НИРКИ KIDNEYS

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The search for new pathogenesis of cardiorenal syndrome: the effect of local Schumann resonance on the occurrence of episodes of kidney disease and myocardial infarction

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Abstract. ***Background.*** *The pandemic of noncommunicable chronic diseases and the high prevalence of combined damage to the cardiovascular system and kidneys determine the relevance of continuing scientific research to solve these medical problems. Therefore, the aim of this study was to compare the influence of the Earth's electromagnetic field on the occurrence of episodes of kidney disease and myocardial infarction in order to search for new pathogenetic components of cardiorenal syndrome and deepen fundamental knowledge. According to the Lithuanian magnetometer GCI003, a number of studies in 2014–2018 found that changes in the Earth's electromagnetic field may play an important role in the pathogenesis of cardiovascular diseases as well as their incidence. Since the functioning of the cardiovascular system and kidneys are closely connected through the metabolic processes of the cardiorenal metabolic axis, this study tested the hypothesis that changes in the Earth's electromagnetic field may also affect the pathogenesis of kidney disease as the changes of local magnetic field have been shown to influence the functioning of the cardiovascular system.* ***Materials and methods.*** *This was a search retrospective study on the relationship between the influence of local Schumann resonances and the occurrence of hospitalizations in 1340 patients with kidney disease. It also examined the relationship between local Schumann resonances and heart attacks in patients admitted to the University Hospital of the Lithuanian University of Health Sciences (703 patients). Mean power of local magnetic field fluctuations in Lithuania was measured in pT2 s2 in five different frequency ranges, which overlaps the Schumann resonance and electroencephalogram's frequency ranges: SDelta (0–3.5 Hz), STheta (3.5–7 Hz), SAlpha (7–15 Hz), SBeta (15–32 Hz), SGamma (32–66 Hz). The data of hospitalizations to the Nephrology Department of University Hospital and the dynamics of Schumann resonances were analyzed from January 1, 2021 to December 31, 2021. The data of hospitalizations for myocardial infarction to the Cardiology Department of University Hospital and the dynamics of Schumann resonances were studied from January 1, 2016 to December 31, 2016.* ***Results.*** *It was found that changes in the strength of the Earth's local magnetic field in 2016 and 2021 were comparable and corresponded to the characteristic annual dynamics of the Earth's local electromagnetic fields. This made it possible to conduct a comparative analysis of annual correlation graphs and establish general trends in the dynamics of indicators and graphical similarities. It confirmed the presence of a general dependence of reactions to the external electromagnetic field of the Earth in female and male patients both with nephrological pathology and myocardial infarction. In nephrological patients of both sexes, all correlation coefficients in all ranges of Schumann resonances were positive. The only negative correlation coefficient P5 (SGamma) (32; 65) Hz ($r = –0.069$; $p = 0.313$) was in the female group. This fact*

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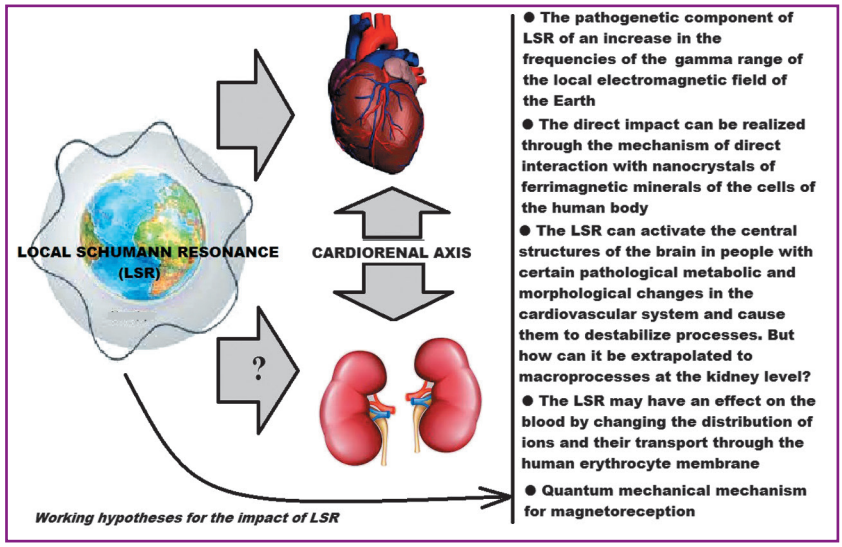
as well as the presence of a significant dynamics of the correlation coefficient P5 (SGamma) (32; 65) Hz (r = 0.009; p = 0.475) in the male group indicate that higher magnetic field strength in this frequency range may be associated with a reduced incidence of kidney disease. We obtained data that a higher magnetic field intensity in the gamma range from 32 to 65 Hz as a pathogenetic component can contribute to the destabilization of the cardiovascular system, but at the same time it is associated with a positive effect on the state of nephrological pathology. Based on this, we can tentatively assume the opposite direction of the Earth's electromagnetic field influence on the pathogenetic mechanisms of renal and cardiovascular diseases. This is clearly demonstrated by comparing the correlation coefficients between the incidence of kidney disease and the occurrence of myocardial infarction in men and women. The Earth's stronger magnetic field in the gamma range contributes to an increase in the incidence of myocardial infarction, which is confirmed by the large number of patients during this period. Under these same conditions, a decrease in the incidence of kidney disease has been detected. This opposite direction is observed in both sexes. But in women the reaction is stronger, which is confirmed by a larger difference in correlation coefficients. **Conclusions.** *1. Changes in the Earth's electromagnetic field are related to the functional state of the cardiovascular system and the condition of the kidneys. 2. It can be assumed that the effect of the Earth's electromagnetic field on the pathogenetic mechanisms of kidney disease is in the opposite direction of that on the cardiovascular one. 3. Reliable gender differences in correlations between the influence of changes in the local Schumann resonance on the functional state of the cardiovascular system and kidneys were not found. 4. The connection of the Earth's local geomagnetic field with kidney function may be another new unexplored pathogenetic mechanism in cardiorenal syndrome and noncommunicable chronic diseases.*

Keywords: *noncommunicable diseases; cardiorenal syndrome; kidney disease; acute myocardial infarction; local Schumann resonance; Earth's magnetic field*

Graphical abstract



Introduction

Relevance explained

Despite the great successes of medicine in all areas of its activity, a pandemic of noncommunicable chronic diseases (NCDs) continues in the world. At the same time, cardiovascular diseases are still the main cause of death and disability [1, 2], and chronic kidney disease is widespread (10–13 % of the population, its affects up to 800 million people worldwide), irreversible, progressive and is associated with higher cardiovascular risk [3–6].

