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REVIEW ARTICLE

Combined Influence of Fluctuations in the Local Atmosphere Conditions and Space Weather on the Chronoperiodic Systems in Patients With Cardiovascular Pathology

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This review paper explores the impact of fluctuations in environmental factors on human chrono-periodic systems. A multitude of external and internal environmental factors influence the organism throughout its lifespan, and many have the potential to disrupt human homeostasis. It would be inaccurate to assume that specific responses to each stimulus were developed and solidified during the evolutionary process. With the exception of genetic defects, there could not have been evolutionarily fixed pathological reactions in the body, as this would contradict the laws of selection. Therefore, all typical responses of the body to the stimulus should be considered primarily adaptive, i.e., physiological.

Keywords: Chrono-periodic system; Homeostasis; Mesor; Amplitude; Acrophase

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INTRODUCTION

The influence of variations in the geomagnetic field (GMF), cosmic rays (CRs), and hydrometeorological factors (HMF) on the human chrono-periodic system continues to be a subject of global studies, but consensus remains elusive. The temporal organization and dynamics of human rhythms evolved over the course of evolution under the influence of environmental factors. The circadian temporal organization has been regarded as a fundamental aspect of human organization. The circadian temporal organization was established under the influence of light oscillations, possessing a daily frequency due to Earth's rotation and accompanied by changes in gravity. Following the discovery of Earth's magnetosphere and CRs, it became evident that biological rhythms and magnetic factors exhibit similar fluctuations. All of these observations suggest the involvement of magnetic factors in the formation of biological rhythms. Dysfunctions in the fluctuations of HMF and magnetic factors may lead to the desynchronization of biorhythms [1-6]. This review paper investigates the combined effects of fluctuations in HMF, GMF, and CRs on the chrono-structure of homeostasis and hemodynamic systems in healthy subjects and patients with cardiovascular pathology. It also identifies the causes that contribute to the transformation of adaptive biorhythms into pathological ones.

INFLUENCE OF FLUCTUATIONS IN THE LOCAL ATMOSPHERE CONDITIONS ON THE CHRONO-PERIODIC SYSTEMS IN PATIENTS WITH CARDIOVASCULAR PATHOLOGY

Human health can be affected by endogenous as well as exoge-

nous factors. Biological rhythms and their temporal structure are adaptive phenomena to variations in environmental factors linked to the Earth's rotation on its axis and around the sun. The study of homeostasis and hemodynamic chrono-periodic system under the impact of fluctuations of natural environmental factors is one of the central problems of medical science and first of all this is due to their applied meaning. The problems of the peculiarities of the chrono-structure of the organism under the influence of natural environmental factors are of the fundamental importance knowledge of the regularities of the formation of adaptive reactions of the human organism. Seventy healthy subjects (25 females and 45 males) and 100 patients with hypertension (H) and 100 with ischemic heart disease (IHD) were investigated [7]. Fifty patients with H were on the first stages (H1) and 50 patients with H were on II, II-III stages (H2). Clinical classification of hypertension and blood pressure were conducted according to Global Hypertension Practice Guidelines which was suggested by the International Society of Hypertension [8]. One hundred males with IHD (stable stenocardia) were investigated, 42 males with functional class II (IHD1) and 58 males with functional class II-III, III (IHD2). Twenty-four patients with IHD had a myocardial infarction (MI) in the past. Those patients were investigated not earlier than 6 months after acute MI. Functional classification was conducted according to the classification which was suggested by the Canadian Cardiovascular Society [9]. Control group consisted of healthy individuals who's clinical and laboratory investigations were within normal limits. The healthy subjects had an average age of 49.2 years with a standard deviation of 2.0, while the patients had an average age of 54.2 years with a standard deviation of 3.0. Healthy subjects and patients were on unified regimen of diet, sleep wakefulness. Urine was collected in 3-h portions over a period of 72 to 120 hours (3 to 5 days) in both healthy individuals and patients. Each specimen was analyzed for electrolytes and microelements. The data of hydrometeorological indices (HMI) were received at 3-h intervals from the Hydrometeorological Service.

