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# Blood flow and rheological disorders in spinal vascular malformations

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## Abstract

Malformation is a condition in which pathologically tortuous shunt vessels appear between arteries and veins instead of a network of capillaries. As a result of replacement of the capillary bed, the exchange of oxygen and nutrients between tissues and blood is disrupted, and oxygen starvation is experienced. Spinal vascular malformations are a rare and poorly studied pathology, which is characterized by significant diversity. There is no single hypothesis for the formation of malformations. Existing classifications do not always reflect the reality and prospects for the development of diseases. This work is an attempt to study the rheological properties and their contribution to fluidity failures during malformations with the aim of a comprehensive study of the problem.

**KEYWORDS:** aggregation; deformation; malformations; coagulation

## Introduction

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Spinal vascular malformations are a rare and poorly studied pathology, which is characterized by significant diversity [1-6]. Publications on this subject are mainly based on descriptions of individual observations [7-12]. Insufficient knowledge of this pathology is associated with the complexity of its diagnosis, which limits the development of differentiated methods of surgical treatment [7]. Great difficulties in this regard are caused by the lack of a clear structural-dynamic classification. Currently, the most widely used classification is according to which they distinguish: Dural arteriovenous fistulas (type I), glomus intracerebral (type II), juvenile or combined (type III), intradural perimedullary arteriovenous fistulas (type IV) [8,9]. Vascular tumors (hemangioblastomas, hemangiopericytomas, angiosarcomas, hemangioendotheliomas, hemangiomas, angioliipomas) and cavernous malformations are identified separately [2,12]. In 2002, R.F. Spetzler et al [12] proposed a new classification of spinal vascular pathology. However, this classification, despite its complexity, still does not cover the entire variety of types of spinal malformations. Therefore, we believe that a detailed systematization of spinal vascular malformations is necessary, which can contribute to the development of differentiated tactics of surgical interventions, taking into account the location, angio structural type and hemodynamic characteristics of the malformations, which will optimize treatment results.

The incidence of acute spinal circulatory disorders is about 1% of other forms of acute cerebrovascular accidents [7]. Among cerebrospinal circulation disorders, ischemic damage most often develops – myelischemia; hemorrhages – hematomyelia – occur less often. All causes of myelischemia can be grouped into three main groups [13-15]. The first group includes lesions of the cardiovascular system itself: congenital (malformations of the spinal vessels – arteriovenous aneurysms, arterial aneurysms, varicose veins; coarctation of the aorta, hypoplasia of the spinal vessels) and acquired (atherosclerosis of the branches of the aorta, arteritis, phlebitis, thrombosis and embolism, insufficiency hemocirculation due to weakness of cardiac activity during myocardial infarction, atrial fibrillation, and hypertension). These causes are observed in 20% of patients with myelischemia. The second group consists of processes leading to compression of vessels from the outside: compression of the aorta and its branches by tumors and space-occupying formations of the thoracic and abdominal cavities (enlarged uterus due to pregnancy, lymph node packages in lymphogranulomatosis, tuberculosis, tumor metastases, etc.), compression of the radicular spinal arteries and radicular veins with prolapse of the intervertebral disc (the most common type of compression), epi – and subdural tumor, vertebral fragments due to trauma, epidural inflammatory infiltrate, thickened soft and arachnoid membranes (including atherosclerotic plaques



in them), etc. The third group consists of iatrogenic factors when myelischemia occurs as a complication of surgical interventions – radiculotomy with intersection of the radicular-spinal artery [5,7,16-20].

However, when describing blood circulation, it is necessary to recognize the very structure of the blood flow. The structure of the blood flow is the flow of elementary particles and plasma in the vessels. Red blood cells form a continuous structure, i.e., tend to aggregate and form in which cells touch their flat surfaces [21,22]

The aggregation of erythrocytes with their deformation properties is an important determinant that shapes the rheological properties of blood and the structure of blood flow. Two parallel models have been proposed to explain erythrocyte aggregation. According to the “bridging theory”, aggregation occurs when disaggregating forces are unable to resist the adsorption of macromolecules by nearby cells. “Depletion model”. With any consideration of the reason for the convergence of contacting particles, the contact area of the molecules is depleted, which leads to the formation of aggregates, overcoming factors such as the electrical charge of membranes, mechanical displacement, and Brownian motion. The formation of erythrocyte aggregates is the result of the action of osmotic forces and the formation of intermolecular bridges [20,23,24].

The blood supply to the spinal cord and spine is carried out from 3 pools – the subclavian arteries, the thoracic and abdominal aorta, and the internal iliac arteries. From all these vessels arise segmental arteries, from which in turn arise dorsal branches, which give rise to the spinal branches.

An increase in the aggregation ability of red blood cells during inflammation, stress and the development of other pathological processes is considered exclusively in a negative context. In particular, it is very popular to note the participation of the aggregation properties of erythrocytes in endothelial disorders, plaque formation and vascular injuries, when the main events develop near the walls of blood vessels, where the shear rate is greatest. Despite the ongoing interest in assessing the aggregation properties of erythrocytes, we will try to determine the feasibility of such studies [25-32].

Naturally, in the case of malformations, taking into account rheological pathologies is very important.

On the other hand, during vascular injury, destroyed red blood cells contribute to the formation of a platelet plug and fibrin clot due to the activation of erythrocyte coagulation factors (chemical role). They are capable of adsorbing and accumulating plasma coagulation factors, fibrinolysis and anticoagulants on their surface; fibrin threads are attached to their surface (mechanical role). Thus, the phenomenon of erythrocyte aggregation appears only when blood flow is completely stopped, but is still of theoretical and practical interest, because serves as a simple model for studying cellular interactions in body systems under normal conditions and especially during pathalgia, such as malformations.

If we consider the literature and epidemiological statistics, Arteriovenous malformation is a condition in which pathologically tortuous shunt vessels appear between arteries and veins instead of a network of capillaries – can occur anywhere, and is a clinically unfavorable disease. As a result of replacement of the capillary bed, the exchange of oxygen and nutrients between tissues and blood is disrupted, and oxygen starvation is experienced. The vessels have a thinner wall and are susceptible to rupture. The risk of rupture reaches 4% per year. Mortality in case of rupture is 30%, disability is 50% [7]. All these facts force doctors of all specialties and clinical rheologists to pay special attention to the diagnosis. It is still impossible to prevent the occurrence of malformation. However, fatal complications can be avoided if this pathology is diagnosed and treated in time.

According to our data, if an arteriovenous malformation is suspected, together with the technique of visualizing vessels to determine the tortuosity and shape of the vessels, it is necessary to register the aggregation ability of erythrocytes, which in turn can become a risk factor for complications and unfavorable outcomes.

We continue research in this direction, believing that experimental and clinical studies will provide new material for discussing problems associated with malformations.

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