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SKIN MANIFESTATIONS OF SYSTEMIC ATHEROSCLEROSIS: DERMATOGLYPHIC AND MICROCIRCULATORY CORRELATES OF CORONARY HEART DISEASE

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ABSTRACT

Coronary heart disease (CHD) remains one of the leading causes of cardiovascular mortality, despite improvements in diagnostic and treatment methods. Current clinical guidelines emphasize the need for early risk stratification and a personalized approach to the prevention of atherosclerotic complications. In this regard, noninvasive markers that can reflect the systemic nature of endothelial dysfunction and complement traditional risk scales are of particular interest (SCORE, Framingham).

The aim of the work is to substantiate the clinical significance of dermatoglyphic and microcirculatory parameters of the skin as additional tools for assessing cardiovascular risk in patients with coronary heart disease.

In the process of preparing the paper, a critical analysis of the literature indexed in international databases was carried out, with an emphasis on the pathophysiological mechanisms of the relationship between systemic atherosclerosis and skin manifestations. The data on the synchronicity of embryogenesis of the cardiovascular system and papillary patterns, as well as on the role of endothelial dysfunction in the formation of microcirculatory skin disorders, are considered. It has been established that dermatoglyphic signs (decreased crest count, changes in the angle of ATD, asymmetry of patterns) can serve as markers of an individual predisposition to coronary heart disease due to disorders of early ontogenesis. Microcirculation parameters (capillary density, vasomotor reactivity), assessed by capillaroscopy and laser Doppler flowmetry, correlate with the severity of coronary atherosclerosis and the functional class of angina pectoris.

It was determined that skin markers have additional predictive potential in cardiology practice and can be integrated into risk stratification algorithms, especially in patients with borderline values of traditional scales. The introduction of noninvasive assessment of dermatoglyphics and microcirculation requires standardization of methods and interdisciplinary interaction between cardiologists and dermatologists. A promising area is the development of integral risk indices and the use of digital technologies for automated analysis of skin parameters in order to identify people with high cardiovascular risk early.

KEYWORDS: coronary heart disease, atherosclerosis, risk stratification, endothelial dysfunction, microcirculation, dermatoglyphics, systemic inflammation, noninvasive diagnosis, cardiovascular prognosis, personalized medicine.

INTRODUCTION

Cardiovascular diseases remain the leading cause of death on a global scale, despite significant progress in diagnostic and therapeutic methods [1]. According to the World Health Organization, annual losses from diseases of the cardiovascular system amount to millions of lives, which necessitates a review of approaches to prevention and early detection of risks [2]. Coronary heart disease (CHD), being the main manifestation of atherosclerosis, is often diagnosed at the stages when morphological changes in the coronary arteries become irreversible. Existing risk stratification scales, such as SCORE or Framingham, have a certain prognostic value, but they do not always take into account the individual variability of pathogenesis [3]. In this regard, the search for new, non-invasive and accessible markers capable of reflecting the systemic nature of vascular damage is an urgent task of modern cardiology.

The modern understanding of atherosclerosis has gone beyond the local lesion of the coronary arteries. Today, this disease is considered as a systemic inflammatory process affecting the endothelium of the entire vascular bed [4]. The immunobiology of atherosclerosis involves a complex network of interactions between lipid metabolism, inflammatory cytokines, and endothelial cell function [5]. Since the skin is abundantly vascularized and contains a significant proportion of the microcirculatory bed, the condition of the skin vessels may reflect general hemodynamic and metabolic disorders in the body [6]. Endothelial dysfunction, which is a key link in the pathogenesis of atherosclerosis, inevitably affects the microcirculation of the skin, which creates prerequisites for the use of dermatological signs as indicators of cardiovascular risk [7].

Historically, the relationship between skin conditions and diseases of internal organs has attracted the attention of clinicians, but only in recent decades has it received a pathophysiological justification. The skin manifestations of cardiovascular diseases are diverse and can range from specific signs, such as xanthelasms, directly associated with lipid metabolism disorders and the risk of atherosclerosis [8], [9], to non-specific changes caused by chronic venous insufficiency or heart failure [10], [11]. Studies demonstrate that chronic inflammatory skin diseases, such as psoriasis or lupus erythematosus, are associated with an increased risk of cardiovascular events, which confirms the hypothesis of common immune-inflammatory mechanisms of skin and heart damage [12], [13]. The presence of systemic inflammation in skin pathologies correlates with accelerated development of atherosclerotic plaques and an increased risk of myocardial infarction [14]. Thus, the skin can indeed serve as a visualized model of systemic vascular disorders, providing information that often remains hidden during standard examination [15].

