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Pathogenetic Mechanisms of the Development of Arterial Hypertension Under the Influence of Environmental Factors

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Annotatsiya. Arterial gipertoniya (AG) rivojlanishida ekologik omillar muhim patogenetik determinant sifatida namoyon bo‘ladi. Ushbu ishda urbanizatsiya, yashil hududlarning qisqarishi, atmosfera ifloslanishi (CO_2, NOx va boshqa toksik komponentlar) hamda iqlimiy omillarning AG patogeneziga ta’siri Shahrisabz hududi misolida tahlil qilindi. Kuzatuvlar shuni ko‘rsatdiki, daraxtlar sonining kamayishi fotosintez intensivligining pasayishiga va kislorod balansining buzilishiga olib kelib, havoda zararli gazlar konsentratsiyasining ortishiga sabab bo‘ladi. Patogenetik jihatdan, ekologik stressorlar oksidlovchi stressni kuchaytiradi, endotelial disfunktsiya va azot oksidi (NO) bioyetishmovchiligini keltirib chiqaradi, natijada tomir tonusi va periferik qarshilik ortadi. Shu bilan birga, issiqlik stressi va atmosfera ifloslanishi simpatoadrenal tizim hamda renin-angiotenzin-aldosteron tizimini faollashtirib, barqaror arterial bosim oshishiga olib keladi. Statistik ma’lumotlar hududda yurak-qon tomir kasalliklari, xususan AG ulushi yuqoriligini va uning ekologik omillar bilan bog‘liqligini tasdiqlaydi.

Kalit so‘zlar: Arterial gipertoniya, yallig‘lanish mediatorlari, PM2.5, endothelial, patogenez, yurak ishemik kasalliklari, NOx, CRP, dinamik tahlil, psixoemotsional stress.

Abstract. Environmental factors act as important pathogenetic determinants in the development of arterial hypertension (AH). In this study, the effects of urbanization, reduction of green areas, air pollution (CO_2, NOx, and other toxic components), and climatic factors on the pathogenesis of AH were analyzed using the example of the Shahrisabz region. Observations showed that a decrease in the number of trees leads to a reduction in the intensity of photosynthesis and disruption of oxygen balance, which in turn results in an increased concentration of harmful gases in the atmosphere. From a pathogenetic perspective, environmental stressors enhance oxidative stress, induce endothelial dysfunction, and cause a deficiency of nitric oxide (NO), leading to increased vascular tone and peripheral resistance. In

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addition, heat stress and air pollution activate the sympathoadrenal system and the renin–angiotensin–aldosterone system, contributing to a sustained increase in arterial blood pressure. Statistical data confirm a high prevalence of cardiovascular diseases in the region, particularly arterial hypertension, as well as its association with environmental factors.

Keywords: Arterial hypertension, inflammatory mediators, PM2.5, endothelium, pathogenesis, ischemic heart disease, NOx, CRP, dynamic analysis, psycho-emotional stress.

Arterial hypertension (AH) is currently one of the most pressing medical and social problems worldwide and is considered a major risk factor for cardiovascular diseases, stroke, and renal failure [14,20,22]. In recent years, alongside traditional factors (heredity, unhealthy diet, physical inactivity), the decisive role of environmental factors in the etiology and pathogenesis of AH has been increasingly substantiated [12,24,25]. In particular, the acceleration of urbanization processes, the increase in industrial and транспорт emissions, the reduction of green areas, and climate change exert complex and multilevel effects on the human body. Air pollution (PM2.5, CO_2, NOx, SO_2, and other particulates) leads to structural and functional changes in the vascular wall through endothelial dysfunction, enhanced oxidative stress, and activation of inflammatory mediators [2,5,18]. As a result, peripheral vascular resistance increases, contributing to the development of persistently elevated arterial blood pressure. In addition, environmental stressors disrupt neurohumoral regulation by activating the sympathoadrenal system and the renin–angiotensin–aldosterone system, which are considered key mechanisms in the development of AH. At the local level, observations conducted in the Shahrisabz region have revealed a decrease in the number of trees, increased air pollution, and microclimatic changes associated with urbanization and reconstruction processes. These changes correlate with a growing prevalence of cardiovascular diseases, including arterial hypertension, among the population. Therefore, an in-depth investigation of environmental factors and their role in the pathogenesis of AH represents an important scientific direction in modern medicine [6,23].