Medical science has thoroughly studied the pathogenesis of cardiovascular and kidney diseases. However, it is now clear that the human body is a complex interconnected multi-hierarchical system in which all organs are functionally united and influence each other. This is confirmed by the fact that cardiovascular and renal diseases are often combined and cause mutual progression of pathology. As a result, more than 90 % of patients with heart failure have chronic kidney disease, and individuals with acute heart failure develop acute kidney injury. According to the existing consensus (the Acute Dialysis Quality Initiative conciliation conference held in Venice in 2008), a pathological combination of cardiovascular and kidney diseases, when acute or chronic dysfunction in one organ caused acute or chronic dysfunction in another, was called cardiorenal syndrome [7–9].

The leading causes of kidney injury in cardiovascular disease are renal hypertension and the adverse effects of diuretic therapy, which lead to hypovolemia, hypokalemia, and nephron damage [10–13].

The kidneys are the most important metabolic organ involved in humoral regulation, water and electrolyte metabolism, and microcirculation. Therefore, impaired renal function leads to fluid retention in the body, metabolic acidosis, and electrolyte imbalance of potassium, sodium, calcium, and magnesium. This, accordingly, creates an additional load of fluid on the heart, reduces the sensitivity of beta-adrenergic receptors to endogenous catecholamines, disrupts the formation of action potentials in cardiomyocytes and contributes to the progression of cardiovascular

diseases [6, 13, 14]. Renal dysfunction is associated with a higher incidence of recurrent myocardial ischemia, myocardial infarction (MI), stroke, major bleeding complications, acute heart failure, atrial and ventricular fibrillation. Even a slight decrease in renal function significantly aggravates the course of the underlying cardiac pathology, while simultaneously increasing the frequency of complications, risk of death, and, conversely, a decreased myocardial contractility affects kidney function in the most negative way [10, 15, 16]. Therefore, the further search for new approaches to solving these problems remains absolutely relevant.

Magnetoelectrochemical theory of metabolism

A promising direction for searching for new components of the pathogenesis of NCDs, in particular cardiorenal syndrome, are approaches from the positions of magnetobiology and complementary medicine, including modern biophysical knowledge about the structure of the micro level of matter [17, 18]. This is due to the transition of science to the level of understanding of quantum processes. Now modern scientists have the opportunity to develop aspects of quantum pathogenesis. New fundamental knowledge about the structure of tissues of the human body at the micro level can change the scientific view on the pathogenesis of NCDs and cardiorenal syndrome. Briefly and simplified, these ideas can be presented as follows.

The modern paradigm of ideas about the microstructure of matter is based on the fact that at levels above 10^{-14} nm, all atoms have an electromagnetic structure and consist of electromagnetic fields. All matter on planet Earth and within the human body are made up of about 100 types of atoms. Regardless of the type, all atoms consist of a nucleus, an electron shell and are divisible. They consist of field structures — fermions, which are united by the fundamental forces of field electromagnetic, strong, weak nuclear interactions, the carriers of which are bosons. Accordingly, all parts of the atom are different forms of energy. The total energy that forms atoms determines their corresponding electrical charges. This determines the exchange interaction of electrons between atoms, the primary properties of atoms and the objects formed by them (molecules, etc.) at the macro level of the world. Accordingly, all chemical reactions are the result of the exchange interaction of electrons between atoms, and the chemical reactivity of molecules is a quality that is determined by electromagnetic characteristics of the atoms that form them. Thus, the substances they form are also different forms of energy at the micro level of their organization [19–22]. This completely changes the scientific understanding and understanding of the structure of the human body. It turns out that all the tissues of the human body, at the micro level of structural organization, are also conglomerates of electromagnetic fields. Therefore, all processes of metabolism of substances in the human body are the result of electromagnetic to chemical interactions between atoms and molecules.

Important scientific discoveries included understanding the role of magnetoelectric processes in the functioning of cell membranes of the human body [23], the role of water [24] and electromagnetic signaling [25] in the intercellular communication *in vivo*. Systematization and analysis of new fundamental knowledge accumulated by world science led to the conceptualization of the magnetoelectrochemical theory of metabolism [22, 26–28]. Now in modern science there is another new idea about the structure and functioning of the human body — the electromagnetic, or frequency-response model. According to this model, it is clear that: 1) the entire human body is formed by different types of electromagnetic energies; 2) electromagnetic processes determine all types of chemical reactions between molecules in the human body *in vivo*; 3) electromagnetic processes and electromagnetic fields of the morphological structures of the human body (membranes, cells, tissues, organs, etc.) form the basis of electromagnetic signaling, which allows the cells of the body to be a single whole and function. The cessation of electromagnetic processes in cells means their death [22, 26, 28].

All this new fundamental knowledge opens up the possibility for medical science to search for new mechanisms of the pathogenesis of NCDs at the quantum level. Now, through magnetobiology approaches, we can try to develop fundamentally different aspects of the pathogenesis of some of the most important NCDs — cardiovascular and kidney diseases.

Local Earth's magnetic field and cardiorenal axis

Since the human body at the micro level of its structure is a conglomerate of electromagnetic energy, all metabolic processes in it are determined and are the result of electromagnetic to chemical interaction, the influence of external electromagnetic fields on humans should have clinical significance in the pathogenesis of NCDs. For example, the influence of the absence of the Earth's magnetic field on the human body, etc., has been proven [29–35]. The cardioprotective effect of stressful conditions by weak magnetic fields in the Schumann resonance band has been found [36] as well as subjective and objective improvement in the state of patients during the treatment of sleep disorders with Schumann resonance frequencies [37].

To understand the pathogenesis of NCDs, it is important that the Earth's magnetic field is constantly changing. It is characterized by daily, weekly, monthly, annual, etc. cycles of oscillations. In winter, the spectral power of the Earth's local magnetic field decreases. In spring, it begins to increase and reaches its maximum in summer. In autumn, the magnetic field strength begins to decrease to its minimum point in winter (data from the Lithuanian magnetometer GCI003 are available from: https://www.heartmath.org/research/global-coherence/gcms-live-data/). These changes can affect the processes occurring in the human body. The health literature has found that both weak and strong magnetic fields are associated with health effects [32, 35, 38–42]. Low-frequency magnetic fields have a positive effect on humans [36], however, high frequencies can cause stress reactions in human regulatory systems [38, 43, 44]. People may have different sensitivity to magnetic field frequencies depending on age, gender and health status [29, 34, 45].

