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## Influence of heliogeophysical factors on the development and outcomes of myocardial infarction // Einfluss heliogeophysikalischer Faktoren auf die Entwicklung und das Ergebnis von Myokardinfarkten

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ERWO PHARMA

# Influence of heliogeophysical factors on the development and outcomes of myocardial infarction

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**Abstract.** The paper investigates the influence of heliogeophysical factors on the development and outcomes of myocardial infarction. It has been established that the dependence of cardiovascular pathology on the action of heliogeophysical stimuli is mediated by a complex interaction of natural, regional and social factors.

An in-depth study of mortality from myocardial infarction in various climatic and geographical regions showed the dependence of the number of deaths on the season of the year and sharp fluctuations in individual meteorological parameters of the weather to a much greater extent in the year of solar activity. It is shown that global climatic changes occurring in the 21st century on our planet have a significant impact on the health of people on every continent of the Earth.

It was found that patients with cardiovascular diseases, in particular with myocardial infarction, are especially susceptible to heliogeophysical disturbances. Despite the numerous literature data on the close dependence of the development and outcomes of myocardial infarction on heliogeophysical factors, many studies have not found a connection between the incidence rate and the course of the 11-year solar activity cycle.

Thus, the presence of contradictory literature data on the influence of heliogeophysical factors on patients with myocardial infarction, the short duration of observations (all studies were carried out in terms of one to 15 years, i.e. within one solar cycle), as well as ongoing global climatic changes dictate the need for further research for at least 3 solar cycles (i.e. 33 years). Of particular interest is the study of the influence of heliogeophysical factors on the development and outcomes of myocardial infarction in the mountainous regions of Central Asia, where the mountain systems (Pamir, Altai, Tien Shan, Himalayas) generate powerful mountain waves that have a significant effect on the oscillatory characteristics of electromagnetic and thermodynamic parameters of the atmosphere.

**Key words:** space weather, mountain climate, ischemic heart disease, mortality

**Kurzfassungfassung: Einfluss heliogeophysikalischer Faktoren auf die Entwicklung und das Ergebnis von Myokardinfarkten.** Die Arbeit untersucht den Einfluss heliogeophysikalischer Faktoren auf die Entwicklung und das Ergebnis von Myokardinfarkten. Es wurde festgestellt, dass die Abhängigkeit der kardiovaskulären Pathologie von der Wirkung heliogeophysikalischer Reize durch ein komplexes Zusammenspiel natürlicher, regionaler und sozialer Faktoren vermittelt wird.

Eine eingehende Untersuchung der Mortalität verursacht durch Myokardinfarkte in verschiedenen klimatischen und geografischen Regionen zeigte die Abhängigkeit der Todesfälle von der Jahreszeit und starke Schwankungen in besonders heißen Jahren. Es wird gezeigt, dass die im 21. Jahrhundert auftretenden globalen Klimaveränderungen auf unserem Planeten einen erheblichen Einfluss auf die Gesundheit der Menschen auf allen Kontinenten haben.

Es zeigte sich, dass Patienten mit Herz-Kreislauf-Erkrankungen, insbesondere mit Myokardinfarkt, besonders anfällig für heliogeophysikalische Störungen sind. Trotz der zahlreichen Literaturdaten zur engen Abhängigkeit der Entwicklung und des Outcomes des Myokardinfarkts von heliogeophysikalischen Faktoren, konnte in vielen Studien kein Zusammenhang zwischen der Inzidenzrate und dem Verlauf des 11-jährigen Sonnenaktivitätszyklus gefunden werden. So erfordern das Vorliegen widersprüchlicher Literaturdaten zum Einfluss heliogeophysikalischer Faktoren auf Patienten mit Myokardinfarkt, die kurze Beobachtungsdauer (alle Studien wurden in einem Zeitraum von einem bis 15 Jahren, also innerhalb eines Sonnenzyklus, durchgeführt) sowie laufende globale Klimaveränderungen weitere Untersuchungen für mindestens 3 Sonnenzyklen (d. h. 33 Jahre).