Arterial hypertension (AH) currently occupies a leading position among cardiovascular diseases and is one of the main causes of global morbidity and mortality [15,25]. In recent years, the increasing prevalence of this condition has been scientifically linked not only to individual risk factors but also to significant changes in the environment. Urbanization, industrialization, the growing number of vehicles, and the reduction of green areas have led to increased air pollution, exerting a continuous harmful impact on the human body [11,21]. In particular, the reduction in the number of trees results in decreased photosynthetic activity, disruption of oxygen balance, and an increase in carbon dioxide and other toxic gases. This contributes to enhanced oxidative stress, endothelial dysfunction, and chronic inflammatory processes, thereby creating a pathogenetic basis for the development of arterial hypertension. At the same time, climate change and rising temperatures adversely affect neurohumoral regulatory systems, leading to sustained elevation of blood pressure. At the local level, observations and medical-statistical data from the Shahrisabz region indicate an increasing prevalence of cardiovascular diseases, including arterial hypertension, in the context of environmental changes. This confirms that the problem is not only global but also highly relevant at the regional level. Therefore, an in-depth study of the pathogenetic mechanisms of arterial hypertension associated with environmental factors, as well as the development of preventive measures, represents an important and priority direction in modern medicine [19,23].

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This study was conducted using an observational-analytical and retrospective–prospective design to comprehensively assess the pathogenetic mechanisms of arterial hypertension (AH) development under the influence of environmental factors. The study area included the Kashkadarya region, specifically the city of Shahrisabz, where regional environmental changes and medical-statistical indicators were analyzed in an integrated manner. The study materials were based on official statistical data recorded at the Shahrisabz City Medical Association as of November 19, 2024. According to these data, a total of 4,327 patients with cardiovascular diseases were registered in the city, of whom 1,346 were newly diagnosed cases, and 4,953 patients were under диспансерное наблюдение (dispensary follow-up). Structural analysis of the diseases revealed that arterial hypertension accounted for 1,406 cases, ischemic heart disease for 1,478 cases, acute myocardial infarction for 88 cases, chronic rheumatic heart disease for 64 cases, congenital heart defects for 46 cases, and other cardiovascular diseases for 96 cases. For population-based assessment, the population of Shahrisabz (227.6 thousand) was used as a reference, and morbidity rates were analyzed in relative terms. The results showed that the overall prevalence of cardiovascular diseases was 1.9%, of which 0.62% was attributable to arterial hypertension. Age stratification demonstrated that the disease was predominantly observed among the middle-aged population. Environmental factors were evaluated considering urbanization and reconstruction processes in the region, which led to a reduction in green areas, a decrease in the number of trees, and increased air pollution due to transport and industrial emissions. These factors were assessed using indirect indicators (proportion of green areas, traffic density, general air quality characteristics) and comparatively analyzed with medical data. Statistical analysis included descriptive statistics (absolute and relative indicators), time-series analysis, and assessment of disease structure proportions. Based on the obtained data, potential associations between environmental factors and the prevalence of arterial hypertension were evaluated using a systemic approach. This methodological framework enabled a scientifically grounded population-level analysis of the relationship between regional environmental changes and the prevalence of arterial hypertension [9].