- The temperature of the air (TA, °C)
- The relative humidity of the air (RHA, %)
- The deficit humidity of the air (DHA, hPa)
- The atmospheric pressure (AP, hPa)
- The speed of the wind (SW, m/s)
- The general cloudiness (GC, mark)

Temporal structure (biological and HMI) parameters have been estimated by nonlinear least squares method for sinusoidal rhythms and dispersion analysis for non-sinusoidal rhythms [7,10-14]. The rhythms were grouped in accordance with international glossary of chronobiology [15,16] which was subjected to some changes [13]. The rhythms with period ranging from 3 to 20, 20 to 28, and 28 to 96 hours were considered to be ultradian, circadian, and infradian, respectively. The results showed that the condition of the fluctuations of TA, DHA, and RHA in Yerevan had circadian nature. Temporal structures of AP and GC were not statistically significant. Fluctuations of SW had circadian and infradian nature and for GC ultradian character. For realization of correlative investigations, within 3−5 days, at 3-h intervals, measurements of volume of the urine, macro- and microelements were used, sliding them with the same 3−5 days, previous and following 2-days (the whole 7−9 days) at 3-h intervals measurements of HMI (TA, RHA, DHA, AP, SW, GC). The data indicated that healthy subject rhythms of water-mineral homeostasis had significant correlative connections (91%) with the rhythms of HMI (external synchronization). Correlative conjunctions of indices were investigated taking into account the outsprint or delay of the acrophases of biorhythms relative to the acrophases of HMI. The data indicated that in healthy subjects, the acrophases of the rhythms of water-mineral homeostasis [7] were outstripped (73%) to the acrophases of rhythms HMI (Table 1). In healthy subjects, the acrophases of biorhythms in 15% of cases occurred simultaneously with the acrophases of HMI rhythms. Healthy individuals were characterized with the circadian structure of water-mineral and with different value of parameters (mesor and amplitude). Acrophases of the temporal organization were individual. In healthy subjects acrophases of water-mineral homeostasis outstripped to the acrophases of the rhythms of HMI (Figure 1). The results indicated that there were changes in water-mineral homeostasis, starting from the early stage, in patients with IHD and H (Figure 1). The data witnessed that in the early stage of H and IHD the electrolytes and trace elements excretion rhythms in 22%−23% were statistically non-significant. Among the significant rhythms infradian prevail (46%−53%), statistically significant rhythms of water-mineral homeostasis were not revealed in most of patients in the late stage IHD and H (31% and 32%, respectively). Among statistically significant rhythms, the circadian prevailed (48%−54%). The results indicated that in individuals with IHD and H1, H2 acrophases of electrolytes and trace elements homeostasis outstripped (32%−38%) to the acrophases of the HMI rhythms. These data were statistically significantly smaller in comparison with results of the healthy subjects [7]. Acrophases of rhythms IHD in 17% of cases were simultaneous with the acrophases of rhythms HMI (Figure 1). Circadian variations in urinary excretion of macro- and microelements have been reported by Kanabrocki et al. [17]. The authors investigated changes by observing each subjects for 27 hours. With that approach, the researchers were only able to determine whether there was a circadian sinusoidal oscillation or not. Data obtained from others authors [7,18-20] were different from the results reported by Kanabrocki et al. [17]. These differences were connected with ecological, hydrometeorological features and the difference of bio-rhythmological approach. Healthy subjects' water-mineral homeostasis had significant correlative connections with the rhythms of HMI (external synchronization). The data of patients with H1 and IHD have shown 31%−37% non-significant correlative connections between biorhythms and the rhythms of HMI (external desynchronizations). In patients with IHD and H acrophases of biorhythms

Table 1. Summary of the changes of urine and minerals excretion rhythms acrophases relative to the acrophases of rhythms hydrometeorological indices (HMI) in healthy subjects