It has also already been found that Schumann resonances, certain dominant frequencies of the Earth's electromagnetic field, have a fundamental influence on the human body. As it turned out, the frequency ranges of Schumann resonances coincide with the frequencies of electrical activity of the brain and can be considered as related processes. At the same time, it has already been shown that high-frequency waves of Schumann resonances have a stressful effect on living organisms [46–56]. It is the high-frequency ranges of Schumann resonances that can be a pathogenetic component, which causes destabilization of the clinical condition in patients with NCDs. Therefore, we consider the study of the frequency ranges of Schumann resonances to be the most promising at this scientific stage.

Since 2014, the Lithuanian University of Health Sciences (LUHS) has begun studying the influence of the Earth's electromagnetic field and Schumann resonance ranges on the pathogenesis of cardiovascular diseases. Thanks to the directorate of the institute, Lithuania received and began to use an extremely sensitive magnetometer (pT sensitivity), the only one of a kind in Europe. Currently, there are six such magnetometers across the globe: USA, Canada, Saudi Arabia, New Zealand, South Africa, and Lithuania. By using magnetometer's live data, we can observe changes in the local earth's time-varying magnetic fields in Lithuania and compare it with medical data. It has been found that changes in the Earth's electromagnetic field have a role in the pathogenesis of cardiovascular diseases and affect their incidence [45, 49–56].

The functioning of the cardiovascular system and kidneys is closely related through the metabolic processes of the cardiorenal metabolic axis [57–59]. Therefore, it is logical to hypothesize that changes in the Earth's electromagnetic field should also affect the pathogenesis of kidney disease if they influence the functioning of the cardiovascular system. Studies on the influence of changes in the Earth's electromagnetic field on the function of the urinary system have never been carried out in world science before, according to the literature we have studied. In 2022, an analysis of correlations between the interaction of the Earth's magnetic field and episodes of kidney disease was performed for the first time. However, questions about the existence of the influence of the Earth's electromagnetic field on the cardiorenal axis remain unanswered for now. The search for new pathogenetic links of cardiorenal syndrome should be continued. Therefore, the aim of this study was to compare the possible influence of the Earth's electromagnetic field on the occurrence of episodes of kidney disease and myocardial infarction in order to search for new pathogenetic components of cardiorenal syndrome and deepen fundamental knowledge.

Materials and methods

Organizational data

Scientific work was carried out in conjunction with the following scientific institutions: 1) LUHS (the cooperation coordinator is Head of the Nephrology Department, prof. I.A. Bumblyte and senior researcher of the Laboratory of Automation of Cardiology Research of the Institute of Cardiology of the LUHS, prof. A. Vainoras); 2) Poltava State Medical University (the cooperation coordinator is Head of the Department of Internal Medicine and Emergency Medicine, prof. M. Potyazhenko); 3) HeartMath Institute, USA (the cooperation coordinator is director of research at the Institute and project coordinator of GCI's Global Coherence Monitoring System R. McCraty; 4) Kaunas University of Technology, Lithuania (the coordinator of the mathematical part is M. Landaukass, assoc. prof. of the Department of Mathematical Modelling).

The analysis of the presented data is a fragment of research work of the Department of Internal Medicine and Emergency Medicine of Poltava State Medical University titled "Development of algorithms and technologies for implementing a healthy lifestyle in patients with noncommunicable diseases based on the study of functional status" (state registration number 0121U108237, UDC 613:616-056-06:616.1/9-03) and it is a fragment of a research project of the LUHS on the topic "Investigation of interactions between the Earth's magnetic field variations and human and animal health and behavior".

Magnetometer data

The local time-varying magnetic field intensity was measured using magnetometer situated in Lithuania, which is part of the Global Coherence Monitoring Network. Two magnetic field detectors (Zonge Engineering Inc.) ANT4 are positioned in north/south and east/west. Data used in the analysis is from the east-west direction. Signals from the magnetometers were digitized with a 24-bit data acquisition system (Symmetric Research, Las Vegas, NV) at a rate of 130 Hz and uploaded hourly to a cloud storage for offline processing. The overview of the magnetometer's data is available on web page (https://www.heartmath.org/research/global-coherence/gcms-live-data/). Hourly data files were downloaded to a PC workstation for post-processing where each file was transformed into consecutive 30-second-long segments. The power spectral density (PSD) was calculated for each segment. All PSD segments for each hour were then averaged together. The sum of the PSD in the frequency range of 0–65 Hz was calculated for each hour in the study period. In the estimated power curve, there is a series of dominant Schumann resonance frequencies, which are divided into ranges that overlap with the EEG wave classification (as related processes): 0 to 3.5 Hz — delta waves (P1), 3.5 to 7 Hz — theta waves (P2), 7 to 15 Hz — alpha waves (P3), 15 to 32 Hz — beta waves (P4), 32 to 100 Hz — gamma waves (P5) [46, 47]. Mean power of local magnetic field fluctuations in Lithuania is measured in $pT^2\ s^2$ in five different frequency ranges, which overlaps the Schumann resonance and EEG frequency ranges (we named them SDelta (0–3.5 Hz), STheta (3.5–7 Hz), SAlpha (7–15 Hz), SBeta (15–32 Hz) and SGamma (32–66 Hz) to distinguish from the EEG bands). Average readings of Schumann's local Earth's magnetic field dynamics and hospitalization data were compared by calendar weeks of the year.

A spectral analysis of the magnetometer data was made and is summarized below.