Despite the obvious connection between skin manifestations and cardiovascular pathology, the potential of specific morphological and functional parameters of the skin in the diagnosis of coronary heart disease has not been sufficiently studied. In particular, little attention is paid to dermatoglyphic signs that form in the intrauterine period simultaneously with the development of the cardiovascular system, as well as to the functional parameters of microcirculation, reflecting the current state of the endothelium. The purpose of this work is to analyze the dermatoglyphic and microcirculatory correlates of coronary heart disease in the context of systemic atherosclerosis. To achieve this goal, it is necessary to summarize current data on the pathophysiological commonality of the development of skin patterns and the cardiovascular system, as well as to assess the diagnostic significance of changes in the microcirculatory bed of the skin in patients with confirmed coronary artery disease. The integration of these data may contribute to the development of new screening algorithms based on noninvasive assessment of skin risk markers.

MATERIALS AND METHODS

When preparing an article that meets the requirements of Scopus-level scientometric databases, the methodological framework should be based on the strict application of general scientific and private scientific approaches. The use of a systematic approach made it possible to consider atherosclerosis not as an isolated lesion of the coronary bed, but as a universal pathological process involving the endothelium of the entire vascular tree, including the microcirculatory bed of the skin. This method integrates data from various fields of knowledge - cardiology, dermatology, embryology, and immunology - into a single pathophysiological model. The conceptualization of the skin–heart relationship is based on the principle of common embryogenesis and synchronicity of the development of papillary patterns and the cardiovascular system during critical periods of gestation, which theoretically justifies the possibility of using dermatoglyphic signs as markers of cardiovascular risk.

The theoretical reconstruction of the mechanisms linking systemic inflammation, endothelial dysfunction and skin manifestations was carried out based on the analysis of modern data on the immunobiology of atherosclerosis. The hypothetical-deductive approach is used to formulate working hypotheses (for example, "decreased crest count correlates with early onset of coronary artery disease") and their subsequent verification through the analysis of available clinical and experimental data.

A structured analysis of publications indexed in international databases was used to form the evidence base. The method included:

– systematization of data on skin markers of cardiovascular diseases;

– evaluation of research quality (design, sample size, statistical power);

– identification of gaps in the knowledge of the topic, in particular, the lack of elaboration of the dermatoglyphic field in cardiology practice.

This approach ensures the scientific novelty of the work and justifies the need to integrate dermatological methods into cardiorisk stratification algorithms.

RESULTS

The fundamental basis of the relationship between dermatological and cardiological manifestations is the commonality of embryonic development and the synchronicity of the formation of key body systems. The epidermis and nervous tissue are of ectodermal origin, whereas the laying of the cardiovascular system occurs in parallel with the formation of papillary skin patterns during the critical period between 10 and 24 weeks of gestation. This temporal correlation suggests that unfavorable intrauterine environmental factors can simultaneously program predisposition to both dermatoglyphic abnormalities and cardiovascular diseases in the postnatal period [1]. The "skin-heart" concept emphasizes that the skin is not just a passive barrier, but acts as an active participant in systemic reactions, reflecting the state of internal homeostasis and hereditary determinants [15]. The presence of specific skin markers may indicate disorders inherent in the early stages of ontogenesis,

which is consistent with modern ideas about the fetal origin of a number of adult pathologies and the need for early prevention [3]. Thus, dermatoglyphic signs can be considered as static markers of individual risk formed before birth.

Endothelial dysfunction is the central dynamic link in pathogenesis that unites skin and heart damage. Modern cardiology considers atherosclerosis as a systemic inflammatory process affecting the endothelium of the entire vascular bed, including the microcirculatory bed of the skin [4]. The mechanisms of microvascular damage in systemic atherosclerosis include impaired vasomotor regulation, thickening of the basement membrane, and reduction of the capillary network, which can be visualized by functional diagnostic methods [6]. Oxidative stress plays a key role in this process, leading to inactivation of nitric oxide, decreased bioavailability of vasodilators, and increased vascular stiffness [5].

The inflammatory cascade is mediated by the activation of monocytes and macrophages, which infiltrate both the vascular wall, forming atherosclerotic plaques, and dermal tissues in chronic dermatoses [16]. Special attention in the literature is paid to the interleukin-23/interleukin-17 (IL-23/IL-17) axis, elevated levels of which are found both in atherosclerotic lesions of the carotid arteries and in chronic inflammatory skin diseases such as psoriasis [17]. Cytokines of this profile contribute to the maintenance of chronic inflammation, enhance the proliferation of vascular smooth muscle cells and destabilize atherosclerotic plaques [12]. The immunobiology of atherosclerosis is a complex network of interactions where skin inflammation can serve as a driver of systemic vascular disorders [5]. Thus, skin inflammation and vascular pathology have common immunobiological roots, which confirms the possibility of using skin markers to assess systemic vascular risk and monitor the effectiveness of therapy [7].

