THERMAL CHARACTERISATION OF SKIN AT ACUPUNCTURE POINTS

© Ewa Dziuban, 2003

Rzeszow University of Technology, Faculty of Electrical and Computer Engineering, Rzeszow, Poland

Подано результати досліджень, метою яких є визначення фізичних параметрів в точках акупунктури, які характеризують стан організму людини. У дослідженнях використано температурні та радіаційні методи вимірювань.

Представлены результаты исследований, целью которых является определение физических параметров в точках акупунктуры, характеризирующих состояние организма человека. В исследованиях использованы температурные и радиационные методы измерений.

Recently, the measurement of the signals related to bioelectromagnetic body activity and their interpretation has been of increasing interest. The idea of presented research is to find the possibility of discovering the parameters identifying the physical properties of the human body at acupuncture points (AP). Thermal characteristics have seemed proper, because acupuncture deals with energetic state of organism. For surface body temperature measurement at acupuncture points the non-invasive infra red (IR) radiation method is proposed and its results are presented and discussed.

1. Introduction. Acupuncture, knowledge concerning the ancient Chinese medicine has been offering significant results in diagnosis and therapy. Nowadays, the acupuncture has its recovery and as the alternative medicine takes part in the development of medicine and healthy style of live. Nevertheless the acupuncture evokes many controversies in the world of modern, scientific medicine because the description of mechanism of its action is not based on the scientific rules. Eastern practitioners of acupuncture use the expressions and terms, which are incomprehensible for medicine doctors educated in the European modern scientific paradigm.

Traditional Chinese medicine introduces the acupuncture points as special places on so called meridians. Acupuncture points control and regulate a human's state of health and fettle by bioenergy distribution. Created in internal organs and systems of organism the bioenergy "chi" combines with the breath and circulates in the body along paths, these particular meridians. The meridians form a multilevel network that connects the various regions of the body, including the surface, with the internal. Meridian systems co-operate together to assure the flow and distribution of "chi" in the body, thus controlling all functions of organism. The interwoven system of meridians and possibilities for diagnosis and treatment, they offer, are called meridian theory. When an internal organ is not balanced energetically, related acupuncture points may become irritated, providing a basis for diagnosis. For the treatment the point on the skin is stimulated using for example: needle insertion, pressure, suction, or heat [1].

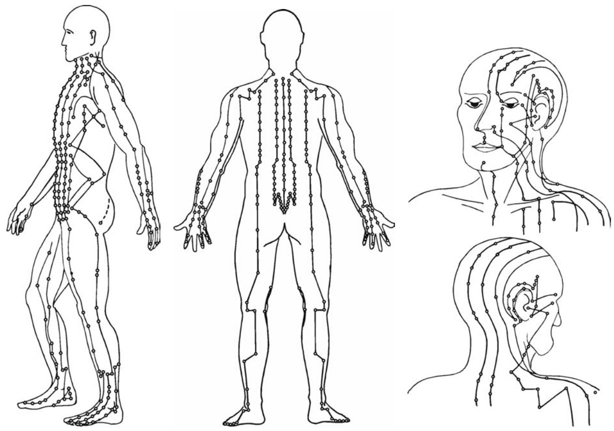

Fig. 1. Profile of human body with meridians and AP [14]

In spite of difficulties in terminology, medicine has domains in which acupuncture application is accepted and its effectiveness is really documented. Analgesia was the first while Julia Tsuei [1] made mention of digestive tract, next cardiovascular system (hypotension), immune system (phagocytosis), endocrine system (the secretion of ACTH, oxytocin, vasopressin, norepinephrine, follicle stimulating hormone, prolactine and 17-hydroxy – corticosteroids) was discovered as well as disorders: hemiparalysis, facial paralysis, cervical spondylosis, humeral epicondylitis, herpes zoster, lumbago, pulmonary disease and mental disorders. In Poland Z. Garnuszewski [2] and E. Ziobro [3] presented many cases of successful applications of acupuncture. Other documented effective acupuncture treatment as well as WHO List of Recommendation for acupuncture treatment is cited in [4].