Consider magnetic field intensity $\{I_t\}_{t=0}^{N-1}$, where t is discrete time variable.

$$f(\omega) = \sum_{t=0}^{N-1} I_t \cdot e^{\frac{-2\pi i t \omega}{N}}, t \in Z. \quad (1)$$

In order to transform $\{I_t\}_{t=0}^{N-1}$ to the frequency domain, the discrete Fourier transform (DFT) (Eq. (1)) was used. The drawback of DFT is that one cannot observe the change in spectral density over time unless sequentially computing DFT. To achieve this, the short-time Fourier transform (STFT) was used.

$$F(\tau, \omega) = \sum_{t=-\infty}^{\infty} I_t \cdot \xi(t - \tau) e^{-it\omega}, t \in Z. \quad (2)$$

STFT for $\{I_t\}_{t=0}^{N-1}$ is represented by Eq. (2). In fact, this is essentially the analogue for Eq. (1) but applied to the function $I_t \cdot \xi(t - \tau)$. $\xi(t)$ is a so-called windowing function, which has a value close to 1 in a subdomain of t centered on 0 and a value close to 0 elsewhere. The units of $f(\omega)$ and $F(\tau, \omega)$ are pT • s due to the fact that the intensity of the magnetic field is measured in pT.

$$S(\tau, \omega) = |F(\tau, \omega)|^2. \quad (3)$$

Spectrograms investigated in this work is the squared modulus of STFT (Eq. (3)). Originally, units of a spectrogram would be $pT^2 \cdot s^2$. $S(\tau, \omega)$ is often referenced as power spectral density. Thus, the value of $S(\tau, \omega)$ is interpreted as signal power at the time interval $\Delta\tau$ starting at the time moment t and at the frequency range $\Delta\omega$ correspondingly starting at the frequency ω.

More detailed algebraic and spectral analysis of local magnetic field intensity is presented in [60].

Participants

This theoretical comparative exploratory study analyzed the influence of local Schumann resonances of the Earth's magnetic field on the occurrence of episodes of kidney disease according to hospitalizations to the Nephrology Department of the University Hospital at the LUHS and on the occurrence of myocardial infarction according to hospitalizations to the Cardiology Department of the University Hospital of the LUHS.

Data about hospitalizations to the Nephrology Department of University Hospital at the LUHS and the dynamics of Schumann resonances in local Earth's magnetic field were analyzed in a retrospective exploratory study. The study period was from January 1, 2021 to December 31, 2021. Admission data for 1340 patients with kidney disease over the period were included in the study. Cases of non-core hospitalizations without kidney pathology were excluded from the analysis. The proportion of emergency hospitalization was 52 % (699/1340). 53 % (716/1340) of patients were men (mean age is 59.10 ± 17.23 years, Me of 60.80 years), 47 % (624/1340) were women (mean age is 62.96 ± 17.55 years, Me of 65.2 years).

Data about hospitalizations to the Cardiology Department of University Hospital at the LUHS and dynamics of local Earth's magnetic field Schumann resonances were analyzed in a retrospective exploratory study. The study period was from January 1, 2016 to December 31, 2016. Admission data for 703 patients with cases of acute myocardial infarction over the period were included in the study. 62 % (435/703) of patients were men (mean age is 63.44 ± 11.65 years, Me of 63 years), 38 % (268/703) were women (mean age is 73.21 ± 10.45 years, Me of 75 years).

All applicable ethical rules have been observed.

Statistical analysis

Statistical analysis was performed using the Prism 5.0 software package. The data obtained are presented as mean values with their standard deviation of the mean (STDEV) error (M ± STDEV). Nonparametric Mann-Whitney U-test was used to compare and determine the statistical significance of differences in statistical properties between groups. The differences were considered significant at $p < 0.05$. Pearson coefficient for the linear correlation between two variables was calculated. The level of $p < 0.05$ was considered statistically significant.

Other scientific methods

General scientific (dismemberment and integration of elements of the studied system, imaginary experiment, logical analysis, induction, deduction, and synthesis of knowledge) and theoretical methods (method of constructing theory, logical methods, and rules of normative nature) were used in this study.

Results

When comparing changes in the strength of the Earth's local magnetic field in 2016 and 2021 (Fig. 1), it was found that the spectral power of the Earth's local time-varying magnetic field decreased in winter, increased in spring, was highest in summer, decreased again in autumn and continued the trend to its lowest point in winter (data from the Lithuanian magnetometer GCI003 from the website: https://www.heartmath.org/research/global-coherence/gcms-live-data/). Thus, changes in the strength of the Earth's local magnetic field in 2016 and 2021 were considered comparable in such a way that they correspond to the known characteristic annual dynamics of the Earth's local electromagnetic fields [45].

In a previous scientific study, a relationship was found between the number of hospitalizations of patients with nephrological pathology per week and the average weekly geomagnetic field strength in different frequency ranges (Fig. 2). A correlation was also revealed between the number of acute ST-segment elevation myocardial infarction cases per week and the average weekly geomagnetic field strength in different frequency ranges (Fig. 3). This allowed to conclude that cases of hospitalization of males and females both with nephrological pathology and MI are statistically significantly associated with seasonal changes in the local geomagnetic field. Thus, changes in the Earth's electromagnetic field are related to the functional state of the cardiovascular system (the occurrence of myocardial infarction) and the condition of the kidneys (the number of hospitalizations with nephrological pathology). A comparative analysis of annual correlation graphs found that each study had a certain graphical similarity and general trends

in the dynamics of indicators. This confirmed the presence of a general dependence of reactions to the external electromagnetic field of the Earth in female and male patients both with nephrological pathology (Fig. 2) and myocardial infarction (Fig. 3).

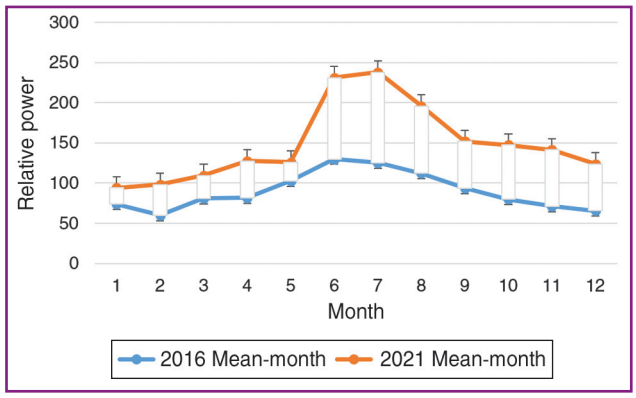


Figure 1. The changes in power of local Earth's magnetic field in Lithuania (GCI003) during 2016 and 2021

