QIRT 10

http://dx.doi.org/10.21611/qirt.2010.078

10th International Conference on Quantitative InfraRed Thermography

July 27-30, 2010, Québec (Canada)

Physiological characteristics of heat and cold weak effects in Zakharin-Head zones

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Abstract

In this paper a model of thermal balance in Zakharin-Head zones, which can be used for diagnostic (assessment of the deviation metabolism) and therapeutic purposes (assessment of the blood flow change). In the experiments, it was shown a functional load on a visceral organ evokes temperature change of the corresponding Zakharin-Head zone for patients suffering from the diseases of this organ. Diagnosis is carried out by the temperature change. In the experiments, it was found that the weak thermal effects in Zakharin-Head zone lead to temperature rise of a visceral organ associated with this zone. The proposed model explains this by the redistribution of blood flow between Zakharin-Head zone and a visceral organ and allows to give quantitative assessment of this change. The relationship between blood flow and metabolism is evaluated by safety factor of substances delivered by blood. Since the disease is followed by a change of this safety factor, then for therapeutic purposes it is useful to know how to change this safety factor.

1. Introduction

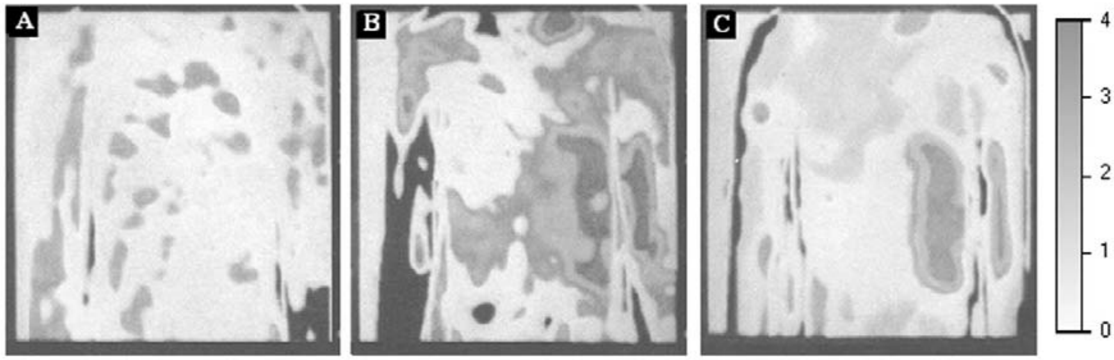
The observation of human body temperature and its relation to a disease is as old as medicine itself. Infrared thermal imaging in medicine is based on the analysis of skin surface temperature which is generally determined by the blood perfusion. The blood flow changes are caused by deviation of metabolism. Diagnostics of visceral organs pathology can be performed by several ways. One of them is based on the analysis of the thermal image corresponding to geometrical projection of the diseased visceral organ onto the skin.

Another method consists in the analysis of the thermal image of the pathological organ projection on some areas of the skin that do not correspond to geometrical projection. These areas were discovered by Russian therapeutist G. Zakharin and English neurologist H. Head. They were termed ‘Zakharin-Head zones’ (‘Head’s zones’). Head’s zones are the well-known projection areas of visceral organs to the skin via the viscero-cutaneous reflex route. Today Zakharin-Head zones are also termed active dermatomes. In these zones changes are observed not only in cutaneous tenderness but also in temperature. These changes are caused by modifications of the blood flow. The nervous system regulating the blood flow makes possible heat removal to some zones. In healthy subjects Zakharin-Head zones were hardly diagnosed. Therefore, a temperature change in the zones is regarded as a pathological factor.

2. The model of thermal balance in Zakharin-Head zones

The experimental data obtained in the Kotel’nikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences are shown in Fig.1 [1]. The temperature changes are determined by the relative scale of temperature shown in the right side of Fig.1. The temperature is decreasing from “0” (some reference temperature) to “4”, the scale factor is the one degree Celsius. After functional load the temperature in Zakharin-Head zones that correspond to the heart (above the heart and on the left forearm) went down (Fig. 1B). The infrared thermal imaging of these zones can be quantitatively evaluated by means of a numerical model described below. We consider a relation of a pathological visceral organ with the skin areas using the heart as an example.

At first we will discuss the model using the heat balance equations for a man in comfortable conditions. It consists of the heat balance equations for each organ. The values of oxygen consumption and cardiac output are physiological parameters of the model [2]. Heat generation rate was calculated from the data of oxygen consumption, while cardiac output was used to assess the blood heat transfer.



A – passive test; B – light load test (clinched fist); C – the field of maximum temperature change (after computer processing of the data).The temperature is decreasing from "0" to "4"; the scale factor is the one degree Celsius.