Indices	TA				RHA				DHA				AP				SW				GC			
	N	00.00	A_0	A_d	N	00.00	A_0	A_d	N	00.00	A_0	A_d	N	00.00	A_0	A_d	N	00.00	A_0	A_d	N	00.00	A_0	A_d
Volume of urine	8	8	84	0	5	11	84	0	3	9	88	0	11	22	67	0	11	11	78	0	8	14	78	0
Na	0	8	92	0	5	11	84	0	0	15	85	0	5	20	75	0	5	17	78	0	3	9	88	0
K	3	11	86	0	0	19	81	0	3	15	82	0	14	11	75	0	0	12	88	0	11	11	78	0
Cl	3	11	86	0	6	11	83	0	9	15	76	0	9	20	71	0	11	14	75	0	14	11	75	0
Ca	3	8	89	0	3	16	81	0	3	15	82	0	6	17	77	0	6	21	73	0	5	14	81	0
Mg	6	17	77	0	0	28	72	0	3	35	62	0	0	12	88	0	20	6	74	0	11	11	78	0
P	6	9	85	0	0	24	76	0	6	23	71	0	6	17	77	0	3	19	78	0	6	6	88	0
Fe	0	50	50	0	0	50	50	0	0	50	50	0	0	0	100	0	17	17	66	0	17	0	50	33
Cu	0	34	66	0	0	33	67	0	0	16	84	0	34	0	66	0	33	17	50	0	17	33	33	17
Zn	40	20	40	0	0	60	40	0	40	20	40	0	20	20	40	20	40	0	40	20	0	0	60	40
Cr	0	0	100	0	25	0	75	0	0	50	50	0	0	25	75	0	0	25	75	0	25	0	50	25
Cd	0	0	100	0	25	0	75	0	0	0	100	0	0	0	100	0	50	0	50	0	0	0	100	0
V	17	0	83	0	0	25	75	0	25	0	75	0	0	0	75	25	25	0	75	0	25	25	50	0
Total percent	7	14	79	0	6	23	71	0	7	20	73	0	8	13	76	3	17	12	69	2	11	10	70	9

N, number (%) of the healthy subjects with statistically nonsignificant correlative connections between rhythms of water-mineral homeostasis and HMI rhythms. 00:00, number (%) of the healthy subjects with acrophases of water-mineral excretion rhythms which occurred simultaneously with the acrophases of the HMI rhythms. A_0, number (%) of the healthy subjects with outstripped acrophases of water-mineral excretion rhythms relative to the acrophases the HMI rhythms. A_d, number (%) of the healthy subjects with delayed acrophases of water-mineral excretion rhythms relative to the acrophases of the HMI rhythms. TA, temperature of the air; RHA, relative humidity of the air; DHA, deficit humidity of the air; AP, atmospheric pressure; SW, speed of the wind; GC, general cloudiness

often were simultaneous (17%–24%) or delayed (14%–17%) relative to the HMI rhythms. That data indicated the direct influence on the chrono-structure of an organism by the fluctuations of HMI and decrease of adaptive possibilities of water-mineral chrono-periodic system in cardiovascular pathology. The seasonal frequency of myocardial infarction (MI) morbidity exhibits a periodic pattern characterized by a single peak in January. Subsequently, the probability of morbidity gradually decreases, reaching its lowest point in July and August, before gradually rising again in November and December [21]. The changes of urinary excretion function are adequate parameter for determination of meteo-sensitivity [22]. The research result of Hayrapetyan et al. [23] showed that correlative connections between the rhythms of HMI and temporal structures of water-mineral homeostasis in healthy subjects and in SVD had seasonal character with positive or negative nature.

