Comparative Analysis of the Response of Microcirculation Parameters and Blood Pressure to Geomagnetic Activity in Healthy People

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We analyze the results of daily laser Doppler flowmetry monitoring of blood microcirculation parameters in 9 healthy volunteers performed in 2006-2009. Dependence of microcirculation and BP parameters on geomagnetic activity was analyzed separately in each volunteer (the influence of ambient temperature was previously excluded). Significantly increased parameters of microcirculation in response to higher geomagnetic activity were found in 4 volunteers (44%) and elevated BP in 1 volunteer; in other cases, no reaction was detected. It was shown that individual sensitivity to geomagnetic activity is proportional to its mean level during the period of measurement. Since blood perfusion volume in tissues directly depends on peripheral vascular resistance, we can conclude that under conditions of high geomagnetic activity microvascular tone varies to a greater extent than the tone of major vessels.

Key Words: *microcirculatory bed; blood pressure; geomagnetic activity*

It is well known that different compartments of the cardiovascular system respond to variations of geomagnetic activity (GMA) [2,4]. It is known that 85% patients with acute myocardial infarction and a history of other forms of coronary heart disease (CHD), demonstrated deterioration of cardiovascular activity during geomagnetic storms [3], including arrhythmias, increased systolic and diastolic blood pressure (BP) [4,10-12], decreased heart rate variability [15], and increased secretion of biogenic amines within the sympathoadrenal system. In addition, rheological characteristics of blood and capillary circulation changed [5,16], which led to enhanced erythrocyte aggregation accompanied by clot formation (sludge) and resulting in tissue hypoxia and ischemia [6,16].

Disturbances in central hemodynamics and their possible response to GMA variations can be identified by traditional methods of BP and heart rhythm variability monitoring. However, some healthy volunteers demonstrated steady health deterioration during magnetic storms in the absence of significant BP changes (psychological factor was excluded) [10]. In these periods, in patients with functional disorders of the cardiovascular system and in healthy people, diagnostics of small vessel dysfunction is very important. The functional state of capillary circulation can be assessed by capillaroscopy (в рус. микрокапилляроскопия) [5] as well as by measurements of endothelial function and pulse wave velocity [16].

Laser Doppler flowmetry (LDF) is a noninvasive method for studying the functional state of skin microvasculature [13]. Detectable statistically averaged parameter, indicator of microcirculation (IM), describes erythrocyte flow per unit time per unit tissue volume measured in relative or perfusion units (PU). A characteristic feature of LDF is that it evaluates the state

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of peripheral circulation, which cannot be evaluated by the methods described in the works [5,16]. Since the blood flow in skin capillaries does not exceed 10% of the total blood flow registered by LDF and the remainder being represented by large microvessels of subcapillary plexuses, the main attention is paid to tissue perfusion, but not to capillary blood flow.

LDF as an efficient method to evaluate the current functional state of the microvasculature is also an effective assessment and prediction tool for individual sensitivity to geomagnetic and meteorological factors.

Here we evaluated the sensitivity of microvasculature to the effects of geomagnetic factors and individual contribution of these factors into changes of microcirculation parameters in healthy volunteers.

MATERIALS AND METHODS

The study was conducted by LDF using computerized laser analyzer of blood microcirculation LAKK-02 (Lazma) [13] in 9 healthy volunteers (7 women aged 40±6 years and 2 men aged 42 and 52 years). Measurements were carried out for 3 years (2007-2009) on working days in the morning at 10:00-11:00 a.m. local time. The tested area was palmar surface of the left hand middle finger. Time of one measurement was 10 min, time to adapt before starting the measurements 15 min.

Simultaneously, systolic and diastolic BP were recorded by Korotkov method in the supine position (mean of 3 measurements made at intervals of 2-3 min) and air temperature in the room was measured by room thermometer.

