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VELIZIY-ZAKHARCHENKO CIRCLE (CEREBRAL ARTERIAL CIRCLE) AND ITS ROLE IN CEREBRAL BLOOD CIRCULATION, ALONG WITH OBSERVED PATHOLOGIES

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Abstract. The Veliziy-Zakharchenko circle, or the cerebral arterial circle (circulus arteriosus cerebri), is an important anastomotic structure in cerebral blood circulation. It connects the anterior (internal carotid arteries) and posterior (vertebrobasilar system) circulatory systems, providing collateral blood flow. This circle plays a key role in protecting the brain from ischemia. However, its anatomical variants are common and can increase the risk of stroke, aneurysm, and other cerebrovascular diseases. The article details the anatomy of the circle, its physiological role, anatomical variants, observed pathologies, and their clinical significance. Research results show that the complete form of the circle occurs in only 20-50% of cases; in the remaining cases, hypoplasia, aplasia, or fetal-type variants are present, which can lead to circulatory disturbances. The article may provide practical benefits to specialists in neurosurgery, neurology, and radiology.

Keywords: Veliziy-Zakharchenko circle, cerebral arterial circle, collateral circulation, cerebrovascular anatomy, aneurysm, ischemic stroke, anatomical variants, posterior communicating artery, anterior communicating artery.

Introduction. The human brain is a highly metabolically active organ, and its constant and adequate blood supply is vital. Cerebral blood circulation is carried out through two main systems: the anterior system (internal carotid arteries – arteria carotis interna) and the posterior system (vertebral arteries – arteria vertebralis, which merge into the basilar artery). The important structure that connects these two systems and equalizes blood flow is the Veliziy-Zakharchenko circle (Circle of Willis). This arterial

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circle is named after the English physician Thomas Willis, who described it in detail in his 1664 work "Cerebri Anatome." However, similar structures had been noted earlier by anatomists such as Giulio Casserio, Johann Vesling, and others. The name Zakharchenko is additionally used in some Russian and former Soviet literature because Russian scientists studied this topic in depth. The Veliziy-Zakharchenko circle is located at the base of the brain, around the sella turcica, encircling the stalk of the pituitary gland. It connects the anterior and posterior circulatory systems, allowing blood to be redirected from one side to the other in case of occlusion or stenosis of an artery on one side. This collateral mechanism protects against cerebral ischemia, but because incomplete variants of the circle are very common, this protection is not always effective. Modern studies show that the classic complete form of the circle is observed in only 20-50% of healthy individuals. In other cases, there is hypoplasia (narrowing), aplasia (absence), or fetal-type configurations. Such variants significantly increase the risk of stroke and aneurysm. This article provides an in-depth analysis of the circle's role, variants, and pathologies based on scientific data.

Main Part. Anatomically, the Veliziy-Zakharchenko circle has a pentagonal or ring shape and consists of the following arteries:

- Anterior part: The terminal portions of the bilateral internal carotid arteries, the first segments of the anterior cerebral arteries (A1), and the anterior communicating artery (ACoA).

- Posterior part: The first segments of the posterior cerebral arteries (P1) arising from the basilar artery, the posterior communicating arteries (PCoA), and the second segments of the posterior cerebral arteries (P2).

The circle is also associated with the middle cerebral arteries (MCA) arising from the internal carotid arteries, although the MCA is not a direct part of the circle. Overall blood flow is as follows: the internal carotid arteries supply the anterior and middle cerebral territories, while the vertebrobasilar system supplies the posterior cerebral territory and the cerebellum. The communicating arteries (ACoA and PCoA) provide blood exchange between the two sides and between the anterior and posterior regions. The circle is located in the subarachnoid space, outside the brain tissue, making it an important landmark during surgical interventions. Its arteries usually have a diameter of about 1-2 mm, though this can vary in different configurations. Its main physiological role is to provide collateral circulation. For example, in unilateral internal carotid artery occlusion, blood flow from the vertebrobasilar system can reach the anterior territories through the PCoA. Similarly, the ACoA equalizes blood flow between the anterior parts of the two hemispheres. This mechanism is especially

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important in atherosclerosis, embolism, or during surgery. Studies indicate that individuals with a complete circle experience fewer ischemic events and have a better prognosis. The circle also ensures stability during blood pressure fluctuations by allowing redistribution of blood flow. However, its collateral capacity is not always sufficient. If the communicating arteries are hypoplastic, blood flow may be inadequate, leading to border-zone (watershed) infarcts. In the fetal-type PCA (narrow P1 segment and large PCoA), the posterior territory blood supply largely depends on the anterior system, increasing risk during vertebrobasilar insufficiency.