INFLUENS OF FLUCTUATIONS IN THE SPACE WEATHER ON THE CHRONOPERIODIC SYSTEM IN THE PATIENTS WITH CARDIOVASCULAR PATHOLOGY

There is a hypothesis that the oscillations of the GMF may be regulatory mechanism of cells acting through the ion cyclotron resonance mechanism has been proposed [24]. Every living being has specific sensitivity to the strength and frequency of variations of GMF [24,25]. Laboratory investigations showed the effect on ion cyclotron mechanism on extracted cardiomyocytes regulation [26]. According to this investigation, it remains unclear whether the GMF has an effect on the heart of the healthy individuals and patients with cardiovascular pathology. Researches have investigated the effect on healthy individuals' cardiovascular system in the absence of GMF. When healthy individuals were isolated from the GMF and compared to a control group, a statistically significant increase in capillary blood flow and average reduction in diastolic blood pressure on was found [27]. In another study was evaluated how oscillations in the GMF affect cardiovascular regulation under laboratory conditions. Baroreflex sensitivity showed statistically significant negative correlative connections between increasing GMF fluctuation and baroreflex sensitivity, heart rate variability (HRV), and arterial blood pressor. These conclusions support the theory that GMF variation affect neural cardiovascular regulation center [28]. The decrease of baroreflex sensitivity may lead to higher mortality after MI [29].

The GMF is a constantly changing. In winter, spectral power of GMF decreases. In spring, starts to increase and reaches the peak in summer. In autumn, the strength of GMF starts decrease to the lowest points in winter [30]. It was shown that variations in the GMF statistically significantly reduces melatonin effect positive levels. It is assumed that melatonin can have a positive effect on patients with cardiovascular pathology [31,32]. Melatonin improves of the heart microcirculation [33]. In this way, reduced