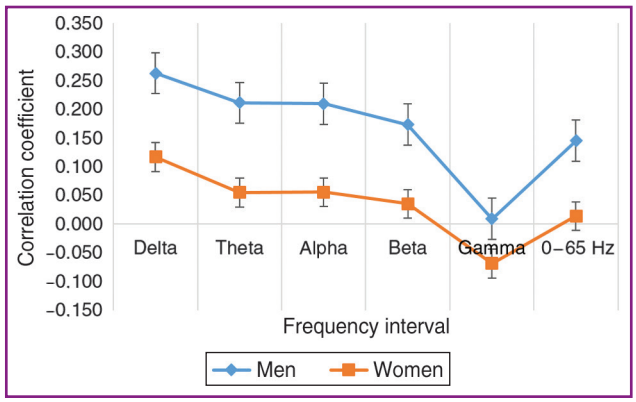


Figure 2. Coefficients of correlation between number of weekly cases of kidney disease among men and women and mean magnetic power in different frequencies for the whole year (data from the LUHS Nephrology Clinic, 2021). Difference between genders is non-significant

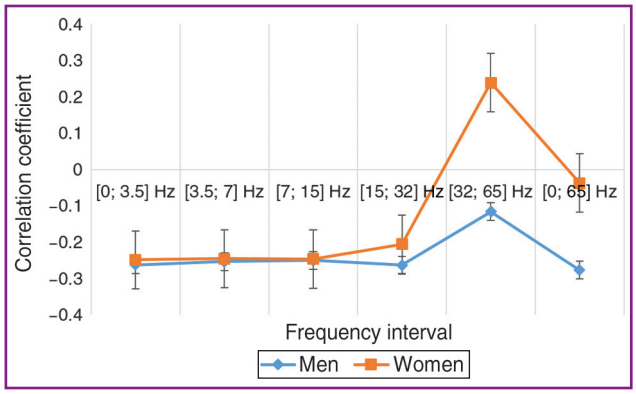


Figure 3. Coefficients of correlation between number of weekly cases of MI in older (> 63 years) men group and women and mean magnetic power in different frequencies for the whole year (data from the LUHS Cardiology Clinic, 2016). Difference between genders is non-significant

Analysis of annual correlations in both studies demonstrated that in nephrological patients of both sexes, all correlation coefficients in all ranges of Schumann resonances were positive, except for a negative correlation coefficient P5 (SGamma) [32; 65] Hz ($r = -0.069$; $p = 0.313$) in the female group. This fact and the presence of reliable dynamics of the correlation coefficient P5 (SGamma) [32; 65] Hz ($r = 0.009$; $p = 0.475$) in the male group indicates that higher magnetic field intensity in this frequency range is associated with a decreased incidence of kidney disease (Fig. 2). In cardiac patients of both sexes, the opposite situation was observed: all correlation coefficients in all Schumann resonance ranges were negative, except for a positive correlation coefficient P5 (SGamma) [32; 65] Hz ($r = 0.240$, $p = 0.455$) in the female group. This fact and the presence of dynamics of the correlation coefficient P5 (SGamma) [32; 65] Hz ($r = -0.115$; $p = 0.424$) in men indicates that higher magnetic field intensity in this frequency range is associated with an increase in the number of myocardial infarctions (Fig. 3). Thus, we obtained data that a higher magnetic field intensity in the gamma range from 32 to 65 Hz as a pathogenetic component can destabilize the cardiovascular system, but at the same time it is associated with a positive effect on the

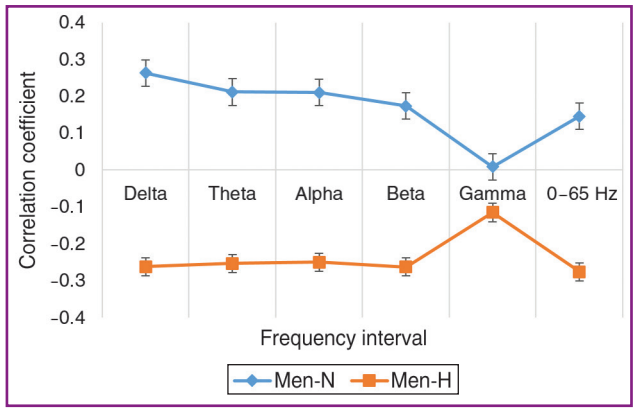


Figure 4. Correlation coefficients in men admitted to nephrology and heart departments (data from the LUHS Cardiology Clinic, 2016, and from the LUHS Nephrology Clinic, 2021)

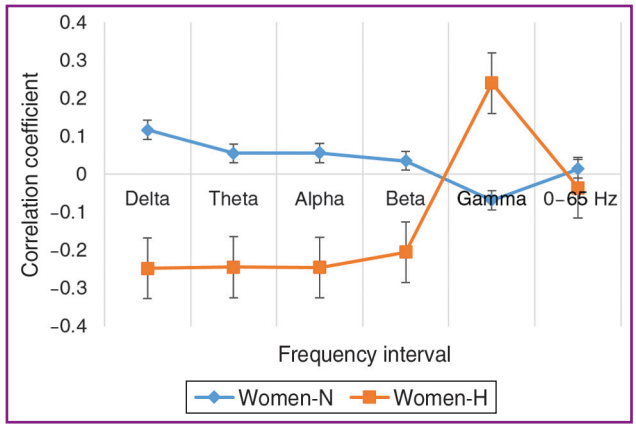


Figure 5. Correlation coefficients in women admitted to nephrology and heart departments (data from the LUHS Cardiology Clinic, 2016, and from the LUHS Nephrology Clinic, 2021)

state of nephrological pathology. Based on this, we can tentatively assume the opposite direction of the influence of the Earth's electromagnetic field on the pathogenetic mechanisms of renal and cardiovascular diseases. This is clearly demonstrated by comparing the correlation coefficients between the incidence of kidney disease and myocardial infarction in men (Fig. 4) and women (Fig. 5). The Earth's stronger magnetic field in the gamma range contributes to an increase in the incidence of myocardial infarction, which is confirmed by the large number of patients during this period. Under the same conditions, a decrease in the incidence of kidney disease has been detected. This opposite direction is observed for both sexes. But in women the reaction is stronger, which is confirmed by a larger difference in correlation coefficients (Fig. 5).

Discussion

Based on the results of this study, we can tentatively assume the opposite direction of the influence of the Earth's electromagnetic field on the pathogenetic mechanisms of renal and cardiovascular diseases. This makes us understand that science still does not know enough about the metabolic interactions in the cardiorenal axis and that there are unknown pathogenetic components of the cardiorenal syndrome due to the influence of local Schumann resonance. To search for scientific truth, let's discuss possible mechanisms of influence of the Earth's local electromagnetic field — Schumann resonance on the cardiovascular and urinary systems.