Existence of medical practice of acupuncture in spite of lack for physical and scientific basis evokes a challenge for researcher. The aim of presented research is to find the physical parameters of the skin at these points, which would characterise the phenomenon of acupuncture points (AP) and their ability for the diagnosis and the healing.

As a general rule, the hitherto existing studies of acupuncture points were based on the measurement and consideration of the electrical properties and parameters at the AP [5 -9]. Their results revealed that the values of some electrical parameters like conductivity, potential and capacity distinguish acupuncture points from their vicinity on the skin. Nevertheless, due to the energetic nature of AP appearance, the temperature measurements seem to be more suitable. Results of temperature measurements both would throw light on a uniqueness of AP and explain the phenomenon of energetic contact at these points, which is actually practised. Presented research announces an advantage to science and to medical practice.

2. Method

2.1. Basic law

There are many methods and related systems that enable temperature measurement. Proper choice of the method is highly important for measurement on the surface of human skin. The contactless therefore non-invasive infra red radiation method is very suitable because it does not influence the natural, physiological processes of organism and causes no disturbance to the temperature field. Hence it would provide virtual utility in the intended studies on the secret of AP ability for diagnosis, control and treating the organism.

Human beings as all objects above the temperature of absolute zero emit electromagnetic power. Planck's law describes the power P emitted into a solid angle $d\Omega$ at a bandwidth Δf by a blackbody of temperature T (in kelvin):

$$P = \frac{2hf^3 \Delta f \, d\Omega}{c^2} \frac{1}{\exp\left(\frac{hf}{kT}\right) - 1}, \qquad (1)$$

where h is Planck's constant, f is the centre frequency of radiation, c is the velocity of light, and k is Boltzmann's constant

Planck's law multiplied by emissivity ε gives the amount of radiation power of a body. For objects at room temperature (organism's temperature is ca 310K) the spectrum is predominantly in infrared region, fig.2. [11]. Wien's displacement law gives the relationship between temperature T of the object and the maximum wavelength λ it radiates as the term:

$$\lambda = 2899/\,T\ [\mu m]. \qquad (2)$$

Spectral radiant emittance versus wavelength for a blackbody at 300K is given on fig 3.[12]. At the figure the wavelength ca 10µm corresponds to human body temperature while the right axis and line show how the total radiant power varies with wavelength for room temperature objects.

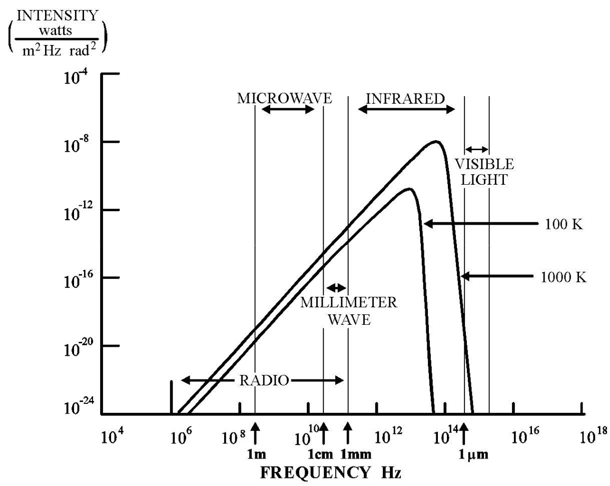

Fig. 2. Intensity of radiation of a blackbody versus frequency (or wavelength) [11]

For the object which temperature is ca 300K, 80% of total radiant energy is included in span of 4 µm to 25 µm.

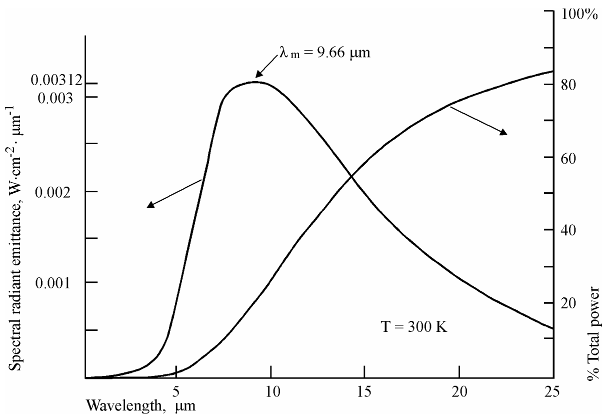

Fig. 3. Spectral radiant emittance versus wavelength for a blackbody at 300K

2.2. Human skin thermal parameters

Corresponding to this consideration thermal parameters of human skin were collected on Table 1. Research revealed that ε is independent on pigmentation of the skin in the visible spectrum [12]. Moreover in the case of measurement on living organism emissivity remains constant over the surface and wavelength.

