutes after training) show the decreasing trends of surface temperature.

It seems that post-training thermoregulation mechanisms may be analysed by using the thermal imaging.

Short,but dynamic training can show surface temperature trends, because of sweating avoid.

A NOVEL TOOL BASED ON LIQUID CRYSTAL CONTACT THERMOGRAPHY FOR ADJUNCTIVE BREAST CANCER DETECTION USED BY MEDICAL PROFESSIONALS

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Breast thermography remains at the forefront of clinical research [1]. The physiological principle of the application of contact thermography in medical imaging diagnostics is a so-called "dermo-themal" effect, in which cancer cells have a higher metabolic rate [1]. A process of neo-angiogenesis induces strong hypervascularization around the tumor core, which can occur even at the very early stages of cancer development. It has been shown that even in a 1 mm diameter tumor, there are enough pro-angiogenic factors to generate completely new vasculature [2,3]. This phenomenon leads to permanent, localized, intraglandular temperature anomalies, which can be observed on the surface of the examined organ [4].

Thermography, albeit being explored in the past as an alternative tool, has sparked new interest due to its new advancements using liquid crystals. One such device is Braster Pro (Braster S.A., Szeligi, Poland). The sensitivity of such method has been shown in pilot trials, reaching a sensitivity of 82% and specificity of 87%. Preliminary data also shows that a result of BI-RADS 4A (from ultrasonography=USG) with a positive result in contact thermography increases the likelihood of breast cancer more than twofold. BI-RADS 4A (from USG) with a negative result in contact thermography decreases the likelihood of breast cancer more than threefold.

Braster Pro also boasts innovative results in women below 50 years of age, who do not fit into national screening programs. These programs aim to effectively reduce mortality from breast cancer. However, in younger individuals, below 50, no standardized recommendations exist for regular breast imaging. Most of these patients have dense breasts, and thus the most frequent suggested diagnostic examination is breast ultrasound. The negative association is the false negative rate for breast ultrasound alone ranges from 0.3% to 47% and is heavily operator dependent, whereby the experience of the operator is directly correlated with the imaging result5. Braster Pro, in addition to breast ultrasound, has the potential to decrease the false negative rate, while retaining a high sensitivity and specificity. The recommended algorithm for using Braster Pro with breast ultrasonography is presented in table 1.

In light of the regulations set forth by the AAT [6] and US Food and Drug Administration[7], the method is recommended for use as a complementary tool to ultrasound and mammography. By no means should Braster Pro be used as a sole diagnostic modality in the detection or diagnosis of breast cancer. In the absence of any recommendations for breast cancer screening in the younger population, Braster Pro used alongside breast ultrasonography may be a potential solution for this patient population. The safe, painless, radiation-free and reliable medical device is investigated in larger clinical trials now on 3000 patients, with results tentatively pending.

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Table 1
Algorithm for using Braster Pro as an adjunctive tool to USG

Braster Pro	Ultrasonography USG	Procedure
+	+*	Further diagnostics according to standard of care
+	-	Control visit in 6 months If the result from Braster Pro is + USG should be performed - in 6 months perform Braster Pro & USG
-	+**	Further diagnostics according to standard of care
-	-	Control visit in 12months with Braster Pro &USG

+ positive result, - negative result

* BI-RADS 3 – upgrade to BI-RADS 4a, invasive diagnostics

** BI-RADS 3 – follow up in 6 months, in accordance with BI-RADS guidelines

THERMAL EVALUATION OF SKIN TEMPERATURE DUE TO BRACHYTHERAPY TREATMENT ON BASAL CELL CARCINOMA

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The aim of this study was to study the thermal response on brachytherapy treatment cycle for patients with suffered from Basal Cell Carcinoma.

MATERIAL AND METHODS: The whole study group consisted of 39 patients. All of them were examined with use of thermal imaging. Each patient has been confirmed with a Basal Cell Carcinoma of the skin by histopathological examination before the study. Patients have been treated with HDR brachy-t herapy in Maria Sklodowska - Curie Memorial Cancer Center and Institute of Oncology, Gliwice branch. Therapy consist of 9 fractions of irradiations and each delivered a dose of 5 Gy at affected area. Examined lesions were localized on the head - chicks and forehead.