Von besonderem Interesse ist die Untersuchung des Einflusses heliogeophysikalischer Faktoren auf die Entwicklung und die Folgen von Myokardinfarkten in den Bergregionen Zentralasiens, wo die Gebirgssysteme (Pamir, Altai, Tien Shan, Himalaya) mächtige Bergwellen erzeugen, die einen signifikanten Einfluss auf die oszillatorischen Eigenschaften elektromagnetischer und thermodynamischer Parameter der Atmosphäre haben. **Z Gefäßmed 2021; 18 (4): 10–4.**

**Schlüsselwörter:** Weltraumwetter, Bergklima, ischämische Herzkrankheit, Sterblichkeit

**Abbreviations:**

ACI: acute coronary syndrome
AMI: acute myocardial infarction
CS: cerebral stroke
CVD: cardiovascular disease
CVS: cardiovascular system
DST: daylight saving time
GMA: geomagnetic activity
GMS: geomagnetic storm
HMD: heliomagnetic disturbances
IHD: ischemic heart disease
MACE: major cardiovascular events
MI: myocardial infarction
MS: magnetic storm
SA: sun activity

## Introduction

Using data on the effect of space weather on a person from France, Germany, China, Israel, Lithuania, Georgia, a number of Russian clinics, wherever patients with ischemic heart disease were observed, during magnetic storms, the number of myocardial infarctions and mortality from them has approximately doubled. One of the most acute international problems of the 21st century is the change in global climate. To date, a sufficient number of generally known and relatively unknown facts for the world community have accumulated, which indicate various changes on the planet that have occurred in a relatively short period of time. This is the acceleration of tec-

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tonic movements, and the increase in the activity of processes, and the aggravation of problems of global nature. This includes seismic, volcanic, solar activity, change in the Earth's magnetic field, drifting speed of magnetic poles, displacement of the Earth's axis, change in the albedo of the planet, its orbital parameters. In addition, there is an increase in surface temperature, permafrost thawing, a reduction in the area and mass of the ice sheet of the land and polar seas, an increase in the level of seas and oceans, a change in river flow, the occurrence of dangerous hydrometeorological phenomena (droughts, floods, typhoons) and much more.

Global climate change is already affecting the health, living conditions and livelihoods of people on all continents. According to many researchers [1–3], the deterioration of the patient's condition is manifested after a solar flare, with the onset of a magnetic storm (MS). After 8 minutes from the beginning of a solar flare, the streams of solar cosmic rays reach the Earth's atmosphere in two days, causing the MS. It was found that patients with cardiovascular diseases (CVD) are especially susceptible to heliogeophysical disturbances. Incidence, complications and mortality from CVD increase on magnetically disturbed days in comparison with magnetically quiet days by 1.5–2 times. The number and severity of CVD depends on many environmental factors (atmospheric pressure, air temperature, precipitation, cloud amount, ionisation, radiation regime etc.), a reliable and stable relationship of CVD is revealed with chromospheric flares and geomagnetic storms (GMS). An increase in the number of patients with myocardial infarction (MI) is observed on magnetically disturbed days and reaches a maximum on the second day after geomagnetic event took place [4]. In patients with MI, the change in psychophysiological parameters depends to a greater extent on the amplitude of the peaks of X-ray radiation from the Sun [5]. Periods of solar activity (SA) repeat on average once every 11 years [6].

## Materials and Methods

The study of the relationship between the incidence of acute myocardial infarction and mortality from ischemic heart disease (IHD) among the population of Kaunas showed that for both men and women aged ≥ 65 years, the greatest increase in the average mortality from ischemic heart disease was noted on the second day after heliomagnetic disturbances (HMD). When estimating solar flares, the average number of cases per day was the highest for 55–64-year-old women and men on the same and second days. The increase in the average number of MI cases per day among 25–54-year-old men was greatest (30%) in 1 day, and death from ischemic heart disease (54%) was observed among women aged ≥ 65 years 2 days before increasing of the energy of proton fluxes of the sun [7]. Space weather increases the risk of developing not only myocardial infarction, but also cerebral stroke (CS). Risks increase on days of extreme weather events, 1–5 days before and after. It was found that at least 75% of magnetic storms are accompanied by an average 1.5-fold increase in the number of persons hospitalised with CVD [8].

According to the results of 214,908 ambulance calls from patients, it was proved with a confidence level (r = 0.95) that the frequency of cerebral strokes increases in men in a year of low solar activity (SA), and in women in a year of high SA. In the year of high SA, cases of sudden death, clinical death, and cardiogenic shock were more often recorded. The largest number of ambulance calls related to myocardial infarction was recorded from 9 to 12 hours, the smallest from 3 to 6 hours. An increase in the frequency of myocardial infarctions during the light period of the day compared to the dark period has been proved. The most intense seasons were autumn and to a lesser extent winter; as for months: December due to low SA, May due to high SA [9]. Studies of the influence of SA dynamics on the state of the cardiovascular system (CVS) of a person in the conditions of Eastern Transbaikal revealed a significant relationship between the rhythms of the average daily cases of MI occurrence and the daylight saving time (DST). In the years when the DST-variation had the largest number of days with a high negative value, there were a lot of calls to the cardiology team. The most biotropic months were in the summer [10].