Table 1

Human skin characteristic data

Parameter	Value
Temperature	*310 K*
IR spectral range	4 – 25 μm
Emissivity ε	0.98

2.3. Pyrometer

Pyrometers (IR radiation thermometers) operate on the basis of Planck's radiation law. Types of pyrometers and their particular characterisation are given in [13]. Nowadays pyrometers with thermal detectors and equipped with lenses specially selected for their infrared thermal properties are finding increased interest in human body temperature measurements. Fig. 4 shows the spectral sensitivity for a number of detectors while figure 5 shows spectral transmission for selected optical materials.

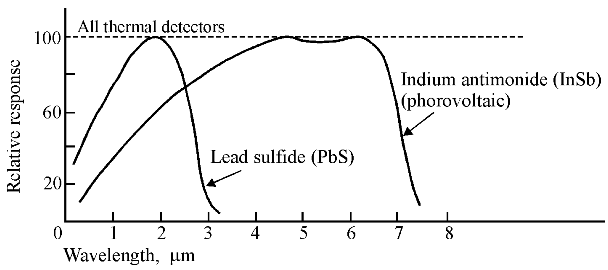

Fig. 4. Spectral sensitivity of thermal and photon detectors [12]

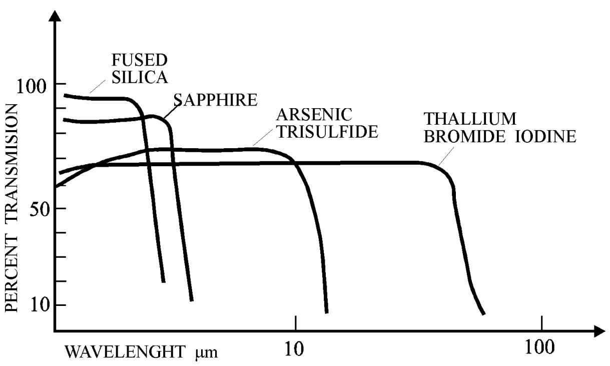

Fig. 5. Spectral transmission for a number of optical lenses [12]

Weak signals from detectors must be amplified and than processed and at last displayed. Suitable measurement system is presented at fig. 6. A mirror focuses the radiation on the detector. Blackened chopper of temperature T_o interrupts the radiation beam at a constant rate. The output of detector circuit is the series of pulses with amplitude dependent on the strength of the radiation source. This AC signal is amplified, while the mean value, which is subjected to drift is blocked. A reference-phase signal used to synchronise the phase-sensitive demodulator is generated in a special circuit consisting of a light source and detector. The signal is then filtered to provide a DC signal proportional to the target temperature. This signal can then be displayed or recorded.

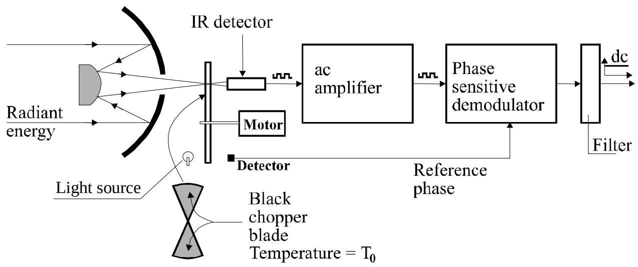

Fig. 6. Chopped -beam radiation thermometer system [12]

2.3.1. Errors of pyrometers

Emissivity variations in hospital conditions (wounds, scarves, grease and sweat) change estimated ε value and may cause measurement uncertainty. It can be evaluated by term [16]:

$$\Delta T = T_s - T_r = T_r \left[\sqrt[4]{\frac{1}{\varepsilon}} - 1 \right], \qquad (3)$$

where: T_s is skin temperature and T_r is reading temperature.