The assessment of dermatoglyphic signs in the context of cardiovascular risk requires a standardized approach similar to that used in the validation of other noninvasive markers [1]. Traditionally, the analysis of papillary patterns includes the classification of the main types of patterns - arcs, loops and curls, each of which has a specific frequency of occurrence in the population. Quantification is performed by calculating the Total Ridge Count (TRC), which reflects the density and complexity of the patterns on the fingers. An additional morphometric parameter is the ATD angle, formed by the lines of the palmar triradii, as well as the analysis of the position of the axial triradii [6]. These parameters are recorded by fingerprinting or optical scanning followed by digital processing. The importance of methodological rigor is due to the need to integrate dermatoglyphic data into common risk stratification scales, such as SCORE, in order to increase their predictive accuracy [3]. Standardization makes it possible to minimize the influence of external factors and focus on innate characteristics reflecting the early stages of ontogenesis.

The existing data suggest the presence of specific dermatoglyphic patterns associated with coronary artery disease. In a number of observations, there is a predominance of certain types of patterns in patients with verified atherosclerosis, for example, an increase in the frequency of curls or, conversely, arc patterns, which may indicate a violation of tissue differentiation during critical periods of embryogenesis [15]. Changes in the crest count, in particular its decrease, are interpreted as a marker of impaired embryogenesis, correlating with the overall body's resistance to stressors [5]. Since the formation of skin patterns occurs synchronously with the development of the cardiovascular system, any deviations in this process can be recorded simultaneously in both organs. Such morphological abnormalities are consistent with the concept of skin as an indicator of systemic disorders, where visible changes reflect underlying pathophysiological shifts, including chronic inflammation and metabolic imbalance [6]. Thus, pattern analysis makes it possible to identify individuals with a potentially high risk of developing coronary heart disease even before the onset of clinical symptoms.

The heritability of dermatoglyphic signs is a high indicator, which makes them a promising tool for assessing genetic predisposition to cardiovascular diseases [1]. Modern studies confirm that polymorphism of genes associated with lipid metabolism and inflammatory response can manifest itself not only in biochemical parameters, but also in phenotypic signs of the skin [5]. An analogy can be traced with other dermatological conditions that have a genetic nature and a connection with cardiorisc, such as androgenetic alopecia, which is considered as an indicator of metabolic syndrome and cardiovascular risk [18]. Genomic profiling of patients with chronic skin diseases reveals systemic alterations relevant for both skin manifestations and vascular disorders [19]. In the context of psoriasis and other inflammatory dermatoses, a link has been proven between the genetic determinants of inflammation (for example, the IL-23/IL-17 pathway) and the development of comorbid cardiovascular pathologies [12]. This confirms the hypothesis that dermatoglyphic signs, being genetically determined, can serve as an external reflection of the internal genetic architecture predisposing to atherosclerosis. The integration of genetic analysis with the assessment of skin markers opens up new opportunities for personalized medicine and early prevention [3].

DISCUSSION

Modern diagnostics of microcirculatory disorders in systemic atherosclerosis is based on a set of noninvasive instrumental techniques that allow visualizing and quantifying the functional state of the peripheral vascular bed. Video capillaroscopy of the nail bed is a method of direct observation of the morphology and dynamics of capillary blood flow in real time [6]. This technique identifies structural abnormalities - changes in the shape, caliber, and density of capillaries - that may serve as early markers of endothelial dysfunction. Laser Doppler flowmetry (LDF) complements the morphological assessment with functional parameters, registering fluctuations in erythrocyte flow and allowing the analysis of vasomotor activity through spectral analysis of perfusion fluctuations [15]. Thermovisiography, based on recording infrared radiation from the skin, provides information about regional

perfusion and thermal homeostasis, violations of which often precede clinical manifestations of ischemia [5]. The combination of these methods provides a multilevel characterization of microcirculation, which is especially important in the stratification of cardiovascular risk in patients with subclinical forms of atherosclerosis [3].