In areas located in high latitudes, there is an increased level of influence of helio-geospheric, cosmophysical factors on biological organisms. The intensity of responses to HMD depends on the individual adaptive capabilities of the human body, formed in the course of evolution, and on the state of human health. Hospitalisation in the intensive care unit with MI occurs 3.6 times more often in men than in women. On magnetically quiet days, gender differences were revealed in the MI occurrence: women were admitted to the hospital more often from 1 pm to 1 am (70.0%), men from 7 am to 7 pm (62.7%). On the days with the HMD, men and women were more often hospitalised from 7 am to 7 pm (67.7% and 69.2%, respectively) [11]. The dependence of cardiovascular pathology on the action of heliogeophysical stimuli is mediated by the most complex interaction of natural and social factors. In addition to the direct exposure to radiation and flares, an influence of different order acts on the body, which can act as synergists or antagonists of solar influences on the human body.

## Results and Discussion

Based on the results of a six-year clinical and statistical study of all reliable cases of MI in the city of Sverdlovsk (about 3000 cases) and its mortality (about a 1000 cases) in comparison with geomagnetic activity (GMA), an interesting clinical fact was found: the highest percentage of severe macrofocal myocardial damage was observed at high values of HMD, whereas piecemeal necrosis in the heart muscle often developed at weaker degrees of GMA. For example, during the MS with a C-index of 0.5 out of 206 cases of heart attacks, 127 heart lesions were macrofocal (including transmural), that is, in a percentage ratio of 61.6%; for magnetic storms with a C-index of 1.0 this figure was 91.2% (54 out of 57) and with a C-index of 1.5 100% [12]. Ambulance data in the city of Stavropol and materials from the city weather station on SA for 1964 showed that between the relative Wolf number and the frequency of MI related calls, there was an average connection (r +0.60). The relationship between magnetic activity (K-index) and the occurrence of MI is strong (r +0.9). The dynamics of MI related ambulance calls in Stavropol is characterised by a pronounced seasonality, most of them were in winter and spring [13]. In Vladikavkaz, which is distinguished by its environmental conditions mountainous landscape and altitude above sea level a

retrospective analysis of the incidence of MI was carried out depending on solar and geomagnetic activity in 2007–2010. The findings revealed that on the days of GMA there was a significant increase in the number of myocardial infarction cases, and mainly in the age group of 50–69 years [14].

The study of the influence of variations in solar and geomagnetic activity on the incidence and complications of MI in the Republic of Tajikistan revealed that climatic and geographical conditions can aggravate the negative biotropic effect of the HMD in different seasons of the year. The summer season with the highest SA compared to the equinox and winter is the most unfavourable for patients with MI. The age of 60–69 years is the most critical in terms of the influence of changes in SA: in the years of the maximum values of the Wolf number, the number of MI cases in this group increased to 37.7%, and in the years of the minimum SA decreased to 30.4% of cases [15]. The study of the influence of space weather on the state of CVS showed that the number of ambulance calls from patients with CVD increased in the autumn and spring, with the highest HMD. The risk of developing myocardial infarction in women over 50 was several times higher than in men aged 50 and over. After 50 years in men, the sensitivity to HMD decreased due to the stabilisation of the adaptive processes in the body and development of resistance to external factors. Women over 50 years turned out to be more sensitive to HMD. There were two maxima in the distribution of patients' complaints about CVD, one of which coincided with the disturbance on the Sun, and the second lagged 2–4 days behind the HMD. The MI incidence has increased when the HMD exceeded the usual unperturbed level by 7–8 times [16].