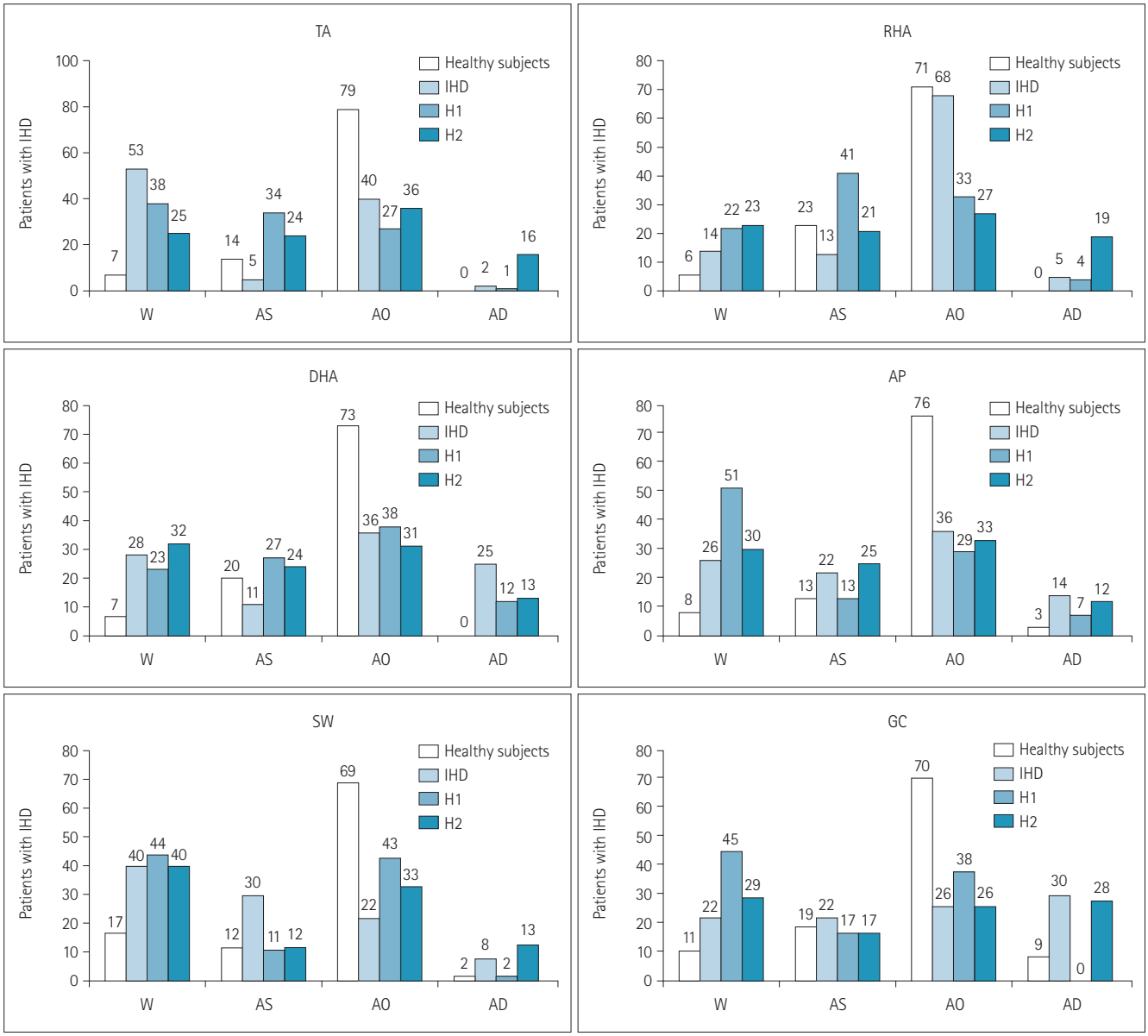

Figure 1. Summary data of the acrophases of excretion rhythms of electrolytes and trace elements relative to the acrophases of HMI rhythms (TA, RHA, DHA, AP, SW, GC) in healthy subject and patients. W: number (%) of healthy subjects and patients with statistically nonsignificant correlative connections between rhythms of water-mineral homeostasis and HMI rhythms. AS: number (%) of healthy subjects and patients with acrophases of water-mineral excretion rhythms which occurred simultaneously with the acrophases of the HMI rhythms. AO: number (%) of healthy subjects and patients with outstripped acrophases of water-mineral excretion rhythms relative to acrophases of the HMI rhythms. AD: number (%) of healthy subjects and patients with delayed acrophases of water-mineral excretion rhythms relative to acrophases of the HMI rhythms. IHD, ischemic heart disease; HMI, hydrometeorological indices; TA, temperature of the air; RHA, relative humidity of the air; DHA, deficit humidity of the air; AP, atmospheric pressure; SW, speed of wind; GC, general cloudiness. Reprinted from Babayan et al. Chronobiol Med 2021;3:35-39 [7].

levels of melatonin can promote development of ischemia due to variations in GMF.

Lithuanian scientists have found correlation between HRV and GMF strength. Some studies have shown that ANS (automatic nervous system) responds to solar and geomagnetic activity [34-36]. Stoupel and Collegues [37,38] also found out that number of acute MI events after low GMF activity and high CRs days of increased their obtained results indicate that GMF can be related to development of MI. These investigations indicate that the effects of variations in GMF should be studied by analyzing the strength of fields in frequency ranges. Ability to measure variations of low frequency GMF provides an opportunity for scientists to begin more detailed future studies. Lithuanian scientists have found that lower number of MI cases has negative correlation with changes in GMF (S Delta, S Theta, S Alpha, S Beta) frequency. The variations in the GMF high frequency (S Gamma) range are correlated with a higher number of MI cases [30].

Many studies have focused on how geomagnetic factors may influence on human organism [39]. The results of many investigations show that variations in the geophysical environment could affect the functions of human organism [40,41]. As it is indicated cardiovascular and nervous chrono-periodical systems re-

spond to variations in geomagnetic factors. The most cases, these reactions of organism are acquired adaptive character. However, these protective reactions from chrono-periodical systems of organism to variations in environmental factors is not observed on pathology [42]. Those protective reactions went out in the late stage of the cardiovascular pathology. Dorman et al. [43] and Stoupel [44] describe how space weather factors and GMF may affect the pathological process, especially in the pathology of the cardiovascular and nervous systems. Many scientific studies have shown on relationship between geomagnetic disturbances (Forbush decreases of cosmic ray intensity) and pathological process (ischemic attacks, MI).