Thermal imaging was done for each patient before treatment and one month after ending treatment. Thermal imaging was performed on the cancer side and also on reference area - symmetrical side of body. All studies were performer with thermal camera Flir Systems E60.

RESULTS: Performed studies showed two types of skin thermal response on the BCC before brachytherapy. Most of them (60%) had positive gradient - higher temperature of the lesion and lower temperature of the surrounding. The rest of the patients indicated opposite thermal map of the skin with cancer. It seems that lower temperature of skin affected by cancer may be caused by cancer cell growing inside (deep in the skin) leading to either necrosis of surface tissues or taking metabolic pathways of healthy tissue. An increase of temperature in cancer lesion area after brachytherapy treatment for that patients was observed and it can be caused by start of regeneration of new healthy tissue what was observed one month after finish of the therapy.

CONCLUSIONS: It may be concluded that thermography may provide additional diagnostic information as well as information about the therapeutic effects in brachytherapy of basal cell carcinoma. However, confirmation of the results obtained is required for a larger group of patients.

CORRELATION OF ISOTHERMS WITH ISODOSES FOR PATIENTS WITH BREAST CANCER TREATED BY RADIOTHERAPY

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Nowadays, there is an alarming increase of the incidence and mortality connected with breast cancer. Modern medicine offers a range of specialised diagnostic method, which can be adjusted to the shape and stage of the breast disease and which allows to confirm or exclude the presence of pathological cancer tissue. A mammography is currently one of the most effective method of early breast cancer diagnosis however it uses X-ray so it is not fully safe. The second method is ultrasonography (USG), which is dedicated to women aged 20-40. Due to the fact that ionizing radiation is harmful to the patient's health, it became clear and obvious that modern medicine needs new, additional diagnostic methods that would not entail the risk of side effects, but would provide us with the same percent accuracy of diagnostic results, repeatability of tests and patient's comfort. Those techniques should be the complementary to existing and currently used diagnostic method and should be effective and helpful with detecting the very early stages of breast cancer. Infrared thermography (thermovision) is surely one of this kind of method.

That is why this studies are focused on correlation of isotherms derived from thermal images with isodoses describing treatment plan for patients with breast cancer treated by radiotherapy.

The study included 5 patients diagnosed with breast cancer who were qualified for radiotherapy treatment. The age range of the patients was 50-70 years (average age: 64.4 ± 5.94). All patients were monitored each week of treatment, during the whole radiotherapy process. The measurements were performed under strictly defined conditions (the patients remained without clothing to the waist about 20 minutes) and were preceded by the process of acclimatization at the temperature of the measuring room. Thermal imaging was done by using the thermal camera FLIR System E60. In the treatment planning system (TPS) the plan was created for each patient. Spatial dose distribution in the patient's body was obtained and presented by the isodoses (lines connecting points with the same dose values). The following areas from the treatment planning system were plotted on the thermograms: target (tumor area) and isodose: 50 Gy, 40 Gy, 30 Gy, 20 Gy and 10 Gy. For the purposes of the analysis, it was possible to combine some regions (50 with 40Gy, 30 with 20Gy), due to the differences in temperature values in the connected areas were not significant.

Obtained results indicated correlation between magnitude of dose represented as isodose and the treated skin temperature. Moreover preliminary analysis showed repeatable increase of the mean temperature in the irradiated area in the third week of treatment.

THERMAL IMAGING FOR MONITORING CHEMOTHERAPY IN BREAST CANCER PATIENTS - PRELIMINARY RESULTS

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Thermal imaging is a non-invasive method that measures infrared radiation released from patient's body. Infrared radiation is directly related to metabolic activity of the tested tissue and most tumors have bigger metabolic activity compared to healthy tissues. Therefore, the cancerous tissue emits more infrared radiation than the surrounding healthy tissue what can be clearly seen and evaluated from thermal image.

The basic diagnosis in breast cancer screening is mammography and ultrasound examination. However noninvasive technique that can bring similar or additional information for physician is still needed. Especially when consider metabolism changes due to some treatment techniques i.e. chemotherapy.

That is why this work focused on using the thermal imaging combined with liquid crystal thermography as a complementary methods to structural examinations such as ultrasound and mammography in the diagnosis and evaluation of the chemotherapy effects in breast cancer treatment.