An in-depth study of mortality from myocardial infarction and cerebral stroke in Moscow showed the dependence of the number of deaths on sharp fluctuations in individual meteorological parameters of the weather. The average daily mortality rate from MI and CS increased with sharp fluctuations in atmospheric pressure, on days of cloudy weather with wind and precipitation, with frontal weather, and during periods of warm front passage. Meteorological, synoptic, heliogeophysical factors exerted their influence on the mortality rate from vascular accidents to a much greater extent in the year with high SA. The response of men and women to the influence of heliogeophysical factors was not the same: the average stable mortality rate in men during MS was significantly higher than on magnetically stable days, while in women, such a relationship was not revealed [17]. The study of the incidence of MI by seasons in the city of Frunze revealed that the largest number of cases occurs in the summer and winter. When comparing the frequency of MI cases with day-to-day fluctuations in atmospheric pressure, it turned out, that the largest number of cases occurred on days when the atmospheric pressure was 910–925 mbar – 198 cases (24.5%), 930–935 mbar – 285 cases (35.4%). At the same time, it was found that the largest number of MI cases occurs on days with fluctuations in atmospheric pressure above average values by 10–15 mbar: over 150 such days, 191 cases were registered. The largest number (32.0%) of MI cases, observed in winter-spring and autumn, falls on days with very humid and damp weather. In the summer, 57.9% of MI cases occurred on hot dry days (relative humidity up to 55.0%) [18]. Analysis of mortality rates from acute myocardial infarction (AMI) depending on the average annual air temperature in Novosibirsk showed that MI more often develops during the cold autumn-winter seasons. The influence of meteorological and geophysical factors increases with the approach to high latitudes. Mortality in working age depends on the minimum air temperature in January, the average annual temperature, and on the geographical latitude of the territories. In high latitudes, in addition to temperature, the condition of patients with CVD is affected by unfavourable climatic and geographic conditions that worsen the course of the disease [19]. In the conditions of the city of Karaganda, the majority of patients with MI had meteorological stability. In these patients, the onset of the disease, as well as the deterioration in their health, always coincided with a change in weather conditions. These fluctuations were especially pronounced in the spring-autumn (March, November) and winter months (December, January) [20].

Studies in the city of Zaporizhzhia showed that when analysing the frequency of major cardiovascular events (MACE) by months of the year, there are regular seasonal fluctuations. Thus, the maximum increase in MACE was observed in the winter: the frequency of MI and unstable angina (UA) reached 10.2–10.9% of all cases, hypertensive crises in 9.2–10.2% of cases. In summer, the incidence of MACE was minimal: MI and UA – 5.4–6.4% of cases, hypertensive crises – 6.0–6.9% of cases [21]. The study of the influence of unfavourable weather conditions on the incidence and mortality of MI in Dushanbe revealed direct links between the combination of differences in atmospheric pressure and air temperature, which were most often encountered during spring, early autumn and late winter [22]. Studies of the role of meteorological factors in the occurrence of MI and CS with fatal outcomes in Samarkand revealed that the greatest number of cases of sudden death from MI was observed in the winter and spring months (January, February, March) and in July, the hottest month [23].

In North China, the influence of ambient temperature on the incidence of MI was studied. A total of 2033 patients were investigated in the period from January 2003 to December 2011. It was found that the day before the development of MI, an increase in the average daily temperature by 50 °C led to a decrease in the occurrence of MI by 5%. Two days before the development of MI, an increase in ambient temperature by 50 °C led to a decrease in the development of MI by 6%, and a decrease in temperature by 2 °C to an increase in the incidence of MI by 4% [24]. A similar study was conducted by doctors in Vietnam. The climate of Vietnam is diverse depending on the territory. The researchers compared the climate effects of two different coasts: South-Central and North-Central. On the South-Central coast, the tropical savanna type of climate prevailed, and on the North-Central coast the tropical monsoon. The study analysed data from 3 different clinics in the period from 2008 to 2015. A significant negative relationship was found between the incidence of MI and the climate of the North-Central coast of Vietnam, and vice versa, a positive relationship between the climate of the South-Central coast and the incidence of MI [25].

Sharp fluctuations in meteorological factors have a negative effect on patients with CVD. The number of patients with MI and exacerbation of chronic coronary insufficiency increases

in spring and winter. The change in weather classes has a significant effect on the occurrence of CVD, regardless of what this change is caused by (the passage of the front or the rapid invasion of a powerful anticyclone etc.) [26]. The study of morbidity by individual months and seasons has shown that the greatest number of heart attacks occurs in the winter and spring months and the smallest in the summer and autumn. It was also found that the adverse effect on patients with CVD is exerted not so much by high and low air temperatures as by sharp barometric fluctuations [27]. The weather with sharp fluctuations in temperature and air pressure, humidity, wind speed and atmospheric phenomena (fog, rain, blizzard, thunderstorm, hailstorm etc.) has an adverse effect on patients with MI. Apparently, during periods of sharp fluctuations in atmospheric pressure, in patients with coronary atherosclerosis, deterioration of coronary circulation occurs more often, due to significant fluctuations in the tone of the vessel wall, the occurrence of spastic vascular reactions. The most unfavourable type of weather, in which myocardial infarctions occur more often, are 3rd and 4th classes [28].