CONCLUSION

During the last years, interest in the role of environmental factors in biological systems had increased [1-4,20,23]. The results of these investigations were contradictory. It was partly connected with the absence of unification methods, patient grouping, and sometimes lack of techniques to identify important indices. Besides, these studies were mostly carried out taking into account the temporal structure of an organism and environmental factors. From the point of system approach, the problem of adaptation is closely connected with an individual reaction of every organism to factors of stress. Bio-rhythmologicl research indicated that many pathological functions are accompanied by disorders of temporal structure of an organism [45].

The organism is a complex system regulated by certain laws. There is hardly any reason to consider biorhythmological characteristics as something special that does not obey these laws, especially since chronobiological components are threads that closely connect the organism with the biosphere and the cosmos. Normally, there should be no rigid links between individual indicators. Each indicator varied quite widely in healthy individuals. Probably, in healthy individuals, this is a certain backlash and ensures the adaptation of the body to changing environmental conditions. As is known the adaptation of an organism is associated with evolutionarily determined mechanisms its functional systems, which belong to the rigid links of adaptation. Adaptation is also associated with individually acquired qualities through which flexible forms of interaction with environmental factors are provided. Thus, the defining qualities of the external world have been created as necessary links in dynamic interactions with the environment that overwhelms them. In our opinion, the basis of the advance of the acrophases of biorhythms in relation to the acrophases of environmental factors is the ability of the organism to reflect the surrounding world with the help of the anticipatory reflection of reality [45,46]. Earlier, we reported that in healthy subjects' parameters of the chrono-periodic systems are mainly characterized by statistically significant rhythms with circadian periods and definite value of mesors and amplitudes. Acrophases of the rhythms were mostly individual. At the same time in practically healthy individuals acrophases of the biorhythms were outstripped to the acrophases of the rhythms of environmental factors. It should be noted that according to the theory of induced noise, biological objects are open nonlinear systems for whose behavior the effect of the influence of weak external factor are in contrast to intuitive representation fundamental [47]. In the study of biological rhythms, it was demonstrated that under certain conditions, under the influence weak violations of biological oscillations including of pulsating heart and brain cells spontaneously become synchronizers and begin to beat unison. It has been shown that stable rhythms can suddenly collapse and at the same time chaotic movements occur, which sometimes lead to fatal consequences. The ambiguity in the response of complex nonlinear systems to weak influences is evident, as it depends not only on the influencing factor but also on the state of the system itself [48]. Building upon these theories, one can also posit that the advancement of biorhythm acrophases in relation to environmental factors represents a form of self-regulation within chrono-periodic systems. These typical responses of the chrono-periodic systems to the acrophases of environmental factors should be considered primary adaptive, i.e. physiological reaction. Living creatures are organized not only in space but also in time. In our opinion, it becomes necessary to study the effect of fluctuations of GMF, CRs on chrono-periodic systems and temporal structure of melatonin, adenosine in healthy subjects and patients with cardiovascular pathology. It is also becoming relevant to study not only neutron oscillations of CRs but oscillations of other particles too (electrons, photons, protons, and muons). Evolutionary, a human organism is adapted to the natural geomagnetic environment, HMF, and its slight variations. Every organism has specific sensitivity to the strength and frequency of fluctuations of GMF and HMF. We look forward those future studies of chrono-periodical systems that will determine these problems and will help to reveal the adequate parameters of meteo-sensitivity. These investigations will also help in the organization of pathogenetic therapy (chronotherapy) in patients with cardiovascular pathology.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Availability of Data and Material

Data sharing not applicable to this article as no datasets were generated during the study. However, aggregated findings and summarized data are available upon request to maintain transparency and facilitate further research in related fields.

Author Contributions

Conceptualization: Hamlet G. Hayrapetyan. Data curation: Lyusya A. Babayan. Project administration: Lyusya A. Babayan. Formal analysis: Jon K. Karapetyan. Investigation: Vahe H. Babayan. Resources: Lyusya A. Babayan. Writing—original draft: Narine A. Gasparian. Writing—review & editing: Naira K. Atoyan.

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