The whole study group consisted of 50 patients of Maria Sk?odowska - Curie Memorial Cancer Center and Institute of Oncology, Gliwice branch. All of them were examined with use of thermal imaging. Each patient has been confirmed with breast cancer and treated by chemotherapy.

Thermal imaging was done for each patient before and after treatment as well as one month after ending treatment. Thermal imaging was performed with thermal camera Flir Systems E60. In similar way liquid crystal thermography (BRASTER) was used.

Performed studies showed significant thermal asymmetry between healthy and affected breast. Moreover the dynamic metabolism changes due to chemotherapy were observed. Observed changes will may be qualitative evaluated on the thermal images, however the new quantitative parameters are searching for chemotherapy effects evaluation.

It seems that thermal imaging may be a good control tool during chemotherapy treatment.

PRELIMINARY STUDIES OF IMPACT OF CRYOTHERAPY ON THERMAL MAPPING OF BODY DURING ENDURANCE TRAINING

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To improve physical fitness of the body, athletes used wellness treatment, such as cryotherapy. In this work we present thermal mapping of ski-runners during endurance training for efforts on threshold strength, before and after cryotherapy treatment.

Our research subjects were students from Katowice Physical Education Academy, who are also part of the Polish national team cross-country skiing (4 man skiers). Our volunteers were in end part of preparatory period of season. The skiers thermograms were registered, before, immediately after and 10 minutes after endurance training including one hour running on the treadmill, on a threshold load. To get thermal images we used camera Flir System E60 with resolution of camera 320 x 240 pixels and with sensitivity 0.05 K, for each participant we made 9 thermograms, 5 at front and 4 from the rear. All measurements were performed in a similar way to the Glamorgan Protocol including thermal imaging in its medical standards. Subjects performed this training twice: the first time before the treatments in cryogenic chamber and the second after the treatments involved 10 visit in cryogenic chamber. Obtained images were analysed by using a ThermaCAM TM Researcher Pro 2.8 SR-3. We divided whole body surface to 22 zones corresponding to the location of the individual muscles. Obtained temperature values were analysed in Statistica 12 witch $p<0.05$. We observe temperature drop in muscles of upper body immediately after training in contrast to muscles of lower body where temperature rises (exception tibialis anterior), both before and after cryotherapy. It can be influenced by a different degree of muscle training. Temperature distribution of body after training showed some significant changes in lower and upper part of body. 10 minutes after exercise we observe similar drop tendencies of temperature in upper body, in lower body that changes were smaller and in most cases reverse when we compare before and after cryotherapy.

Cryotherapy treatment changes slightly temperature of muscles of lower part of body in comparison with thermal mapping before wellness treatment. Probably this can be caused by changes in the behaviour of blood vessels.

News in Thermology

European Association of Thermology website: usage data for the period 9th February-9th April 2019

The new EAT website www.eurothermology.org was launched early in January 2019. The web pages have been extensively redesigned so that they can be viewed equally well on a smartphone, tablet, or desktop browser. The site includes information about the EAT Board, a news page, links to upcoming events, and a gallery of photos from past congresses. There are also details about EAT thermography courses, and information about how to join the Association.

All the pages on the website include a small section of HTML code which allows the EAT to see basic anonymous data about visits to the site via the Google Analytics app. At the EAT Board meeting on 13th April, I presented website usage data for the period 9th February - 9th April 2019. These data are reproduced below: columns represent usage data for the period 11th March - 9th April 2019, whereas the blue bars show comparative data for the previous 4-week period 9th February - 10th March 2019.

Figure 1 shows the users of the website grouped by country. For both periods, we had most visits from users in the United States. South Korea was the only other non-European country to feature. Users from the United Kingdom, Portugal and Poland were the most common European visitors to the site.

Figure 2 shows how the new users who visited the website came to find us. During both periods, most new users reached us via "organic search": i.e. they were directed to our pages after entering a search term in a search engine. A significant number of new users also came via the "direct" route: they knew the website address and typed it directly into a browser (or had the address stored in a browser "bookmark"). There were only a few new users who followed a link on another website to reach us ("referrals"), or who linked through to us from social media (e.g. our Twitter account profile).