Moreover nonisothermal environment (cold windows, hot lights, reflexes from other parts of body (fig. 7) may cause additive heat fluxes that are reason of measurement errors:

$$q = \sigma \left[T_s^4 - \sum F_{sj} T_j^4 \right], \qquad (4)$$

where q is heat flux, σ is Boltzmann's constant, T_s is skin temperature, F_{sj} is the geometric view factor from skin to the jth surface at temperature T_j. For isothermal surrounding T_j is constant while $F_{sj} = 1$.

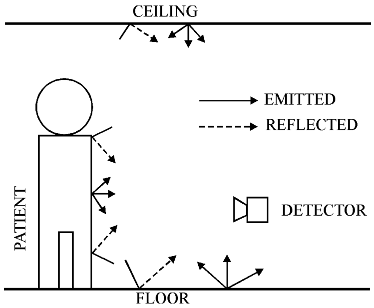

Fig. 7. Sources of additional heat fluxes caused by nonisothermal vicinity [10]

Besides, measurement signal can be modified by optical and electronic path of the system which main sources of disturbances like noise generated in detector or other analog electronic block, variation of the preamplifier gain as well as limited resolution of analogue / digital converter can result in the error:

$$\frac{\Delta T}{T_s} = \frac{\Delta S / S_{bb}}{RDRF} \qquad (5)$$

where T_s is skin temperature, ΔS is the difference between corrected signal and blackbody signal S_{bb} and RDRF means relative disturbance resistance function and depends on wavelength dependent parameters [13]

Also calibration error can occur, which can be estimated by relationship (6):

$$E \sim K\left(T_r^b - T_d^b\right), \qquad (6)$$

where E is emf of thermocouple, T_r is black body real temperature [K], T_d is temperature of detector, b is exponent (b ~ 3,5-4,5), K is construction constant.

Errors of pyrometers are deeply discussed and calculated in [13].

2.4. Specificity of biomedical measurements

Results of biomedical measurements have a specific character consisting in an influence of natural biodiversity of alive on them. For this reason an individual measurement can not be treated as accurate independently on accuracy of measuring device and on researcher's honesty hence for evaluation of results related to biological systems a statistical analysis is indispensable.

3. Material

The volunteers, women and men aged 23 to 26 years took part in the experiments. They were asked to declare their state of health and level of good feeling (fettle), results are given on the Table 3. Experiments consisted in following measurements:

a. six persons for three weeks at AP on the left and right hands in the same conditions. The aim of them was to check the symmetry of temperature on body as well as the dependence between health and fettle versus temperature,

b. numerous sample of persons in the vicinity of acupuncture point: at the point (centre) and 8-10 mm away from it in four perpendicular directions (the control "neutral" points: finger, elbow, thumb, little finger). The aim of them was to check the existence of AP as the distinguishing points on the skin.

3.1. Location of acupuncture points

Description of AP layout can be found in numerous atlases. Acupuncture points which were measured are presented on fig. 8. They were selected in order to respond to common illness (cold, sore throat, cough, indisposition and weakness), met among generally healthy young people.

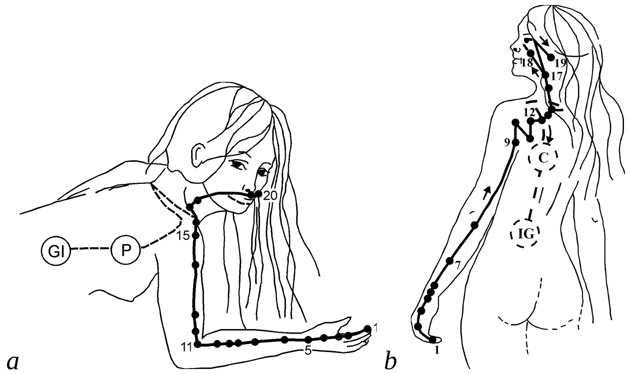

Fig. 8. Approximate locations of acupuncture points on Large intestine Li (a) and Small intestine Si (b) meridians [15]

4. Results

4.1 Metrological parameters of used pyrometer

Measurements were led using the handheld radiation pyrometer. Its technical parameter are listed below:

temperature range: 0 to 300°C,

accuracy: 1°C,

resolution: 1°C,

spectral response: 8 to 14μm,

emissivity: 0.10 to 1.00, step 0.01.