Fig. 1. *Thermal image of patient with stenocardia.*

In figure 2 the solid lines show the direction of the blood flow, the dashed lines show the heat flux into the environment. Each structural unit is described by heat generation rate *P* [W], blood flow rate *G* [kg/s] and temperature *T* [K] with corresponding subscripts («remainder» includes bones, marrow, adipose and connective tissue, etc. [2]). Heat transfers into the environment through respiration (Q_l) and the skin (Q_s) (evaporation, radiation, convection). The environment is characterized by temperature (T_e), humidity (φ_e), air speed (υ_e) and pressure (p_e) for comfortable conditions.

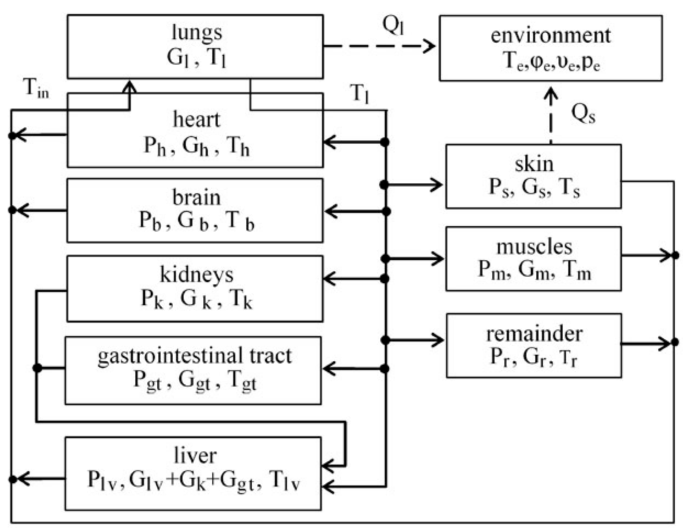


Fig. 2. *Block diagram of heat balance for a man.*

The model is based on the assumptions that:

1. internal heat transfers by the blood circulation only;
2. structural units shown in fig.2 are ideal heat exchangers;
3. heat-exchange in the blood vessels connecting structural units is not taken into account;
4. heat exchange between the heart and the pumped blood is not taken into account.

The first assumption was made for the calculation of the brain heat-exchange [3]. This calculation showed a considerable importance of the blood circulation for heat-exchange.

The second assumption suggests that the outlet blood temperature equals the visceral organ temperature. This fact was confirmed by indirect measurements and theoretical calculations [4].

The third and the fourth assumptions are based on the negligible heat-exchange of great vessels [4]. For aorta, precava and postcava, Greiz number is greater than 1000 which means a negligible heat-exchange with a tissue. Arteriole, venule and capillary are ideal heat exchangers, i.e. the outlet blood temperature equals the tissue temperature. Their Greiz number is less than 0.4. For intermediate vessels Greiz number is greater than 6 and less than 54. So in each specific case some special calculations are required.

The system of heat balance equations on the basis of the block diagram (fig.2) was solved using MathCad [5]:

$$\begin{cases} P_h - cG_h(T_h - T_l) = 0 \\ Q_l + cG_l(T_l - T_{in}) = 0 \\ P_b - cG_b(T_b - T_l) = 0 \\ P_k - cG_k(T_k - T_l) = 0 \\ P_{gt} - cG_{gt}(T_{gt} - T_l) = 0 \\ P_{lv} - cG_{lv}(T_{lv} - T_l) - c(G_k + G_{gt})(T_{lv} - T_{k-gt}) = 0 \\ P_r - cG_r(T_r - T_l) = 0 \\ P_m - cG_m(T_m - T_l) = 0 \\ P_s - cG_s(T_s - T_l) - Q_s = 0 \\ T_{k-gt} = \dfrac{G_k T_k + G_{gt} T_{gt}}{G_k + G_{gt}} \\ T_{in} = \dfrac{G_h T_h + G_b T_b + (G_k + G_{gt} + G_{lv}) T_{lv} + G_r T_r + G_m T_m + G_s T_s}{G_h + G_b + G_k + G_{gt} + G_{lv} + G_r + G_m + G_s} \end{cases} \quad (1)$$

where c is the blood specific heat; $T_{k\text{-}gt}$ is the average blood temperature coming from kidneys and gastrointestinal tract; T_{in} is the average blood temperature coming from all structural units. The normal coefficient values from (1) are given in [2].

The following results were obtained: T_h=37.98°C, T_l=37.48°C, T_{in}=37.51°C, T_b=37.80°C, T_k=37.54°C, T_{gt}=37.55°C, $T_{k\text{-}gt}$=37.55°C, T_{lv}=37.68°C, T_r=37.73°C, T_m=37.76°C, T_s=32.05°C.