It has long been believed that the Earth's static magnetic field does not affect humans, while alternating magnetic fields such as power frequency fields [61] and pulsed fields [62] may have adverse health effects and have therapeutic use, respectively [63–65].

A scientifically validated connection between the biological influence of the Earth's local electromagnetic field on humans is the fact that the frequencies of the Schumann resonance coincide with the frequencies of the human brain. It has been found that the brain rhythm of a sleeping person is a sinusoidal delta rhythm (frequency 0.3–4 Hz, amplitude 50–500 μV). The rhythm of human brain activity in a completely relaxed state and transition to a state of sleep, anesthesia is a sinusoidal theta rhythm (frequency 4–8 Hz, amplitude 10–30 μV). The rhythm of brain activity of a waking person in a state of abstract thinking is a sinusoidal alpha rhythm (frequency 9–13 Hz, amplitude 30–60 μV), dominant in the occipital regions of the brain. The rhythms of brain activity of a waking person in the normal state are aperiodic beta rhythms, dominant in the frontal regions (frequency of the beta 1 rhythm 13–25 Hz, frequency of the beta 2 rhythm 25–35 Hz, amplitude 3–10 μV). Sporadic oscillations in a state of wakefulness with a frequency of 35–100 Hz and an amplitude of 5–15 μV are the gamma rhythm. The gamma rhythm coincides in frequency with muscle potentials, is observed when solving problems that require maximum concentrated attention, and makes it possible to judge the balance of inhibitory and excitatory impulses, helping to identify its disorders in a person. If the amplitude of the gamma rhythm is above 15 μV, the electroencephalogram is considered pathological [64–67].

The first four harmonics of the Schumann resonance are recorded at frequencies of 7.8 (variations during the day ± 1.5 Hz), 14.5, 20, 26 Hz (with a spread of ± 0.3 Hz) and they coincide in the frequency range with the rhythms of the human brain. The physical mechanism for adjusting brain rhythms to the first harmonic of the Schumann resonance is forced resonance, since there is a coincidence of the frequency of the forcing effect (the local electromagnetic field of the Earth) and the natural frequency of the system (brain rhythms) [68, 69]. Another classic example of forced resonance is the response of the human body to a frequency of 40 GHz, which coincides with the resonant frequency of the tertiary structure of the DNA helix [70]. Apparently, the scientifically validated coincidence of frequencies of brain activity and Schumann resonance is a special case of general biological electromagnetic synchronization observed in the Solar system and in the biosphere.

The pathogenetic component of the influence of increased frequencies of the gamma range of the local electromagnetic field of the Earth can be described as the following chain of events of indirect impact on the human body: variations in the electron concentration in the ionosphere during electromagnetic disturbances lead to fluctuations in the frequencies and periods of the ionospheric resonator, which in turn may affect the rhythms of the components of the body. An increase in the frequencies of the gamma range causes resonance phenomena in the neurons of the brain. In response to this, a stress adaptation reaction of the body occurs, which leads to activation of the hypothalamic-pituitary-adrenal axis and an increase in the production of stress hormones — catecholamines and glucocorticoids. These hormones influence the activation of factors of the blood coagulation system, primarily the aggregation activity of cellular elements, causing a spasm in the vessels of the microvasculature, up to the complete cessation of blood flow in the capillaries. This can lead to the development of ischemic foci in the tissues of the heart and brain.

Also, the direct impact of variations in the amplitudes of the local electromagnetic fields of the Earth can be realized through the mechanism of direct interaction with nanocrystals of ferrimagnetic minerals of the cells of the human body, for example, with magnetite (Fe_3O_4). Biogenic magnetite is found in the brain and other human organs, it is of biogenic origin and is gradually formed as a result of crystallization directly in the cells of the body. The presence of magnetite in living cells and organisms is one of the possible reasons for their sensitivity to weak magnetic fields and local electromagnetic fields of the Earth. Ferromagnetism remains a viable biophysical mechanism for sensory transduction and provides a basis for initiating behavioral studies of human magnetoreception [68, 71]. There is a theory that geomagnetic field disturbances affect the nerve centers of cardiovascular regulation [63, 72]. This was experimentally confirmed when assessing baroreflex sensitivity by the response of blood pressure and heart rate to intravenous injections of phenylephrine and nitroprusside. A significant negative correlation was found with increasing geomagnetic field disturbance and baroreflex sensitivity, heart rate variability and

blood pressure. Decreased baroreflex sensitivity may lead to increased mortality after myocardial infarction [73].

The close connection between the regulation of brain activity and the functions of the cardiovascular system has been sufficiently studied. Therefore, the situation seems quite logical when the increasing contribution of the frequencies of the gamma range of the local electromagnetic field of the Earth can activate the central structures of the brain in people with certain pathological metabolic and morphological changes in the cardiovascular system and force them, through a system of cascade reactions, to destabilize processes and cause myocardial infarction, as, for example, in this study. It would be quite expected to get the same reaction from the urinary system. But, as this study has shown, here we have an opposite result. Since the contribution of the gamma band increased, the number of hospitalizations for kidney disease decreased, it appears that the gamma band may have a stabilizing effect on the functioning of the urinary system. And this makes our understanding of the role of the electromagnetic pathogenetic component in the cardiorenal metabolic axis even more complex and still difficult to fully explain. This requires additional clinical and theoretical research. Now we can only discuss possible hypothetical mechanisms. In a chain of logical thoughts, we propose to go from the opposite. What idea or model can be the starting point for studying and understanding these processes?

On the one hand, we propose to start logical reasoning with the concept of the magnetoelectrochemical theory of metabolism and the fact that all tissues, molecules, atoms and subatomic structures and all micro level processes (nano level and deeper) are the result of electromagnetic interaction and exhibit the properties of wave-frequency duality. Therefore, every atom, ion, molecule, etc. have characteristic frequency and can have a resonant response to the same frequency from the environment. There are scientific works describing the existence of bioeffective frequencies in the range of 0.3–30 Hz, causing resonance of bound ions. These ions can be considered isotropic oscillators that carry a charge. This mechanism is assumed to be associated with resonances of ions that regulate the rate of biochemical reactions in the cells of biological systems. It is described in the scientific literature as cyclotron resonance [74–80]. Laboratory data demonstrate the influence of the ion cyclotron mechanism on the regulation of isolated myocardial cells [81]. The mechanism at the micro level is somewhat clear. But how can it be extrapolated to macroprocesses at the kidney level?