Data arrays included 100 to 350 measurements for each volunteer, therefore our findings concerning the nature of correlations between IM and BP parameters with various external factors have high statistical significance.

For comparison with the level of GMA, daily values of planetary Kp index were used (ftp://ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP).

Possible relationship of IM and BP parameters between themselves and with GMA was analyzed separately for each volunteer by our specially developed method [9,12], including methods of correlation, variation, and regression analysis. Since in some volunteers sample data values of Kp index and IM did not fit the normal distribution, we used Spearman's rank correlation coefficient ρ and Mann–Whitney test to assess statistical significance of differences in the mean values of two samples.

At the preliminary stage of the assay, the dependence of IM on room temperature was evaluated for each volunteer separately. If the observed correlation was significant, this contribution was subtracted by linear regression.

RESULTS

Significant ($p<0.05$) correlation between IM and Kp index was documented in four volunteers; with BP in only one volunteer. In all cases, an increase in GMA was associated with an increase in all physiological parameters. In case of IM, in two volunteers the response was detected always synchronously with the onset of the magnetic storm and in two with a delay of 1-2 days. In case of BP, the peak response also was observed 1-2 days after geomagnetic storm.

We present the segments of time series of daily synchronous measurements of IM and Kp index (Winter/Spring 2007; Fig. 1, *a*). IM increased synchronously with GMA. The dependence of IM from Kp index is nonlinear: tissue perfusion increased at daily Kp index above 20, which means at least weak geomagnetic perturbation (Fig. 1, *b*). The difference between the mean values of IM samples, obtained under quiet and disturbed geomagnetic conditions, in the whole data array on this volunteer (2007-2010, 348 values) amounts to 3.1 PU ($p<10^{-6}$), in the segment of time series Winter/Spring 2007 (Fig. 1, *a*), 4.1 PU ($p<10^{-3}$; Fig. 1, *c*). Similar in magnitude amplitudes of IM fluctuations were obtained for the other three volunteers who showed the significant response.

Long time series of observations (with some omissions within 3 years) made it possible to trace the dynamics of IM depending on the level of GMA. To this end, the whole time series of IM values was divided into segments entering successive 90-day periods corresponding to seasons of the year during 2007-2009 (13 seasons). For each interval, Spearman's correlation coefficients ρ for IM and Kp index were calculated and its significance was evaluated (Fig. 2). Omissions in this chart indicate the lack or small amount (less than 20) of IM measurements during that period. It was found that the extent of correlation between these two parameters varies considerably. Maximum effect of GMA on the IM was documented during Winter/Spring 2007 and Spring 2008. In other periods measurements were not performed, or coefficient of correlation between IM and Kp index was insignificant. A similar pattern was found for IM of the other volunteers, which measurements occupied a considerable time interval.

As was shown earlier [10-12], typical response of BP to the effect of GMA in healthy volunteers manifests in short term BP spikes occurring at the day of magnetic storm onset (in 80% cases), or with a delay of 1-2 days (20%). In our previous studies, the proportion of volunteers whose BP dynamics depended on the GMA level varied considerably and ranged from