When a visceral organ falls sick its metabolic processes may change. In the model this change corresponds to a change in the heat generation rate of the diseased organ. To maintain a constant body temperature the rate of metabolic heat production must be equal to the rate of the environmental heat loss, 85% of which is from the skin. The fastest and efficient way to change the heat transfer is to change the skin blood flow. In this case the organ temperature may not change and the area of changed skin temperature coincides with the region of the changed skin blood flow.

Let us consider the heat transfer in Zakharin-Head zones using the heart as an example. Fig.3 shows a block diagram of the model. In this model we use the following notation: P_{as} is the heat generation rate of the Zakharin-Head zone; G_{as} is the blood flow rate of the Zakharin-Head zone; T_{as} is the temperature of the Zakharin-Head zone; S_{as} is the area of Zakharin-Head zone. The P_h value is set with some deviation from the norm.

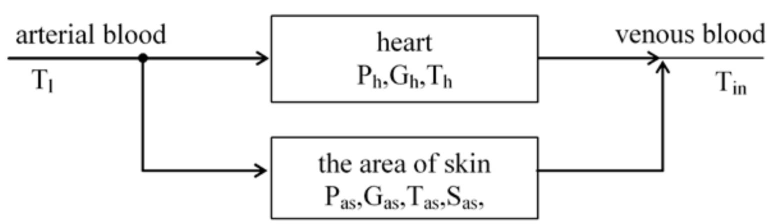


Fig.3. *Block diagram of the model for the diseased heart.*

Since changes in G and T are unknown we have to solve systems of equations for two extreme cases:

1 – G_h equals the normal value which corresponds to the maximum change of T_h;

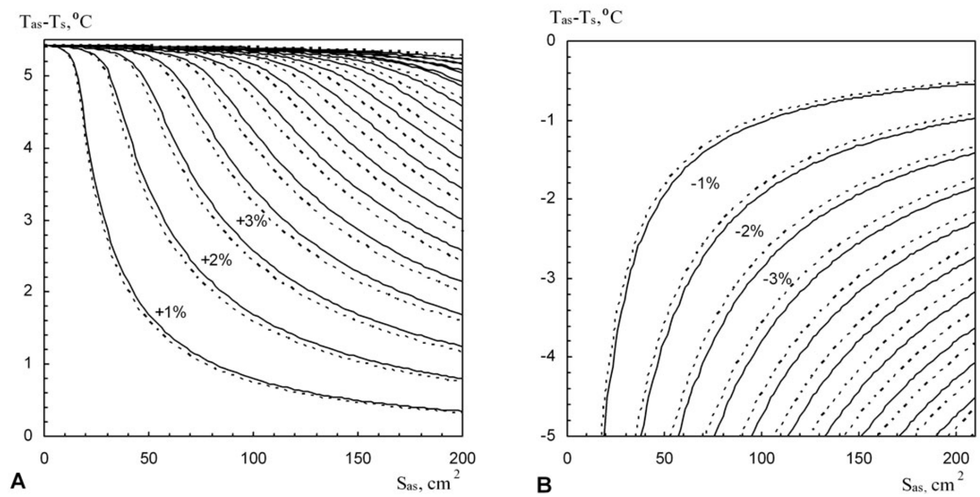
2 – T_h equals the normal value which corresponds to the maximum change of G_h.

For each case the system of equations (2) was solved with various deviations of P_h and S_{as}: for the first case it was solved with respect to the function $f(T_h, G_{as}, T_{as})$; for the second case – with respect to the function $f(G_h, G_{as}, T_{as})$. So let us assume that all the organism characteristics except for the diseased organ and the skin area of Zakharin-Head zone are not changed.

$$
\begin{cases}
P_h - cG_h(T_h - T_l) = 0 \\
P_{as} - cG_{as}(T_{as} - T_l) - Q_{as} = 0 \\
T_{in} = \dfrac{G_h T_h + G_b T_b + (G_k + G_{gt} + G_{lv})T_{lv} + G_r T_r + G_m T_m + (1 - r(S_{as}))G_s T_s + G_{as} T_{as}}{G_h + G_b + G_k + G_{gt} + G_{lv} + G_r + G_m + (1 - r(S_{as}))G_s + G_{as}}
\end{cases} \quad (2)
$$

where $r(S_{as})$ is the fraction of the Zakharin-Head zone area from the total skin area (S_s): $r(S_{as}) = S_{as}/S_s$; Q_{as} is the heat transfer of the Zakharin-Head zone area, it is determined as sum of convection (C_{as}), radiation (R_{as}) and evaporation (E_{as}): $Q_{as} = C_{as} + R_{as} + E_{as}$; P_{as} value is determined by the formula: $P_{as} = r(S_{as})P_s$.