In systemic atherosclerosis, the microcirculatory bed of the skin undergoes a number of specific transformations reflecting the universal mechanisms of vascular damage. One of the most reproducible signs is capillary reduction, a decrease in the density of functionally active capillaries, which correlates with the severity of endothelial dysfunction and oxidative stress [5]. Structural disorganization manifests itself in the form of capillary tortuosity, the formation of aneurysmal extensions and microhemorrhages, which are visualized during capillaroscopy and are associated with increased vascular wall permeability [6]. Functional disorders include a decrease in basal perfusion and a weakening of the vasodilator reserve, which is revealed during functional tests (occlusive, thermal, postural) [15]. These changes are caused by an imbalance of vasoactive mediators, primarily a decrease in the bioavailability of nitric oxide and an increase in endothelin-1 levels, which is characteristic of systemic inflammation in atherosclerosis [4]. It is important to note that similar microcirculatory shifts have been described in chronic inflammatory dermatoses such as psoriasis or lupus erythematosus, which confirms the common pathophysiological mechanisms of skin and cardiovascular system damage [7], [12].

The clinical significance of the assessment of microcirculatory parameters is determined by their ability to reflect the degree of systemic vascular damage. Studies show a direct correlation between the severity of capillary abnormalities and the number of stenosed coronary arteries, confirmed by coronary angiography [6]. Patients with multivessel lesion are characterized by a more pronounced reduction of the capillary network and a decrease in vasomotor reactivity compared with individuals with a single-vessel disease or a control group. In addition, microcirculation parameters correlate with the functional class of angina according to the classification of the Canadian Cardiovascular Society.: A decrease in the perfusion index and impaired postocclusive hyperemia are associated with a more severe course of coronary heart disease and a worse prognosis [3]. These observations are consistent with the concept of the skin as a "window" into the systemic vascular system, where changes in microcirculation precede or parallel the progression of coronary atherosclerosis [15]. The integration of microcirculatory markers into risk stratification algorithms can improve the accuracy of predicting cardiovascular events, especially in patients with borderline values of traditional scales [5]. A promising direction is the use of dynamic microcirculation monitoring to evaluate the effectiveness of anti-atherosclerotic therapy and the personalization of treatment strategies [4].

Modern approaches to the stratification of cardiovascular risk are increasingly shifting towards multi-marker models that take into account not only traditional metabolic parameters, but also organ damage [1]. The integration of dermatoglyphic data reflecting genetic predisposition and embryonic programming with dynamic microcirculation indicators makes it possible to form a more complete patient profile. Dermatoglyphic signs act as static markers of risk, while the state of the microcirculatory bed demonstrates the current activity of endothelial dysfunction and systemic inflammation [6]. The development of an integral risk index, which includes skin parameters along with classical factors (blood pressure, lipid spectrum, smoking), can improve the accuracy of predicting events in people with borderline values of traditional scales. Such algorithms have already demonstrated effectiveness in risk assessment in metabolic syndrome, where skin manifestations serve as a visible indicator of systemic disorders [20]. The combined approach makes it possible to offset the disadvantages of each method individually: low specificity of clinical examination and insufficient sensitivity of laboratory tests in the early stages of atherosclerosis.

Comparing the diagnostic value of skin markers with conventional scales such as SCORE or Framingham reveals a number of advantages in certain clinical scenarios. European guidelines for the prevention of cardiovascular diseases emphasize the importance of risk individualization, however, standard scales may underestimate the threat in patients with chronic inflammatory skin diseases [3]. Studies show that the SCORE and Framingham risk assessment in patients with rosacea or psoriasis often does not correlate with the actual degree of vascular damage, which requires supplementing the clinical picture with specific markers [21]. The presence of xanthelasm, for example, is associated with an increased risk of atherosclerosis regardless of serum lipid levels, which is confirmed by data from systematic reviews and meta-analyses [9]. Chronic systemic inflammatory skin diseases are considered as an independent risk factor capable of modifying the patient's risk category upward even at moderate values of traditional indicators [7]. Thus, skin markers have additional predictive value, especially in the context of inflammation and endothelial dysfunction, which are not always fully reflected in biochemical analyses.

The introduction of skin assessment into clinical practice has two main vectors: primary screening and monitoring of therapy. Dermatologists can play a key role in the early detection of patients at risk by sending them for an in-depth cardiological examination if specific patterns or signs of microcirculatory disorders are detected [6]. The concept of a "cardio-cutaneous" connection emphasizes the need for interdisciplinary collaboration to improve treatment outcomes [15]. In terms of monitoring the effectiveness of therapy, microcirculation parameters demonstrate high sensitivity to changes in vascular status. For example, the use of biological therapy in patients with psoriasis leads to an improvement in endothelial function and a decrease in vascular inflammation, which can be recorded by methods of functional skin diagnostics [22]. Dynamic monitoring of the microcirculatory system makes it possible to assess the response to lipid-lowering and antihypertensive therapy before changes occur in the macrovascular system. This opens up prospects for personalized treatment correction and timely prevention of complications of coronary heart disease [1].