A living human body is a complex multi-hierarchical system whose life activity is accompanied by many micro- and macroscopic processes. The body exists thanks to the close connection and coordination of the activities of its organs and systems. It has been scientifically proven that this consistency is determined by numerous oscillatory processes at different levels of the hierarchy of the body's life systems (starting with redox processes in the cell and ending with oscillatory interactions between various organs) [22, 23]. In a living organism, oscillations of various types simultaneously exist, for example, mechanical and electrical, and the excitation of one type of oscillations can led to the excitation of others (mechanical movements are caused by the propagation of a nerve impulse, electrical processes in the heart tissues cause mechanical contraction of the heart and the appearance of a pulse wave in the vessels, etc.). Thus, there are systemic information processes in the human body, and it can translate one signal into another. This gives the opportunity to perceive vibrational information of all types, quickly react and adapt to changes in the external environment. A classic example is the consideration of heart rate as a systemic information process through which regulation and metabolism are carried out in the body. From a biophysical position, an organism is a self-oscillating and nonlinear system. This implies the existence of a system of resonators, "devices" for replenishing energy, a nonlinear limiter for the growth of oscillations, and feedback between the resonator and the energy source. The nervous system has a high speed of signal transmission and is responsible for feedback throughout the entire body. At the level of organs and tissues, feedback is provided by electrochemical processes and mechanical movements in the oscillatory systems. And here we can put forward a hypothesis that the kidneys as a paired organ of significant size and function, due to many electrochemical processes associated with ion exchange, have individual frequency-wave characteristics and, apparently, reactions to the local electromagnetic fields of the Earth that are still unknown to science. This requires further study.

Blood is also a magnetically saturated medium that can exhibit properties of magnets because it contains red blood cells, hemoglobin, which includes iron atoms with a non-zero magnetic moment. Therefore, the local electromagnetic fields of the Earth may have an effect on the blood by changing the distribution of ions and their transport through the human erythrocyte membrane. This leads to a change in the electrical potential of erythrocytes, in the processes of depolarization of membranes and in their structures. In erythrocytes whose membranes were exposed to an electromagnetic field, changes in the transfer of electrogenic sodium and potassium ions, a decrease in electrical mobility, an increase in membrane permeability and activation of their aggregation properties were observed. Spontaneous magnetization of an array of particles can lead to the appearance of groups with an ordered packing of particles due to the parallel orientation of their magnetic moments. Moving in the vascular bed, such a group represents a soliton-like object [63, 82–84]. The formation of such objects in the blood stream is obviously facilitated by the phenomenon of reversible aggregation of erythrocytes. Since an object moves due to a change, for example, in the lumen of the vascular bed, its magnetic flux inevitably changes, then, in accordance with the law of electromagnetic induction, electric currents will arise, seeking to compensate for differences in the magnetic flux. Because blood plasma contains a large number of ions, it is electrically conductive. Electric currents induced by moving objects can cause increased plasma circulation around them, and, consequently, around each red blood cell. Since the kidneys are an organ whose functions are closely related to the blood flow, this mechanism can influence their general electromagnetic state and response to exposure.

Research results have been published [85, 86] that further confirm the existence of the human magnetic sense and suggest an underlying quantum mechanical mechanism for magnetoreception. It has been found that a magnetic field resonance mechanism provides light-dependent magnetic orientation in humans. The subjects' magnetic orientation was sensitive to the wavelength of incident light and critically dependent on the blue light reaching the eyes. These reactions appear to be mediated by a mechanism dependent on the resonance of the magnetic field, as evidenced by the impairment or enhancement of the ability to navigate using radiofrequency magnetic fields at the Larmor frequency and the dependence of these effects on the angle between the radiofrequency and geomagnetic fields [85–87].

We want to put forward another hypothesis that explains the different responses of the cardiovascular system and kidneys to changes in the Earth's external magnetic field. It is based on the fact that the tissues of the heart and kidneys have a fundamentally different atomic composition. An atom of each substance has individual quantum mechanical characteristics and therefore each atom is characterized by its own physical feature of changing the magnetic moments of electrons and atomic nuclei when interacting with an external magnetic field. Atoms of different chemical elements interact differently with an external magnetic field, depending on which class of magnets they belong to. There are three classes of atoms of chemical elements or substances consisting of them: diamagnetic, paramagnetic, and ferromagnetic. The human body is 99 % composed of such chemical elements as carbon, hydrogen, oxygen, nitrogen. Of these, 60 % is hydrogen, which probably plays an important role in the response to changes in external electromagnetic fields. Hydrogen, carbon, silicon, phosphorus, sulfur, chlorine, copper, iodine, bromine are diamagnetic, and they are magnetized against an external magnetic field. Oxygen, sodium, magnesium, potassium, calcium are paramagnetic, and they are magnetized in an external magnetic field in the direction of the field [22]. An increase in the strength of the external magnetic field will lead to an increase in the oppositely directed magnetic moments of elements belonging to diamagnets and paramagnets, and to an increase in the precessional effect of vibrations of the electron orbits of individual atoms. Since the atomic composition and content of microelements in the heart and kidneys are a priori different, the total reaction of the moments of their constituent atoms possibly determines the further different functional response of these organs to changes in the local field of the Earth. This is a simple and logical explanation for our results. But it needs additional theorization to be confirmed.

It must be said that, of course, the use of magnetobiology approaches in clinical medicine research is a new and absolutely promising direction. It has been scientifically demonstrated that both weak and strong magnetic fields are associated with negative health effects [38, 39]. Each living organism has a specific sensitivity to the strength and frequency of oscillations of magnetic fields [50, 74, 76, 77]. Modern biophysical knowledge about the role of electromagnetic fields in the structural and functional organization of the human body, in particular the concepts of the magnetoelectrochemical theory of metabolism, determines the importance of further study on the influence of external constant electromagnetic fields on humans and the pathogenesis of NCDs. One cannot but agree with the fact that conducting such studies is quite difficult and is still methodologically imperfect. Very often, the results obtained raise new questions for scientists instead of answers.

Study limitations

This study has several limitations. The results compared were obtained in different years and this was a limitation of this study. The fact that the studies were conducted in different years did not fundamentally affect the results of the analysis, since the general trend of the relationship between the Earth's electromagnetic field and cases of diseases was compared in order to find new links in the pathogenesis of cardiorenal syndrome. These studies were carried out only in patients who were hospitalized to the departments of the University Hospital at the LUHS. They did not evaluate the possible effect of the Earth's electromagnetic field on other concomitant pathologies of internal organs. The effect on specific kidney diseases was not assessed, since the study was performed as an exploratory one. The research did not evaluate solar activity or other weather conditions that could have an additional effect beyond changes in the local geomagnetic field.