The analysis of statistical data from the Shahrisabz City Medical Association as of November 19, 2024, demonstrated a high prevalence of cardiovascular diseases and a significant proportion of arterial hypertension (AH) within their structure [1,7]. A total of 4,327 patients with cardiovascular diseases were registered, of whom 1,346 were newly diagnosed cases, and 4,953 patients were under dispensary follow-up. Structural analysis revealed that ischemic heart disease (1,478 cases) and arterial hypertension (1,406 cases) occupied leading positions, while other conditions such as myocardial infarction (88 cases), rheumatic diseases (64 cases), and congenital defects (46 cases) were less common. Population-based calculations showed that the overall prevalence of cardiovascular diseases was 1.9%, with arterial hypertension accounting for 0.62%, indicating its significant epidemiological importance. Age distribution analysis demonstrated that AH and other cardiovascular diseases were predominantly observed among the middle-aged population. Dynamic analysis (covering the period from 2010 to 2025) revealed a gradual increase in cardiovascular diseases, particularly arterial hypertension and ischemic heart disease. According to structural analysis, arterial hypertension accounted for approximately 50% of all cases, ischemic heart disease for 33%, and myocardial infarction for 17%. Comparative analysis with regional environmental changes indicated that, against the background of urbanization, reduction of green

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areas, and increased air pollution, there has been a corresponding rise in cardiovascular diseases, particularly arterial hypertension. This relationship confirms the role of environmental factors as significant risk factors in the development of arterial hypertension [3,8].

The obtained results confirm the existence of a significant pathogenetic relationship between environmental factors and the development of arterial hypertension (AH). The high proportion of AH among cardiovascular diseases recorded in the Shahrisabz region, as well as its progressive increase, can be explained by urbanization, reduction of green areas, and the intensification of air pollution. These findings are consistent with contemporary epidemiological studies, which consider environmental stressors as independent risk factors in the development of AH [1,3,12]. From a pathogenetic perspective, harmful particles and gases present in ambient air (particularly PM2.5 and NOx) enter the body, enhance oxidative stress, and increase the production of free radicals [4,18]. As a result, endothelial cell function is impaired, nitric oxide (NO) synthesis decreases, and endothelin-1 secretion increases. This leads to the predominance of vasoconstriction in the vascular wall, increased peripheral resistance, and the development of persistently elevated arterial blood pressure. Moreover, environmental factors, especially heat stress and air pollution, disrupt neurohumoral regulation [10,24]. Activation of the sympathoadrenal system and the renin–angiotensin–aldosterone system leads to increased cardiac output and vascular tone, representing key mechanisms in the pathogenesis of AH. In addition, chronic low-grade inflammation (elevated CRP and IL-6 levels) contributes to structural changes in the vascular wall and promotes disease progression. A comparison of regional statistical data with environmental conditions showed that AH is particularly prevalent among the middle-aged population, indicating a cumulative effect of long-term environmental exposure [11,17]. The reduction of green areas not only deteriorates air quality but also increases psycho-emotional stress, which further negatively affects blood pressure regulation. Thus, the discussion highlights that environmental factors are involved in the development of arterial hypertension through multilevel mechanisms (molecular, cellular, and systemic), and their control is of critical importance for disease prevention [12,16].

The results of the conducted study scientifically substantiate that environmental factors play a significant pathogenetic role in the development of arterial hypertension (AH). Medical-statistical data obtained from the Shahrisabz region demonstrate that AH constitutes a substantial proportion of cardiovascular diseases and that its prevalence has been increasing over the years [6,13,23]. This trend is directly associated with urbanization, reduction of green areas, and the intensification of air pollution.From a pathogenetic perspective, environmental stressors contribute to sustained elevation of arterial blood pressure through oxidative stress, endothelial dysfunction, chronic inflammation, and activation of neurohumoral systems (sympathoadrenal and renin–angiotensin–aldosterone systems). These mechanisms are closely interconnected and collectively drive the development and progression of AH [21,25].Therefore, controlling environmental factors—particularly by expanding green areas, reducing air pollution, and promoting a healthy lifestyle among the population—should be considered key priorities in the prevention of arterial hypertension. This approach is essential for reducing the disease burden and improving public health.

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