4.2. Temperature measurements of several days

Measurements described at point **a.** revealed the symmetrical temperature run at acupuncture points lying symmetrically on both hands as well as dependence between the state of health and the temperature at AP [4]. For example a young women temperature is presented (Table 2). She had a cold on 3ed, 4 th, 5th day and on 4th day she took drugs. In order she was unwell on 14th, 15th and 16th day. The indispositions have caused the temperature drop on the plot presented on fig.9.

Table 2

Young women temperature [°C] at acupuncture point Si 1

Day	temp.	day	temp.	day	temp.
1	33	8	36	15	31
2	33	9	34	16	34
3	34	10	34	17	35
4	28	11	33	18	34
5	35	12	34	19	34
6	34	13	32	20	35
7	36	14	33	21	34

AVERAGE TEMPERATURE: 33.69,
VARIANCE: 3.04

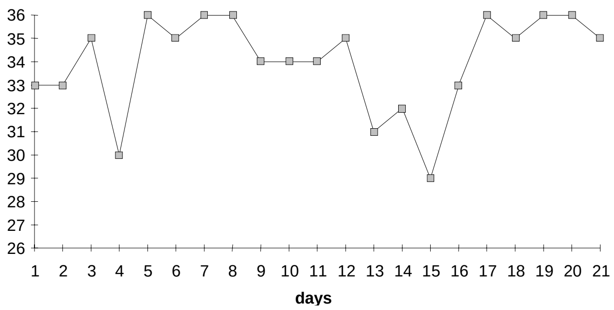

Fig. 9. Plot of temperature of a young female at acupuncture point Si

4.3. Temperature at AP and their vicinity

Results of measurements described at point 3b were analysed and tested statistically. Results concerning the largest data set are presented on Table 3. Analysis revealed a local temperature maximum at acupuncture points on most objects (t-test, significance level $\alpha < 0.05$).

Table 3

Statistic analysis of temperature at AP: a) Li 4, b) P7, c) Si

a

Variable:	fingers	Centre	elbow	Thumb	little finger
Sample size	129	129	129	129	129
Average	**30.8605**	**<u>31.4341</u>**	**31.1473**	**31.3023**	**30.9225**
Median	31	31	32	31	31
Mode	32	31	32	32	32
Geometric mean	30.7497	31.3617	31.0591	31.226	30.8259
Variance	6.246	4.54445	5.15782	4.69695	5.65019
Standard deviation	2.4992	2.13177	2.27108	2.16724	2.37701
Standard error	0.220042	0.187692	0.199958	0.190815	0.209284

б

Variable:	fingers	centre	elbow	thumb	little finger
Sample size	91	91	91	91	91
Average	**30.846**	**<u>31.626</u>**	**31.275**	**31.275**	**31.297**
Median	30	32	32	32	32
Mode	30	33	32	32	32
Geometric mean	30.7981	31.5624	31.1985	31.1634	31.2276
Variance	2.99829	4.01441	4.57924	6.62369	4.25543
Standard deviation	1.73156	2.0036	2.13992	2.57365	2.06287
Standard error	0.181517	0.210034	0.22432	0.269792	0.216248

c

Variable:	fingers	centre	elbow	thumb	little finger
Sample size	25	25	25	25	25
Average	**31.24**	**<u>31.64</u>**	**30.64**	**30.92**	**31.4**
Median	31	32	30	32	32
Mode	33	34	32	32	33
Geometric mean	31.1299	31.5097	30.5569	30.7532	31.2911
Variance	6.85667	8.15667	5,24	9.57667	6.58333
Standard deviation	2.61852	2.85599	2.2891	3.09462	2.5658
Standard error	0.523705	0.571198	0.457821	0.618924	0.51316

Moreover study of large samples of objects showed relationship between the temperature at acupuncture point and the fettle and state of health. The information concerning objects' fettle and state of health were collected on Table 4.