Figure 3 demonstrates that most visitors used a desktop browser to view our website, although there were also a small number of views on smartphones.

Figure 4 analyses the "bounce rate" of visits to our website. This is the proportion of users who only view one page and do not go on to explore the website further. The bounce rate was lowest for users who reached us via a search en-

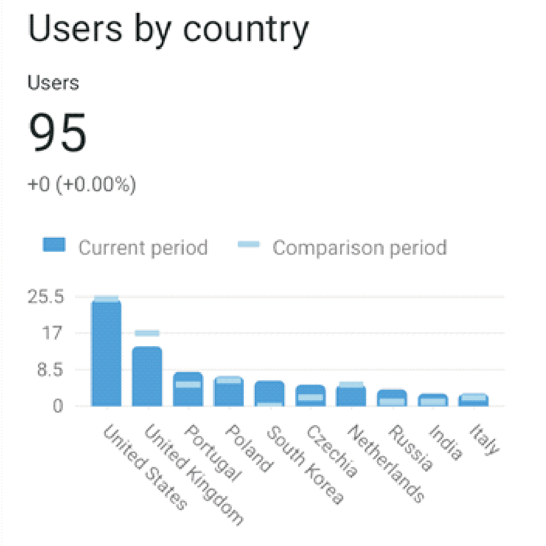


Figure 1
Website users by country

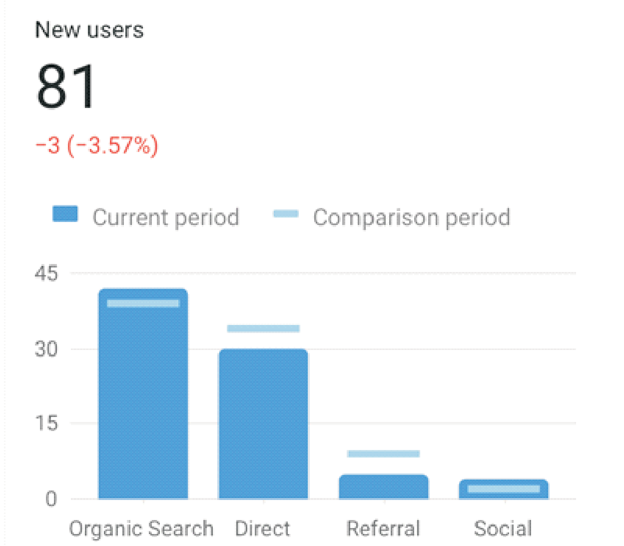


Figure 2
New users by route to the website

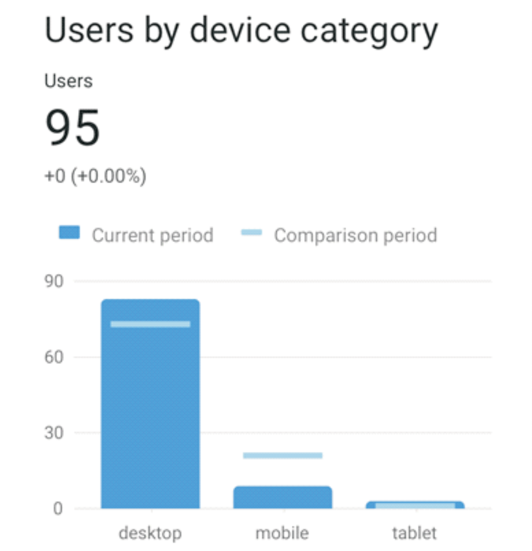


Figure 3
Users by browsing device

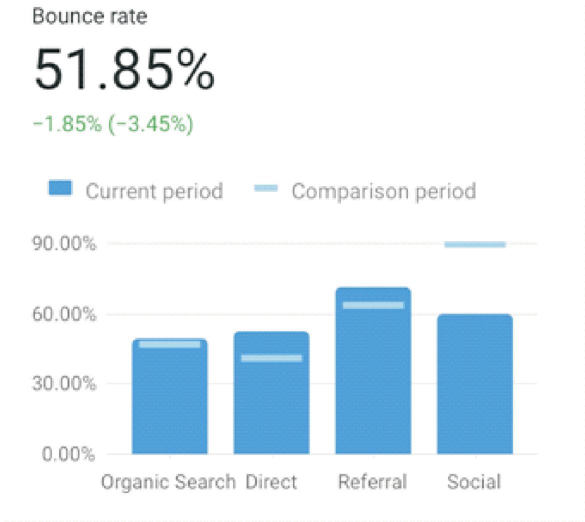


Figure 4
Bounce rate of visits

gine, and highest for those clicking through to us from referring websites and social media.