Despite the growing interest in skin markers of cardiovascular risk, their introduction into clinical practice is hindered by the lack of unified protocols. Methodological heterogeneity is a significant obstacle: different methods of removing dermatoglyphic fingerprints (classical fingerprinting versus optical scanning) and different settings of video systems for capillaroscopy make it difficult to compare the results between research centers [6]. The lack of uniform criteria for assessing the density of the capillary network or the classification of papillary line patterns reduces the reproducibility of data, which is a critical disadvantage from the point of view of evidence-based medicine. The European Guidelines for the prevention of cardiovascular diseases emphasize the need to validate new risk stratification tools before their widespread integration, which requires the development of standardized surgical procedures for dermatological diagnosis in cardiology [3]. Without addressing the issue of standardization, it is impossible to conduct large multicenter studies necessary to confirm the prognostic value of skin signs.

The interpretation of skin markers is complicated by the effects of multiple confounders that can modify the condition of the skin and microcirculation, regardless of the presence of atherosclerosis. Age, gender, and ethnicity determine the basic characteristics of dermatoglyphics and vascular bed density, which requires the creation of correction factors for different demographic groups [1]. In addition, professional activities associated with mechanical effects on the skin of the hands can distort papillary patterns, and working temperature conditions affect peripheral blood flow. The metabolic status also makes a significant contribution: the presence of metabolic syndrome is associated with specific skin changes that may overlap or enhance the symptoms caused directly by coronary heart disease [20]. Ignoring these covariates can lead to false positive or false negative results, so future studies should provide for strict control of related variables when forming samples.

Overcoming the described limitations is seen in the digital transformation of the diagnostic process. The complexity of immunobiological interactions in atherosclerosis and the multifactorial nature of skin manifestations create the need for data analysis tools that exceed the capabilities of human visual assessment [5]. The use of neural networks to process images of capillaries and dermatoglyphic patterns makes it possible to identify hidden patterns and minimize the subjectivity of interpretation. The concept of a "cardio-cutaneous" connection can be developed in the format of mobile screening applications, where machine learning algorithms will integrate visual skin data with anamnestic information [15]. A promising area is the creation of telemedicine platforms that allow dermatologists and cardiologists to jointly assess risks remotely. However, the implementation of these technologies requires not only technical improvement, but also confirmation of their clinical effectiveness in randomized trials that meet modern standards for the management of cardiovascular diseases [1].

CONCLUSIONS

The analysis of literature data and pathophysiological mechanisms confirms the hypothesis of the existence of reliable cutaneous correlates of coronary heart disease, reflecting the systemic nature of the atherosclerotic process. The skin acts not only as a protective barrier, but as a dynamic model of the vascular bed, where structural and functional changes can precede the clinical manifestation of coronary pathology [10], [11]. The revealed patterns indicate that dermatoglyphic signs indicating disorders of embryogenesis and microcirculation parameters reflecting current endothelial dysfunction have additional prognostic potential in the stratification of cardiovascular risk [6], [15].

The systemic nature of atherosclerosis, mediated by common immunobiological mechanisms of inflammation and oxidative stress, causes parallel damage to the macro- and microvessels of various target organs, including the skin [4], [5]. The presence of specific dermatological markers, such as changes in papillary patterns or reduction of the capillary network, correlates with the severity of coronary atherosclerosis and can serve as an independent predictor of adverse outcomes, complementing traditional risk scales [3], [7]. It is particularly important to identify a link between chronic inflammatory dermatoses and the accelerated development of vascular complications, which highlights the role of systemic inflammation in the pathogenesis of coronary heart disease [12], [9].

The implementation of the obtained data in clinical practice requires a transition from highly specialized patient management to interdisciplinary interaction. The integration of dermatological diagnostics into the algorithms of cardiological examination will make it possible to identify risk groups at earlier stages, when preventive measures have maximum effectiveness [15]. The collaboration of cardiologists and dermatologists, based on an understanding of the pathophysiological unity of "skin–heart", contributes to the personalization of therapy and the improvement of long-term prognosis in patients with systemic atherosclerosis [1], [6]. Further research should be aimed at standardizing skin marker assessment methods and validating integral risk indices in large multicenter cohorts.

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