Table 4

Declared fettle (a) and state of health (b) for AP Li4

a

	Fettle	Sample Size	Average Temperature
1.	well	88	31,7
2.	not well	36	30,9
3.	bad	5	29,6
		129	31,4

б

	State of health	Sample Size	Average Temperature
1.	well	101	31,6
2.	cold	22	30,5
3.	sick	6	31,8
		129	31,4

5. Discussion and conclusions

Temperature of measured AP consistently dropped with declared degree of feeling "not well" and "bad". Likewise temperature of persons having cold was lower than this of persons in good health. It is similar to previous observation of young women. Observation could be explained taking into account an opinion that AP reflects an energetic state of organism, in this case its weakness. In turn temperature value of sick objects rose.

Besides, the measurements confirmed the objective existence of acupuncture points as points of local temperature maxima on investigated meridians. Taking into account the analogy of the electrical and temperature fields, this conclusion corresponds to the electrical conductivity maximum at the acupuncture points shown in [5,6,7,8,9].

Study shows following properties of the human body at acupuncture points:

a) local temperature maximum exists at AP;

b) temperature at particular AP decreases when level of fettle is falling;

c) temperature at AP changes when organism is out of order: its value, compared to healthy persons is statistically lower for persons having cold or indisposition while for sick person temperature is higher.

The first conclusion (a) would lead to a new method of identification of AP on the skin while the next (b,c) would provide valuable medical information for diagnostics.

1. Tsuei J.J., The science of acupuncture- Theory and practice // IEEE Eng. in Medicine and Biology Magazine. – Vol.15. No3. –P. 52–57. May/June, 1996. 2. Garnuszewski Z., Akupunktura we współczesnej medycynie, t.1 – 1996, t.2 – 1997. 3. Ziobro E., Jakuszko J., Veraenderungen elektrischer Leitfaehigkeit der Haut in der Diagnostik zerebraler Bewegungsstoerungen, Sonderdruck aus Sozialpaediatrie und Kinderaerztliche Praxis 17, Nr 11, – S. 659–553, 1995. 4. Dziuban E., Termiczne właściwości punktów akupunkturowych. Rzeszów, 1999. 5. Nakatani Y. Skin electric resistance and ryodoraku // J. Autonomic Nerve,6, 52, 1956. 6. Niboyet J.E.H. Nouvelle constatations sur les proprietes electriques des ponts Chinois, Bull. Soc. Acup.30,7, 1958. 7. Reichmanis M., Marino A.A., Becker R.O. Electrical correlates of acupuncture points // IEEE Trans. on Biomedical Engineering, Nov. – P. 33–535, 1975. 8. Zhu Z.X. Research advances in the electrical specifity of meridians and acupuncture points // Am. J. Acupunct. 9. – P. 203–216, 1981. 9. Chen K.G. Electrical properties of meridians // IEEE Eng. in Medicine and Biology Magazine. – Vol.15. – No3. May/June. – P. 58–63, 1996. 10. Love T.J. Thermography in Medical Diagnosis, in Shitzer A., Eberhart R.C.(ed), Heat transfer in Medicine and Biology, Plenum Press, New York. P. 338, 1985. 11. Carr K.L., Thermography, in:Webster J.G.(ed), Encyclopedia of Medical Devices and Instrumentation, Wiley&Sons, New York. – P. 2747–2759, 1988. 12. Webster J.G. (ed), Medical Instrumentation Application and Design. Houghton Mifflin Company, 1992. 13. Chrzanowski K., Non-contact Thermometry Measurement Errors// SPIE Polish Chapter RTD Series,Warsawa, 2001. 14. Trevelyn.J.,Booth B. Medycyna niekonwencjonalna, Wyd. Lek. PZWL, Warszawa, 1998. 15. Portnow F.G. Elektropunktura, Wyd. Elektron, Warszawa, 1991. 16. Michalski L.,Eckersdorf K., Pomiary temperatury, WNT, Warszawa, 1986.