A meta-analysis of 19 studies on the effect of ambient temperature on the incidence of MI showed that 8 of 12 studies in winter and 7 of 13 studies in summer showed a significant increase in the risk of MI. Some differences were identified in the studies depending on the population, demography, and location. The authors believe that further research is needed [29]. A meta-analysis of 26 studies according to Medline, Web of Science from 2000 to 2015 that examined the relationship between cardiovascular mortality and ambient temperature found that the risk of mortality increased by 5% at low temperatures and by 1.3% at high temperatures. In the elderly, the risk of mortality increased to 8.1% and 6%, respectively [30]. A study of the influence of weather and climate on 6560 patients with acute coronary syndrome showed a statistical relationship between the occurrence of MI by high atmospheric pressure (pressure gradient) and wind force. Temperature, warm and dry wind, lightning did not reveal a significant statistical relationship. Snow and rain had inconsistent effects [31]. A reliable relationship was found between the frequency of MI, the minimum daytime ambient temperature and the maximum daytime humidity [32]. It was shown that with a decrease in temperature by 10 °C, the number of hospitalisations of persons over 65 years old increased by 19% [33]. A significant increase in the frequency of hospitalisations of young women with MI with ST-segment elevation on days with high fever in the summer was found [34].

A study of the relationship between climate change in Italy (the city of Florence) and the frequency of hospitalisations for myocardial infarction showed a significant increase in the number of hospitalisations after 24 hours of the day characterised by anticyclonic, continental air masses [35]. A study of the impact of climate on non-fatal acute coronary syndrome (ACS) in the Mediterranean Sea (Greece, Crete, Leranetra) showed that the maximum number of ACS occurred in August and May. A relatively high frequency of ACS was observed at the beginning of winter. The influence of weather (temperature, air humidity, wind speed and cloudiness) on the incidence of ACS was not statistically significant [36]. The study of the influence of temperature, relative humidity, wind speed, barometric pressure and thermo-hydrological index on the frequency of hospitalisations of patients with ACS in the region of the city of Athens showed that a decrease in air temperature by 10 °C led to an increase in the number of hospitalisations by 5% ($p < 0.05$). This relationship was more significant in older adults and women. A positive correlation was found between relative humidity and hospital admission rates for ACS. Despite the short follow-up period (2 years), a significant relationship was found between cold weather and the frequency of ACS, especially among the elderly and women [37]. At the same time, a study of the relationship between the frequency of hospitalisations of patients with MI and the winter season in Sweden found that weather conditions (temperature, wind speed, acceleration and atmospheric pressure) are not a trigger factor for MI in Sweden [38]. The study of the relationship between meteorological factors and AMI during the year in the city of Helsinki showed that the highest frequency of MI was observed in late autumn, and the lowest in summer. Ambient temperature did not correlate with the incidence of AMI, but deaths were more frequent on cold days. The greatest correlation was with atmospheric pressure. A sharp decrease in atmospheric pressure triggered an increase in the number of MI cases. Relative humidity had little effect. The most adverse impact was associated with cold and wet weather with low atmospheric pressure, which is common in Helsinki in early winter and late autumn [39].

Despite the numerous literature data on the close dependence of the development and outcomes of myocardial infarction on heliogeophysical factors, there are studies in which the relationship between the incidence rate and the course of the 11-year solar cycle was not noted, and no connection was found when comparing the monthly incidence with the average monthly values of Wolf numbers, due to which, it seems that the course of CVD is a test incomparably more complex than chemical, leukocyte and epidemiological tests, and its correlation with SA is much more complicated than with simple tests. Similar results were obtained by American researchers for 4 years of studying mortality from coronary insufficiency and cerebral strokes (275 million indicators). These studies did not reveal statistically significant linear correlations of medical and heliogeophysical parameters, which contributed to the emergence of serious scepticism towards this problem in the Western World [40].

## Conclusion

Summarising the literature data on the influence of heliogeophysical factors on patients with MI, it can be concluded that all studies were carried out within a period from one to 15 years, i.e. within one solar cycle, while the International Meteorological Conferences (in 1935 in Warsaw and in 1957 in Washington) recommended to select thirty-year averaging periods to determine the characteristics of the modern atmospheric climate. The presence of conflicting literature data on the influence of heliogeophysical factors on patients with MI, dictates the need for research for at least 3 solar cycles (i.e. 33 years).

Of particular interest is the study of the influence of heliogeophysical factors on the development and outcomes of MI in the mountainous regions of Central Asia, where mountain

systems (Pamir, Altai, Tien Shan, Himalayas) generating powerful orographic waves have a strong effect on the oscillatory behaviour of electromagnetic and thermodynamic parameters of the atmosphere.

## Conflict of interest

None.

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