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RETINAL MICROCIRCULATION DISORDERS IN PATIENTS WITH HYPERTENSIVE DISEASE: A MORPHOMETRIC APPROACH

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Abstract: This study aimed to investigate the morphometric parameters of retinal vessels in patients with hypertensive retinopathy. A total of 60 patients who were referred to the Bukhara Branch of the Republican Specialized Scientific and Practical Medical Center for Eye Microsurgery were included in the study. The patients underwent a comprehensive examination using visual acuity testing, tonometry, A-scan ultrasonography, biomicroscopy, ophthalmoscopy, fundus photography, and optical coherence tomography (OCT).
The results showed that most patients exhibited arteriolar narrowing, venular dilation, arteriovenous ratio disruption, as well as signs of vasospasm and sclerotic changes in the vessel walls. Changes in the optic nerve head and the retinal nerve fiber layer (RNFL) were manifested as mild optic disc cupping and thinning of the RNFL in the superior and inferior quadrants. Morphometric parameters of the retinal vessels were significantly correlated with the severity and duration of hypertension ($p < 0.05$).
Morphometric analysis of retinal vessels using fundus photography and OCT is a reliable and objective method for assessing microcirculatory alterations in hypertensive retinopathy. These methods can be utilized for early diagnosis, monitoring disease progression, and evaluating the effectiveness of therapeutic interventions.
Keywords: retinal vessels, morphometric parameters, optical coherence tomography (OCT), fundus photography, microcirculation, hypertensive retinopathy.

Relevance of the Topic. Hypertension is a cardiovascular disorder that develops against the background of elevated arterial blood pressure. In addition to cardiovascular pathologies, increased blood pressure can lead to disorders of the visual system. Hypertensive disease is gradually becoming one of the most pressing medical and social problems worldwide, as its prevalence continues to rise annually. Globally, among the leading causes of blindness and visual impairment are age-related ophthalmic diseases, the prevalence of which is increasing due to population aging. Hypertension is primarily detected in patients over 40–45 years of age. Hypertensive episodes are usually accompanied by headache, palpitations, insomnia, chest pain, and tinnitus. In some patients, hypertensive crises are associated with visual disturbances and eye pain. However, not all patients are aware that even minor fluctuations in blood pressure can cause pathological changes in the visual system. In certain cases, elevated blood pressure leads to alterations in the retinal vessels, which, if left untreated, can result in decreased visual acuity.

Furthermore, it is important to have a comprehensive understanding of the mechanisms, etiological factors, and causes underlying the development of ophthalmic complications in the context of hypertension. This knowledge allows for the early identification of risk factors, timely diagnosis, treatment, and preventive measures, thereby reducing the risk of certain vision-related diseases.

Retinal angiopathy is a vascular disorder that usually develops against the background of systemic diseases (autonomic-vascular disorders, hypertension, diabetes mellitus, etc.). Angiopathy is a consequence of pathologies affecting the vessels throughout the body and typically occurs simultaneously in both eyes. This condition affects men and women equally. Currently, ophthalmologists pay special attention to this pathology because it can lead to irreversible changes in visual function, up to complete blindness.

The causes of angiopathy may include hypotension or hypertension, atherosclerosis, hyperglycemia in diabetes mellitus, autoimmune processes, traumatic factors, and hereditary diseases. All of these conditions negatively impact the state of vessels and arteries throughout the body. In retinal angiopathy, the following changes are observed: impaired vascular wall permeability, development of vasospasm, thrombosis, and formation of atherosclerotic plaques.

Aim of the Study. To assess morphometric changes in the retinal vessels of patients with hypertensive disease using fundus photography and optical coherence tomography (OCT).

Methods of the Study. The study included 60 patients who sought medical care at the Bukhara branch of the Republican Specialized Scientific and Practical Medical Center of Eye Microsurgery (RSSPMCEM).

The subject of the study was the morphofunctional characteristics of the visual analyzer in patients with hypertension, in particular the condition of the optic nerve head, retina, and retinal vessels. Special attention was paid to the detection of morphometric changes in the retinal vascular bed, as well as to the assessment of structural alterations in the posterior segment of the eye associated with arterial blood pressure levels and the severity of hypertensive retinopathy.

To achieve the study objectives, a comprehensive set of modern clinical and instrumental examination methods was employed. All patients underwent a standard ophthalmological examination, including:

- Visiometry – to determine visual acuity and assess the functional status of the visual analyzer;
- Tonometry – to measure intraocular pressure and rule out concomitant ocular hypertension;
- A-scan ultrasonography (biometry) – to determine the anatomical parameters of the eye;
- Biomicroscopy – for detailed examination of the anterior segment and vitreous body;
- Ophthalmoscopy (direct and indirect) – to assess the condition of the optic nerve head and the vascular pattern of the fundus;
- Fundus examination – to visually document changes in the retinal vessels;
- Optical coherence tomography (OCT) – for high-resolution visualization and quantitative assessment of retinal and optic nerve structures, and for detecting microstructural changes not visible with standard ophthalmoscopy.