Finally, figure 5 lists the number of views for each page on the website. During the second 4-week period there were 600 page views in total, and all pages increased the number of views compared to the previous period. The most popular pages (other than the Home page) were our Events and News pages.

These data show that www.eurothermology.org has become and established and frequently visited source of information about the EAT on the worldwide web. The EAT will continue to use Google Analytics data to teach us about how our site is used, as we expand and improve the content.

Kevin J. Howell, President, European Association of Thermology

Page views by page title

Page title	Page views
Total	600 +145 (+31.87%)
Home - EAT	227 +49 (+27.53%)
Events - EAT	75 +28 (+59.57%)
News - EAT	51 +20 (+64.52%)
Thermology International - EAT	45 +3 (+7.14%)
Join us - EAT	40 +6 (+17.65%)
Education - EAT	39 +5 (+14.71%)
Board - EAT	37 +15 (+68.18%)
Gallery - EAT	36 +8 (+28.57%)
About us - EAT	29 +10 (+52.63%)
Statutes - EAT	21 +1 (+5.00%)

Figure 5
Page visits

2019

23th-27th June 2019

SPIE Optical Metrology Conference Munich

Venue: International Congress Center, Munich, Germany

The conference 11060 - Optical Methods for Inspection, Characterization, and Imaging of Biomaterials

includes a session on
"Thermal imaging for Medicine and Bioengineering"

Session Chair:
Giuseppe Chirico, Univ. degli Studi di Milano-Bicocca (Italy)

Paper 11060-35
Margaux Bouzin, Mario Marini, Amirbahador Zeynali, Univ. degli Studi di Milano Bicocca (Italy); Laura Sironi, Laura D'Alfonso, Francesca Mingozzi, Francesca Granucci, Giuseppe Chirico, Maddalena Collini, Univ. degli Studi di Milano-Bicocca (Italy)
Photo-activated thermal imaging at subdiffraction resolution

Paper 11060-36
Kurt Ammer, European Association of Thermology (Austria)
Sources of uncertainty in the evaluation of thermal images in medicine (Invited Paper)

Paper 11060-37

Guillaume Baffou, Institut Fresnel (France)
Toward single cell thermal biology

Further information on the conference website at
https://spie.org/EOM/conferencedetails/optical-methods-inspection

22th - 24th July 2019

HEFAT 2019
14th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics in Wicklow, Ireland

Venue: POWERSCOURT HOTEL RESORT & SPA, Wicklow, Ireland

Contact Information

For all queries pertaining to abstracts, manuscripts and the conference programme:

CONFERENCE CHAIR
Prof. Josua Meyer
University of Pretoria, South Africa
Josua.meyer@up.ac.za

29th-30th August 2019

2nd International Symposium on Sensors and Instrumentation in Internet of Things Era (ISSI) in Lisbon, Portugal

Special Session_TG
Thematic session on thermal measurements

This session will welcome presentations about thermal IR sensors and cameras, as well as the use of IR technology in medical and industrial applications. This Special Session is mainly focusing on:

- IR technology applications both, medical and industrial
- Thermal sensors
- Thermal simulation software
- Electromagnetic thermal effect
- IR based Maintenance
- Non-destructive tests
- IR Spectroscopy
- Image processing software
- Security and Surveillance
- Remote sensing
- Drones sensing

Session Chairs:

Joaquim Mendes & Ricardo Vardasca,
University of Porto, Portugal

Important Dates

Call for Special Sessions - May 19, 2019

Call for Workshops - May 19, 2019

Papers Submission Deadline - May 19, 2019

Paper Submission is active. Please see Authors Instruction and visit IMS-ISSI'19 EDAS.