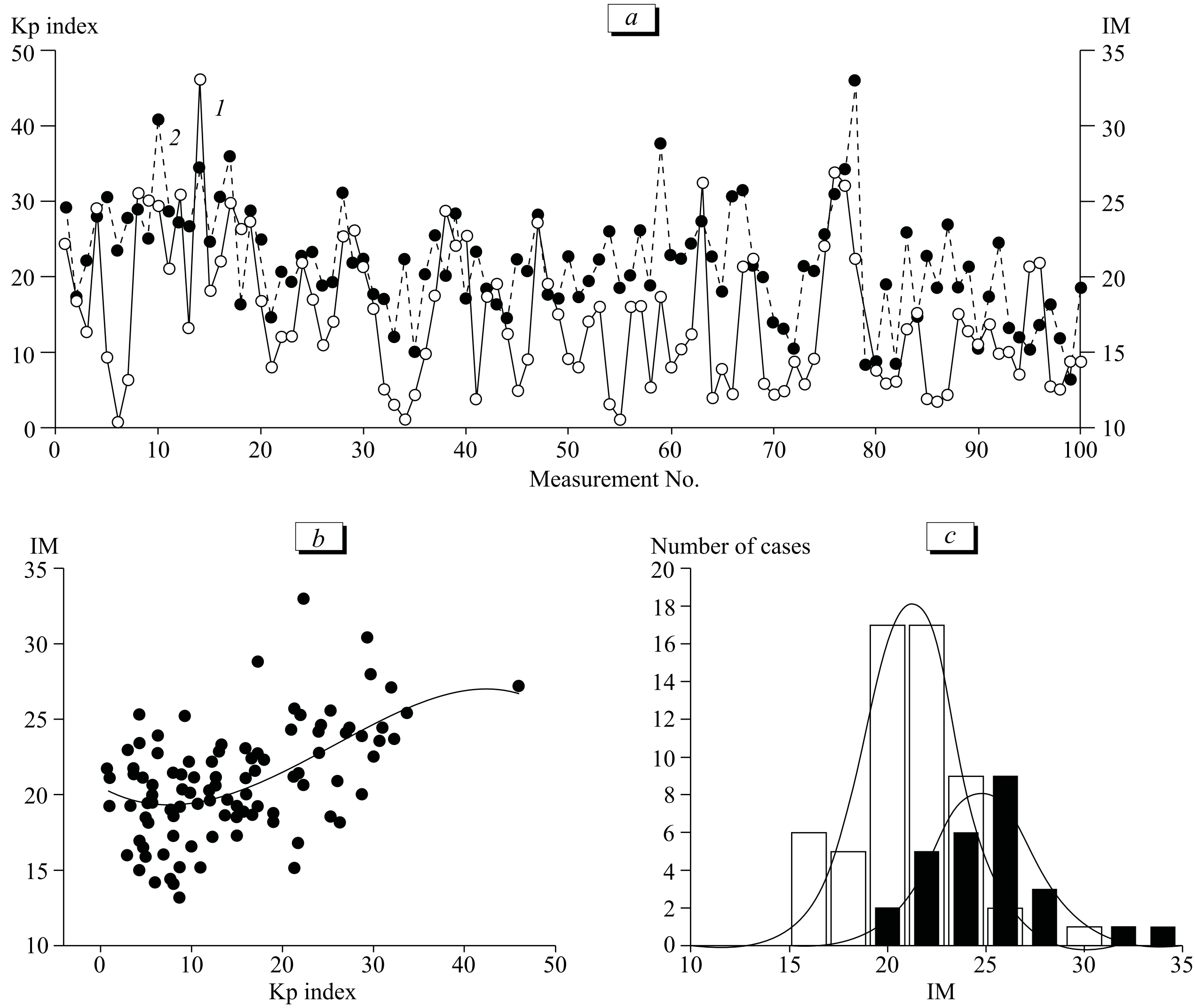

Fig. 1. Typical dependence of IM on GMA. *a*) Dynamics of synchronic daily values of Kp index (*1*) and IM (*2*) during the winter and spring of 2007; *b*) dependence of IM from the corresponding values of Kp index and third-order polynomial approximation (the best approximation by R^2-criterion); *c*) distribution of IM sample values shown in *a* and *b* at Kp index <20 (magnetically quiet days, light bars) and >20 (magnetically disturbed days, dark bars). The difference between the means for these two samples (21 and 25 perfusion units, respectively) is statistically significant at $p<10^{-4}$.

52% of total group [12] (measurements of 2001-2002, maximum of GMA cycle) to 14% (measurements of 2007-2008, minimum of GMA cycle) [12]. The percent of GMA-sensitive BP in this paper (11%) is close to the value in [12] at the same time period.