The application of this comprehensive set of methods enabled a thorough morphometric and functional evaluation of retinal vessels in patients with hypertension, ensuring the objectivity and reliability of the obtained data.

Results and Discussion. Ophthalmological examinations were conducted on 60 patients with hypertension of varying severity. The age of the participants ranged from 40 to 65 years, including 32 women (53.3%) and 28 men (46.7%). The duration of hypertension ranged from 2 to 15 years.

Based on fundus examination and optical coherence tomography (OCT) data, characteristic morphometric changes in the retinal vessels and optic nerve head were identified, which depended on the duration and stage of hypertension.

1. Changes in Retinal Vessels. The majority of patients (83.3%) exhibited signs of hypertensive retinopathy of varying severity. At early stages, moderate changes in the caliber of arteries and veins were observed: narrowing of arterioles, slight dilation of venules, and disruption of the arteriovenous ratio (normally 2:3; in hypertension, it decreased to 1:3 or 1:4).

With progression of hypertension, more pronounced vascular abnormalities were observed: irregular arteriolar caliber, localized vasospasm, sclerotic changes in the vessel wall, and arteriovenous crossing phenomena (Gunn, Salus, and Bonnet signs). In some cases (18.3% of patients), microaneurysms and dot- or flame-shaped retinal hemorrhages were visualized, indicating the development of hypertensive retinopathy.

2. Optic Nerve Head Condition. OCT data revealed that patients with long-standing hypertension exhibited moderate cupping of the optic nerve head and thinning of the retinal nerve fiber layer (RNFL), predominantly in the superior and inferior quadrants. These changes correlated with the duration of hypertension ($r = 0.68$, $p < 0.05$), indicating gradual involvement of the optic nerve in the pathological process due to chronic vascular ischemia.

3. Morphometric Parameters of Vessels. Morphometric analysis of fundus images showed a significant reduction in the mean diameter of retinal arteries compared to the control group ($p < 0.01$), while venous diameter remained relatively stable or slightly increased. The arteriovenous ratio (A/V) in hypertensive patients decreased on average to 0.64 ± 0.05, compared with 0.73 ± 0.04 in normotensive individuals.

These changes indicate progressive vascular wall tone disturbances, increased peripheral resistance to blood flow, and reduced retinal perfusion. These processes, in turn, contribute to chronic hypoxia and microvascular damage.

4. Comparative Analysis by Hypertension Stage. In patients with Stage I hypertension, primarily functional vascular changes were observed (arteriolar spasm, mild arterial narrowing). Stage II patients showed structural changes in the vessel wall, arteriole thickening, increased reflectivity, and arteriovenous crossing symptoms. In Stage III hypertension, pronounced destructive changes were diagnosed, including multiple hemorrhages, exudates, and optic disc edema, indicating the development of hypertensive angio-retinopathy.

5. Discussion of Findings. The results are consistent with the literature, which indicates that hypertension induces systemic vascular changes, including alterations in the retinal microcirculation. Morphometric vessel parameters assessed using fundus photography and OCT can serve as objective biomarkers of vascular damage severity in hypertension.

Thus, the identified structural and functional changes in the retinal vessels and optic nerve confirm a strong relationship between systemic arterial pressure and ocular microcirculation. The use of modern imaging techniques (OCT and digital fundus photography) enables early detection of vascular abnormalities and evaluation of therapeutic efficacy.

Conclusions. Morphometric changes in the retinal vessels of patients with hypertension reflect systemic vascular damage. The study revealed narrowing of arterioles, dilation of venules, disruption of the arteriovenous ratio, as well as signs of vasospasm and sclerotic changes in the vessel walls. These changes become more pronounced with increasing duration and severity of hypertension, confirming the dependence of retinal microcirculation on arterial blood pressure.

The condition of the optic nerve head and the retinal nerve fiber layer (RNFL) also undergoes changes: in patients with long-standing hypertension, moderate optic disc cupping and thinning of the RNFL in the superior and inferior quadrants were observed, which may serve as early markers of optic nerve involvement.

Morphometric parameters of retinal vessels obtained through fundus photography and optical coherence tomography (OCT) are objective biomarkers of the degree of microvascular damage. Reduction in the mean arteriole diameter and arteriovenous ratio significantly correlates with the severity and duration of hypertension ($p < 0.05$).

Progressive vascular changes in stages II–III of the disease include arteriovenous crossings, microaneurysms, hemorrhages, and exudates, indicating the development of hypertensive angio-retinopathy and emphasizing the importance of early detection of microcirculatory disturbances.

The practical significance of this study lies in the possibility of quantitatively assessing morphometric parameters of retinal vessels using fundus photography and OCT, enabling objective monitoring of microcirculation and optic nerve condition, early diagnosis, and evaluation of therapeutic efficacy in patients with hypertension.

The results confirm the necessity of regular ophthalmologic monitoring for patients with arterial hypertension, particularly those over 40 years old and with long-standing disease. Morphometric analysis of retinal vessels is recommended as part of a comprehensive assessment of microcirculation and for monitoring the progression of hypertension.

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