Fig.4 shows solutions of systems of equations for two cases: the increasing variation (from their norm) of the heat generation rate is plotted in Fig.4(A); the decreasing variation of the heat generation rate is plotted in Fig.4(B). We see that for the two extreme cases deviations are negligible. Similar graphs can be plotted for other visceral organs by means of the model. Graphs on Fig. 4B are corresponding to the experimental data showed on the Fig.1.



A - increasing heat generation rate; B - decreasing heat generation rate

Fig.4. *Dependence of the temperature deviation from Zakharin-Head zone area of the skin for different heat generation rates of the heart (solid line for the first case; dashed line for the second case).*

To pass on from the calculated average temperature of the skin to the experimentally measured temperature we use the equality:

$$T_{ms} - T_{norm} = T_{as} - T_s \quad (3)$$

where T_{ms} is the average skin temperature measured in Zakharin-Head zone for disease; T_{norm} is the average skin temperature measured in Zakharin-Head zone for norm.

3. The calculation data of heat and cold weak effects in Zakharin-Head zones

In the Kotel'nikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences the research were done in which the thermal element simulated effect of the psychic's hands on Zakharin-Head zone (weak thermal effect). In these experiments, the same effect of the psychic's hands and the heat element was detected. Under these influences internal organ associated with the zone starts to warm up with a delay no more than a minute [6]. In this paper, weak effects was simulated changes of environment temperature by ˚C over Zakharin -Head zone. It is known that the oxygen safety factor for the whole organism is 3, but for each organ it is different.

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So let us assume that for weak effects all the organism characteristics except for the diseased organ and the skin area of Zakharin-Head zone are not changed (fig.3).

It should be noted that the experiments were done only for the weak thermal effects, for the weak cold effects analogical reasoning was drawn. Fig.5 shows solutions of systems of equations for heat and cold weak effects in Zakharin-Head zone. Fig.5(A,B) shows change of temperature zone. The change of temperature zone consists of the changes caused by changes of environment temperature (ΔT_e) and the changes caused by the redistribution of blood flow between the zone and internal organs. Fig.5(a,b) shows the change of coefficient K. Coefficient K is the relative change of blood flow rate before and after effect (safety factor of substances):

$$K = G_h / \overline{G_h} \tag{4}$$

where $\overline{G_h}$ is the blood flow rate before weak effect.

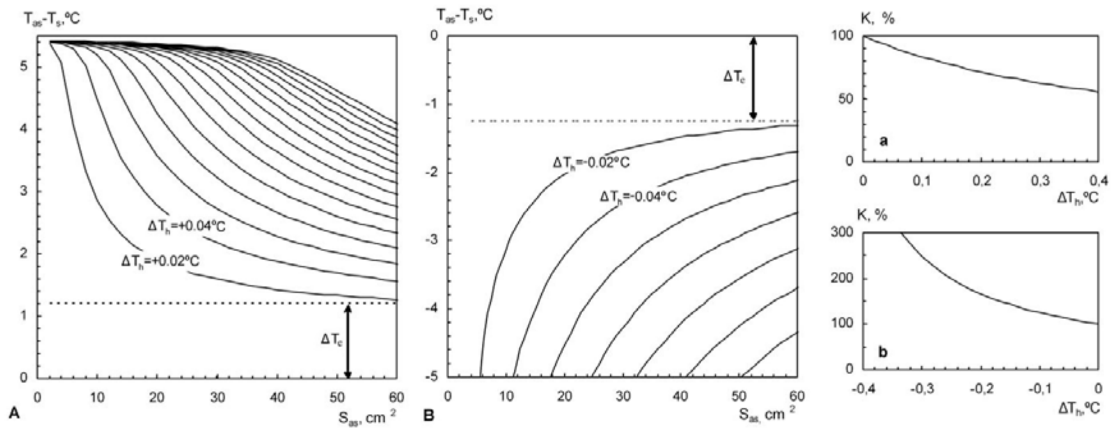

Fig. 5. *Dependence of the temperature deviation from Zakharin-Head zone area of the skin for different deviation of the heart temperature (A - heat weak effect; B - cold weak effect) and dependence of the safety factor of substances from the deviation of the heart temperature (a - heat weak effect; b - cold weak effect).*

Thus, a heat weak effect leads to a decrease of safety factor of substances and can be used for diseases occurring with increased metabolism (e.g. cancer). A cold weak effect leads to an increase of safety factor of substances and can be used for diseases occurring with lowered metabolism. The growth of tumors can predict using cellular automata model with insufficient resources [7].

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