In this paper we first traced the changes in the degree of IM sensitivity in the same volunteers to GMA effects within 3 years (Fig. 2). Significant positive correlation between IM and Kp index was observed at independent intervals of time series in 2007 and first half of 2008, when geomagnetic disturbances yet have been observed. Since mid-2008 average level of GMA significantly decreased, time interval between successive perturbations increased almost up to 1 month. For comparison, in the same period 2002-2003 (maximum of GMA cycle) geomagnetically disturbed days amounted to nearly 60%, in 2004-2005 (phase of the recession), about 45%. Thus, from mid-2008, geomagnetic disturbances, even weak, practically ceased, and IM response was detected with increasing Kp index above 20 (Fig. 1, *b*). Thus, on the one hand, the observed dynamics of the correlation between IM and Kp index confirms again the reality of the effect, on the other hand, agrees with the observations on direct dependence of the proportion of subjects in population reacting to the GMA effects, on the average GMA level.

At the same time, we found that in healthy people increased IM against the background of multidirectional BP reactions reflects improvement of peripheral tissues perfusion during the rise of GMA. There are

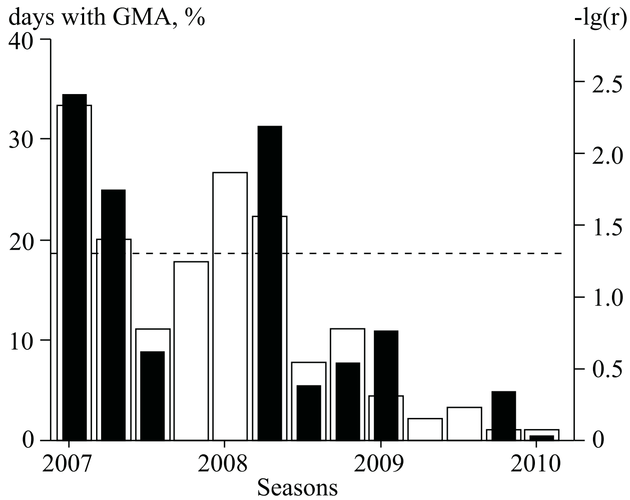

Fig. 2. Percent of geomagnetically disturbed days (daily value of Kp index >20) by seasons for the period 2007-2009 (light bars) and the logarithm of the significance level of the correlation coefficient lg(*r*) (inverted scale, dark bars) between IM values in one of the volunteers and the Kp index for the respective periods. Dotted line, logarithm of 5% confidence level.

published reports on slowing of capillary blood flow in humans during geomagnetic disturbances. However, this concerns mainly subjects with cardiovascular dysfunction or persons under specific conditions of the experiment, for example, geomagnetic field shielding [5]. We assume that natural environment determines the optimum background for the development of compensatory vascular responses, accompanied by increased capillary blood flow and tissue perfusion.

Hormones may also provide this response. Thus, in healthy subjects during CMA increase, the levels of melatonin, which has antioxidant and stress-limiting properties, may not decline as in individuals suffering from cardiovascular diseases [7,8], but increase [14]. Given that melatonin restricts vasoconstrictor effects, activation of mechanisms (including hormonal) that prevent the spasm of peripheral vessels may underlie the mechanisms of increase in tissue perfusion during geomagnetic disturbances. Living organism as a self-organizing system has many degrees of freedom [1], which is biologically expressed in permanent synaptic relays in neurovegetative structures, optimally regulating vascular tone in a changing environment. Therefore this study did not reveal hard links between BP rhythmicity and GMA fluctuations. Reaction at the level of peripheral tissues perfusion is apparently more deterministic, that may be due to the modification of the ionic permeability of cell plasma membranes. Therefore, we believe that in the heliobiology physiological monitoring of indicators reflecting the state of blood flow to peripheral tissues, is the more sensitive and promising method to identify individual sensitivity to GMA than BP monitoring.

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