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Professional paper

ANATOMICAL VARIATIONS OF THE VERTEBRO-BASILAR SYSTEM AND THEIR CONSEQUENCES ON CEREBRAL CIRCULATION

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Abstract

The intracranial portions of the vertebral arteries (VA), the basilar artery (BA), and their branches together form the vertebrobasilar system (VBS). The vertebrobasilar system (VBS) is particularly important because it supplies the posterior circulation of the brain [1,2]. The VBS supplies blood and glucose to the spinal cord (medulla spinalis), brainstem (truncus cerebri), cerebellum, thalamus, inferior temporal lobe (pars inferior lobi temporalis) and internal occipital lobe of the cerebellum (pars interna occipitalis cerebri [3,4,5] and is responsible for vision, body coordination, body balance, consciousness and a large number of human physiological functions. In this region, atherosclerotic manifestations with atheromatous plaques with extremely serious consequences including artery blockage and cerebrovascular ischemia most often occur. Anatomical variations of the VBS are numerous and a large number of them are benign. It is assumed that these anomalies develop due to some errors during embryonic development. Clinically, the vertebral arteries (VA) are divided into 4 segments. The first segment (V1) starts from its origin in the subclavian artery to the transverse process of C6, the second segment (V2) from starts from C6 to the transverse process of C2, the third (V3) from C2 to the foramen magnum, and the fourth (V4) forms the foramen magnum at the vertebrobasilar junction

Keywords: Anatomical variations of the vertebrobasilar system (VBS).

1. Introduction

Anatomical variations of the vertebrobasilar system are numerous and a large number of them are benign. A large number of authors have reported unilateral hypoplasia of the vertebral arteries (VA), posterior and anterior inferior cerebellar arteries and variation in the origin of the branches of the VA and the basilar artery (BA).Hemodynamic assessments of flow in the VBS can help detect hemodynamic factors that affect cerebral circulation aberrations and anatomical-physiological deviations which can then help to predict the locations of possible pathological changes, to detect early signs of the disease and to assess their treatment options and efficacy [6,7].Anatomical variations of the vertebrobasilar system are numerous and a large number of them are benign. A large number of authors have reported unilateral hypoplasia of the vertebral arteries (VA), posterior and anterior inferior cerebellar arteries and variation in the origin of the branches of the VA and the basilar artery (BA). It is assumed that these anomalies develop due to some errors during embryonic development. Clinically, the vertebral arteries (VA) are divided into 4 segments. The first segment (V1) starts from its origin in the subclavian artery to the transverse process of C6, the second segment (V2) from starts from C6 to the transverse process of C2, the third (V3) from C2 to the foramen magnum, and the fourth (V4) forms the foramen magnum at the vertebrobasilar junction [8]. V1 is formed by the dorsal division of the 7th cervical intersegmental artery. V2 is formed by post-costal anastomoses between the first to sixth cervical intersegmental arteries. V3 arises from the spinal branch of the first cervical intersegmental artery and V4 from the first cervical intersegmental artery [9]. Variations in the

VB system are mainly related to the site of origin, size, diameter (usually bilateral with a difference in their size) and the mode of branching [10,11].
The most common variations of VBS are:

1. Asymmetry of the vertebral arteries: one artery (usually the left) is dominant over the other (about 17.8% of cases);
2. Hypoplasia of the vertebral arteries - Hypoplasia of one or both vertebral arteries most often affects the right VA (present in 10-26% of cases);
3. Fenestration of the basilar artery occurs in 6-9% of cases;
4. Aplasia of a vertebral artery occurs in 1-2% of cases;
5. Trifurcation of the basilar artery occurs in 5-8% of cases;
6. Agenesis of the posterior cerebral arteries in 1-2% [12,13,14,15,16].

The most common symptoms that occur as a result of vertebrobasilar insufficiency are: headache, dizziness, paresthesia, confusion, vomiting, dysphagia, hemiparesis, aphasia, loss of balance, disturbances of consciousness, ataxia, tinnitus, nystagmus, diplopia, memory problems, mild forms of dementia, atherosclerosis and others. (17,18). The clinical significance of anatomical variations of the vertebrobasilar system are: the risk of ischemia, posterior cerebral infarctions, dysphagia, aneurysms, arteriovenous malformations, dementia, degenerative diseases, early atherosclerotic changes in blood vessels (premature atherosclerosis). Vertebrobasilar syndrome is a problem that affects many people, especially in old age because these variations can complicate the risk of cerebrovascular damage [19,20,21,22]. Vertebrobasilar insufficiency is a condition characterized by poor blood flow to the back of the brain, which is fed by two vertebral arteries. The blockage of these arteries with age and the passage of time is manifested by the appearance of atherosclerotic changes (Ath) or the accumulation of atherosclerotic plaques from the deposition of cholesterol, calcium and other cellular components that can impede or even block cerebral circulation. Stroke can occur due to either occlusion of the vertebral or basilar artery or an embolus that lodges more proximally in the brain. In emergency situations, VBI is an important differential diagnosis to consider [23,24]. Hypoperfusion or complete occlusion of the blood supply (cerebral infarction—permanent loss of brain function, cerebral ischemia, or transient ischemic attack-temporary loss of brain function) damages brain cells and results in loss of their function. The basilar artery serves as the main source of arterial supply for the brainstem and posterior cerebral hemispheres. The basilar artery passes anterosuperiorly within the basilar sulcus of the pons, giving rise to the bilateral anterior inferior cerebellar arteries, the multiple paramedian perforating pontine arteries, and the paired superior cerebellar arteries. As the basilar artery approaches the base of the pituitary gland, it divides to form the cerebral arteries bilateral posterior and posterior communicating arteries to complete the circle of Willis [25,26]. The connection of the basilar artery with the circle of Willis allows the collateral pathway of the basilar artery to supply the anterior structures of the brain if the flow through one of the internal carotid arteries (ICA) is compromised. The etiology of vertebrobasilar insufficiency is multifactorial but one of the most important factors is genetic predisposition and premature atherosclerosis, diabetes, high blood pressure, hyperlipidemia, adiposity, smoking, hyperfibrinogenemia, inflammation, hypercoagulable states, etc. cardioembolic conditions, advanced age, etc. The above-mentioned factors can lead to insufficient blood perfusion, hemodynamic ischemia, occlusion of both basilar arteries or the subclavian artery.