Paper Acceptance Notification -June 15, 2019

Camera Ready Paper Submission - July 7, 2019

Registration - July 17, 2019

furter information at https://sens-in-net.tech
or contact
Octavian Postolache
ISCTE-IOL and Institute de Telecomunicacoes
Email: opostolache@lx.it.pt

6th-8th September 2019

9th Annual Scientific Session of the American Academy of Thermology in Atlanta, Georgia plus Physician`s Interpretation Course on 6th September

Venue: Emory Conference Center & Hotel, Atlanta, Georgia

Registration via https://annualmeeting.aathermology.org

16th -19th September 2019

AITA 2019- Advanced Infrared Technology and Applications in Florence, Italy

In the 15th AITA edition, special emphasis will be given to the following topics:

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

Submission

Authors are invited to submit an extended abstract of up to 4 pages prepared according to MDPI Proceedings template. Please download the LaTex package or the Word template. Extra pages might be subject to additional fees.

All the contributions should then be submitted in PDF format by using Easychair submission system:
http://www.easychair.org/conferences/?conf=aita2019

Publication

Selected papers will be published in a Special Issue of Applied Optics, OSA, which has already published selected papers during the last three editions of the workshop.

The Proceedings of the Workshop will consist of the abstracts of all the papers, including those selected for the Special Issue, and will be published electronically in a dedicated issue of MDPI Proceedings; each abstract will be provided with a digital object identifier (DOI) and will be submitted to relevant indexing databases.

Important Dates

- Paper submission: May 31st, 2019
- Notification of acceptance: June 17th, 2019
- Camera-ready submission: July 1st, 2019

For details, please refer to the workshop website:
http://ronchi.isti.cnr.it/AITA2019.

16th -18th October 2019

International Conference VipIMAGE 2019 - VII ECCOMAS THEMATIC CONFERENCE ON COMPUTATIONAL VISION AND MEDICAL IMAGE PROCESSING in Porto, Portugal.

Chairs: João Manuel R. S. Tavares & Renato Natal Jorge, Universidade do Porto

Venue: Axis Vermar Conference & Beach Hotel, Porto, Portugal.

Possible Topics (but not limited to)

- Signal and Image Processing
- Computational Vision
- Medical Imaging
- Physics of Medical Imaging
- Tracking and Analysis of Movement
- Simulation and Modeling
- Image Acquisition
- Industrial Applications
- Shape Reconstruction
- Segmentation, Matching, Simulation
- Data Interpolation, Registration, Acquisition and Compression
- 3D Vision
- Machine Learning, Deep Learning and Big Data
- Virtual Reality
- Visual Inspection
- Software Development for Image Processing and Analysis
- Computer Aided Diagnosis, Surgery, Therapy, and Treatment
- Computational Bioimaging and Visualization
- Telemedicine Systems and Applications

Invited Lecturers

- Aurélio Campilho, Universidade do Porto, Portugal
- Danail Stoyanov, University College London, UK
- Daniela Iacoviello, Sapienza University of Rome, Italy
- João Paulo Papa, Universidade Estadual de São Paulo, Brazil
- - Jos Vander Sloten, KU Leven, Belgium
- - Wafa Skalli, Arts et Métiers ParisTech, France

Thematic Sessions

Proposals to organize Thematic Sessions under the auspicious of VipIMAGE 2019 are welcome.

The proposals should be submitted by email to the conference co-chairs (tavares@fe.up.pt, rnatal@fe.up.pt).

Accepted Thematic Sessions

- Cardiovascular, Cerebrovascular and Orthopaedic diseases: Imaging and Modelling
- Advances and Imaging Challenges in Micro and Nanofluidics

- Intersection between Image Processing and Machine Learning in Biomedical Applications
- Direct Digital Fabrication in Medicine: from digital data to physical models
- Computer Simulations and Visualization Applied to Tissue Engineering
- Parameterization of Reconstructed Organ Models
- Computational vision and image processing applied to Dentistry
- Network Neuroscience
- Applications of Ontologies for Medical Image Analysis and Computer-Assisted Interventions

Publications

Proceedings: The proceedings book will be published by Springer under the book series "Lecture Notes in Computational Vision and Biomechanics" indexed by Elsevier Scopus.