Conclusions

1. Changes in the Earth's electromagnetic field of the local Schumann resonance (SGamma) are related to the functional state of the cardiovascular system (the occurrence of myocardial infarction) and the condition of the kidneys (the number of hospitalizations with nephrological pathology).

2. It can be assumed that the effect of the Earth's electromagnetic field of the local Schumann resonance (SGamma) on the pathogenetic mechanisms of kidney disease is in the opposite direction of that on the cardiovascular one.

3. Reliable gender differences in the influence of changes in the local Schumann resonance on the functional state of the cardiovascular system and kidneys were not found when analyzing studies.

4. The connection of the Earth's local geomagnetic field with kidney function may be another new unexplored pathogenetic mechanism of cardiorenal syndrome and NCDs.

To finally resolve the issue of the local Schumann resonance influence on kidney function, research must be continued and an analysis of the relationship between Schumann resonances and chronic kidney diseases must be performed.

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У пошуках нового в патогенезі кардіоренального синдрому: зв'язок локального резонансу Шумана з виникненням епізодів захворювання нирок та інфаркту міокарда

Резюме. Актуальність. Пандемія хронічних неінфекційних захворювань та висока поширеність поєднаного ураження серцево-судинної системи й нирок зумовлюють актуальність продовження наукових досліджень для вирішення цих медичних проблем. Тому **метою роботи** було порівняти вплив електромагнітного поля Землі на виникнення епізодів захворювання нирок та інфаркту міокарда задля пошуку нових патогенетичних компонентів кардіоренального синдрому та поглиблення фундаментальних знань. Низка досліджень 2014–2018 років щодо даних з литовського магнітометра GCI003 довели, що зміни в електромагнітному полі Землі відіграють важливу роль у патогенезі серцево-судинних захворювань, а також їх частоті. Функціонування серцево-судинної системи та нирок тісно пов'язане через метаболічні процеси серцево-ниркової метаболічної осі. Тому в цій роботі треба було перевірити гіпотезу про те, що зміни в електромагнітному полі Землі також можуть впливати на патогенез захворювань нирок, оскільки доведено, що вони впливають на функціонування серцево-судинної системи. **Матеріали та методи.** Виконане пошукове ретроспективне дослідження впливу місцевих резонансів Шумана на частоту госпіталізацій за участі 1340 пацієнтів із захворюваннями нирок. Також вивчено взаємозв'язок між місцевими резонансами Шумана та виникненням інфаркту міокарда в 703 хворих, госпіталізованих до університетської лікарні Литовського університету наук про здоров'я. Середня потужність флуктуацій локального магнітного поля в Литві визначалась у pT2 s2 у п'яти різних частотних діапазонах, які перекривають резонанс Шумана та частотні діапазони електроенцефалограми: SDelta (0–3,5 Гц), STheta (3,5–7 Гц), SAlpha (7–15 Гц), SBeta (15–32 Гц), SGamma (32–66 Гц). Було проаналізовано дані госпіталізацій у нефрологічне відділення університетської лікарні та динаміку резонансів Шумана з 1 січня по 31 грудня 2021 року. Вивчали дані госпіталізацій з приводу інфаркту міокарда в кардіологічне відділення університетської клініки та динаміку резонансів Шумана з 1 січня по 31 грудня 2016 року. **Результати.** Встановлено, що зміни напруженості локального магнітного поля Землі в 2016 та 2021 рр. були порівнянні та відповідали характерній річній динаміці локальних електромагнітних полів Землі. Це дало змогу провести порівняльний аналіз річних кореляційних графіків, установити загальні тенденції динаміки показників та графічні подібності, а також підтвердило наявність загальної залежності реакцій на зовнішнє електромагнітне поле Землі в пацієнтів як з нефрологічною патологією, так і з інфарктом міокарда. У нефрологічних хворих обох статей усі коефіцієнти кореляції в усіх діапазонах резонансів Шумана були позитивними. У жіночій групі негативним був лише коефіцієнт кореляції P5 (SGamma) [32; 65] Гц ($r = -0{,}069$; $p = 0{,}313$). Цей факт, а також наявність значної динаміки коефіцієнта кореляції P5 (SGamma) [32; 65] Гц ($r = 0{,}009$; $p = 0{,}475$) у групі чоловіків може свідчити про те, що більша напруженість магнітного поля в цьому діапазоні може бути пов'язана зі зниженням частоти захворювань нирок. Отримано дані про те, що підвищена напруженість магнітного поля в гамма-діапазоні від 32 до 65 Гц як патогенетичний компонент може викликати дестабілізацію серцево-судинної системи, але водночас пов'язана з позитивним впливом на стан нефрологічної патології. Виходячи з цього, можна умовно припустити протилежну спрямованість впливу електромагнітного поля Землі на патогенетичні механізми захворювань нирок і серцево-судинної системи. Це наочно демонструється при порівнянні коефіцієнтів кореляції між частотою випадків захворювань нирок і інфаркту міокарда в чоловіків і жінок. Посилення магнітного поля Землі в гамма-діапазоні призводить до збільшення захворюваності на інфаркт міокарда, що підтверджується великою кількістю пацієнтів у цей період. За цих же умов реєструється зниження випадків госпіталізацій з приводу патології нирок. Цей протилежний напрямок спостерігається в осіб обох статей, але в жінок реакція сильніша, що підтверджується більшою різницею коефіцієнтів кореляції. **Висновки:** 1. Зміни електромагнітного поля Землі пов'язані з функціональним станом серцево-судинної системи й нирок. 2. Можна припустити, що вплив електромагнітного поля Землі на патогенетичні механізми хвороби нирок є протилежним, ніж серцево-судинної. 3. Достовірних гендерних відмінностей у кореляціях між впливом змін локального резонансу Шумана на функціональний стан серцево-судинної системи та нирок не встановлено. 4. Зв'язок локального геомагнітного поля Землі з функцією нирок може бути ще одним невивченим патогенетичним механізмом кардіоренального синдрому та хронічних неінфекційних захворювань.

Ключові слова: неінфекційні захворювання; кардіоренальний синдром; захворювання нирок; гострий інфаркт міокарда; локальний резонанс Шумана; магнітне поле Землі