Anatomical variants of the Veliziy-Zakharchenko circle are very common. The classic complete form is observed in only 21-50% of cases. The most widespread variants include:

- Unilateral or bilateral hypoplasia or aplasia of the posterior communicating arteries (PCoA) — the most common, approximately 25-50%.

- Hypoplasia or absence of the anterior communicating artery (ACoA).

- Fetal-type posterior cerebral artery (narrow P1, large PCoA) — approximately 10-30%.

- Hypoplasia of the A1 segment of the anterior cerebral artery.

- Duplication, fenestration (window-like), or accessory arteries.

Studies (e.g., based on MR angiography) show that the frequency of a complete circle varies with age: it is higher in younger people and increases with variants in the elderly. Gender differences also exist — in some studies, incomplete circles are more common in men. Geographically, variants associated with stroke are more frequently observed in African and Asian populations. Such variants lead to hemodynamic changes: blood flow becomes turbulent, pressure distribution is disrupted, creating additional stress on arterial walls.

Pathologies and clinical significance. The most common pathologies in the Veliziy-Zakharchenko circle are:

1. Aneurysms. Approximately 85% of all intracranial aneurysms are located in this circle. They most frequently occur at the anterior communicating artery (ACoA), followed by the PCoA and ICA bifurcation. Aneurysms form in areas where the vessel wall is weakened due to turbulent flow and increased pressure. Rupture leads to subarachnoid hemorrhage (SAH), which has a high mortality rate. Variants (e.g., ACoA hypoplasia) can increase aneurysm risk by 2-4 times.

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2. Ischemic stroke and TIA (transient ischemic attack). In an incomplete circle, collateral failure occurs during occlusion of one artery. For example, with bilateral absence of PCoA, vertebrobasilar insufficiency can damage anterior territories. Studies show that an incomplete circle increases stroke risk by 1.8-2.0 times. Watershed infarcts are particularly characteristic.

3. Atherosclerosis and calcification. Disturbed blood flow in variants increases susceptibility to plaque formation in arterial walls. In some variants (e.g., bilateral PCoA hypoplasia), vertebrobasilar calcification is more common.

4. Other pathologies. Moyamoya disease, arteriovenous malformations, and ischemic complications during surgery. In neurosurgical interventions (aneurysm clipping, carotid endarterectomy), prior knowledge of circle variants is crucial for predicting blood flow. MRI and CT angiography are the main modern diagnostic methods. They accurately show the circle's configuration and help identify risk groups.

Research Results. Many large-scale studies have examined variants of the Veliziy-Zakharchenko circle. For instance, a meta-analysis found a classic complete circle in only 21.2% of cases; the most common anomaly was bilateral absence of the PCoA (25.1%). This variant increased stroke risk with OR=1.82; complete anomalies carried OR=2.03. Variant frequency increases with age. In another study (1,667 participants), an incomplete circle increased the risk of intracranial aneurysm by 2.3 times, especially with absence of all three communicating arteries (OR=4.2) or absence of the P1 segment (OR=3.6). These variants accounted for 28% of all aneurysms. Clinical studies (e.g., in Ethiopia and other regions) showed that incomplete circles were more common in women and had a strong association with stroke (OR=15.4 in some analyses). Hypoplastic arteries were most often observed in the posterior part (PCoA). Radiological studies using MR angiography detected variants in 70-80% of cases. Fetal-type PCA may reduce vertebrobasilar calcification, while other variants increase it. Cadaveric studies reported variants in 50-90% of cases, with the most changes noted in the ACoA and PCoA. These results confirm that circle variants are widespread in the population, and preventing cerebrovascular diseases is difficult without taking them into account. Modern computer simulations (CFD – computational fluid dynamics) model turbulent flow and wall stress, confirming the mechanisms of aneurysm formation in variants. For example, increased pressure in ACoA hypoplasia contributes to aneurysm development.

Conclusion: The Veliziy-Zakharchenko circle is the main "circular pathway" of cerebral blood circulation, protecting against ischemia and stroke through collateral mechanisms. However, its anatomical variants are very common and significantly

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increase the risk of aneurysm, ischemic stroke, and other pathologies. A complete circle exists in only a portion of people; in the rest, hypoplasia and aplasia predominate. Early detection of these variants is possible through modern diagnostics (MRI/CT angiography) and a personalized approach (risk assessment). Accounting for circle anatomy in neurosurgery and neurology reduces surgical complications and improves patient prognosis. Future research should more deeply study genetic factors and geographical differences. Overall, understanding the Veliziy-Zakharchenko circle is of great importance in the prevention and treatment of cerebral circulatory disorders.

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