Journal Publication: A dedicated special issue of the Taylor & Francis international journal "Computer Methods in Biomehanics and Biomedical Engineering: Imaging & Visualization" indexed in Scopus, DBLP and Clarivate Analytics Emerging Sources Index will be published with extended versions of the best works presented in the conference.

Springer Book: A book with invited works from the ones presented in the conference will be organized for publishing by Springer.

Important Dates

- Deadline for Extended Abstracts: May 31, 2019
- Authors Notification: June 15, 2019
- Deadline for Papers (non-mandatory): July 15, 2019

Submission

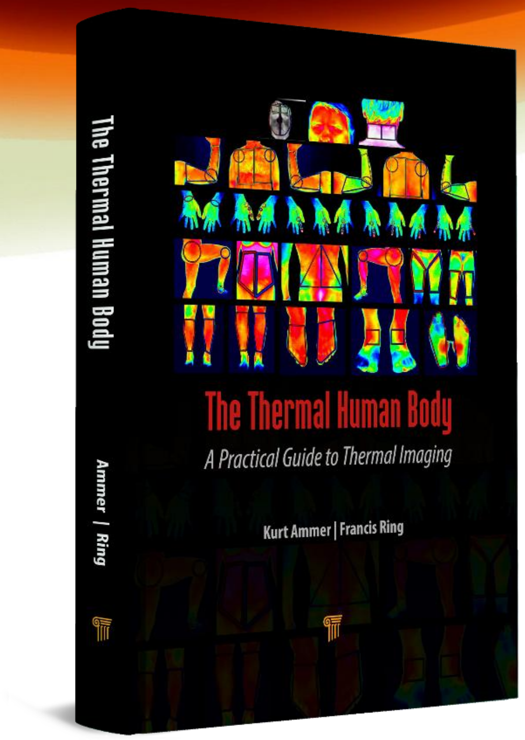
Instructions for authors available at:
https://paginas.fe.up.pt/~vipimage/nav/conference/instructions.html

The contributions should be submitted using the conference management system at:
http://conference.mercatura.pt/vipimage2019

For further details, please, have a look in the conference website at: www.fe.up.pt/vipimage

The Thermal Human Body

A Practical Guide to Thermal Imaging



by

Kurt Ammer & Francis Ring

978-981-4745-82-6 (Hardback)
978-0-429-01998-2 (eBook)
US$149.95
260 Pages – 19 Color & 38 B/W Illustrations
May 2019

Key Features

- Combines the physics of heat transfer with thermal physiology to understand skin temperature distribution
- Provides a framework for standardized recording and analysis of medical thermal images
- Includes an atlas of body positions of proven reproducibility for infrared image capture
- Proposes regions of interests for reliable quantitative analysis

How to Order

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Reviews

"There is no way to study thermal imaging and not learn from the writings of Francis Ring and Kurt Ammer. Pioneers of the application of infrared thermography in medicine, the authors unveil the direction for a sensible use of the method. Luck for us—students, professionals and enthusiasts—because we can be grateful to receive a differentiated material that shortens the learning path. No doubt a remarkable book."
- Prof. Danilo Gomes Moreira, Science and Technology of Minas Gerais, Brazil

"This book is set to become essential reading for anyone who wants to perform reliable thermal imaging of the human body, whether it be in medicine, clinical practice, sports science or research."
- **Prof. Graham Machin**, National Physical Laboratory, UK

"This book is a wonderful practical guide that takes the reader through all the main stages required and will be of special interest for those interested in entering the fascinating field of clinical thermal imaging."
- Prof. James B. Mercer, UiT—The Arctic University of Norway, Norway

Description

This book is a guide for the constantly growing community of the users of medical thermal imaging. It describes where and how an infrared equipment can be used in a strictly standardized way and how one can ultimately comprehensively report the findings. Due to their insight into the complex mechanisms behind the distribution of surface temperature, future users of medical thermal imaging should be able to provide careful, and cautious, interpretations of infrared thermograms, thus avoiding the pitfalls of the past. The authors are well-known pioneers of the technique of infrared imaging in medicine who have combined strict standard-based evaluation of medical thermal images with their expertise in clinical medicine and related fields of health management.

JENNY STANFORD PUBLISHING