2. Purpose of the work

Identification and evaluation of anatomical variations of the vertebrobasilar system using imaging methods: MRI (magnetic resonance imaging), Magnetic resonance angiography, CT (computerized tomography) and measurement of the dimensions of the SVB arteries. The work also aimed to compare our results with the results of other authors. The study aims to determine the internal diameter of the AVD, AVS and AB in the Polog region in relation to gender and age.

3.Material and methods

The prospective-retrospective study included 50 patients aged 18 to 70 years hospitalized in the Department of Traumatology and Neurosurgery at the Clinical Hospital of Tetovo (due to head injuries, neck injuries, road accidents, headaches, dizziness, head injuries during skiing, etc.) over a period of one year, randomized according to symptomatology, gender, age and nationality. All patients were examined with computed tomography, magnetic resonance angiography, computed magnetic resonance imaging, during which the diameters of the vertebral arteries-AV (right and left) and the diameter of the basilar artery (AB) were measured. We compared our results with the results of other authors.

4.Statistical processing

From the basic statistical methods, the arithmetic mean value and the standard deviation X ± SD were used. Comparative statistics of lipid parameters between groups will be analyzed with the STUDENT "t" test for dependent and independent samples and non-parametric tests according to the Mann-Whitney test. Wilcoxon. The value with <0.005 was considered as a value; with statistical significance for The results were processed with the SPSS V26 program.

Table 1: number of patients by gender

Total number of patients	**50 (100)**
Female	**15 (30 %)**
Male	**35 (70 %)**

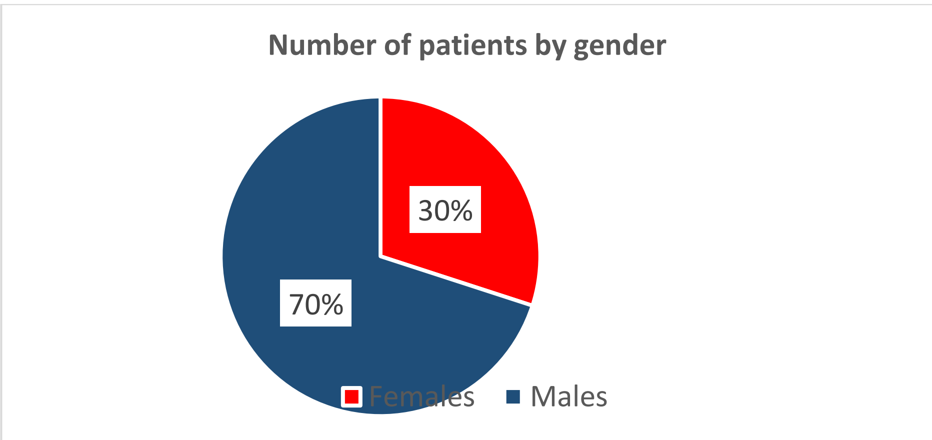


Table 2: distribution of patients by age

Total number of patients	**50 (100 %)**
<40 year	**10 (20%)**
>40 year	**40 (80 %)**

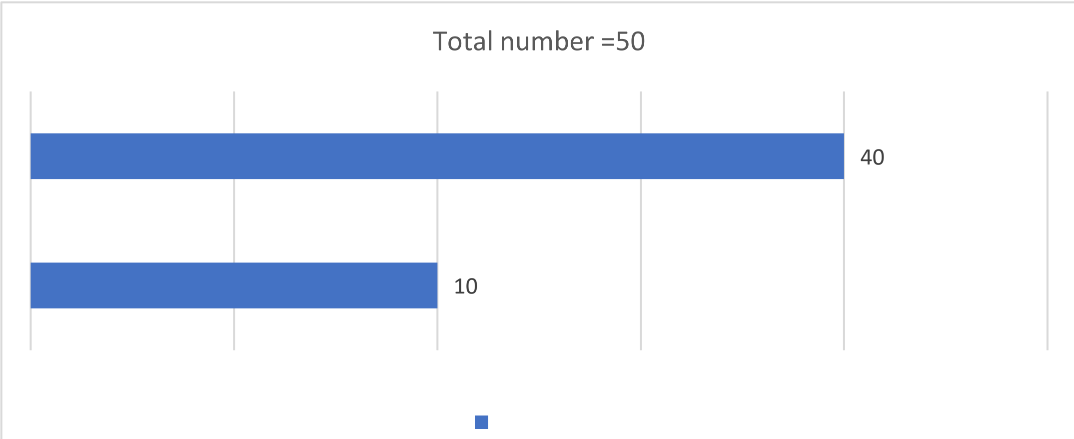
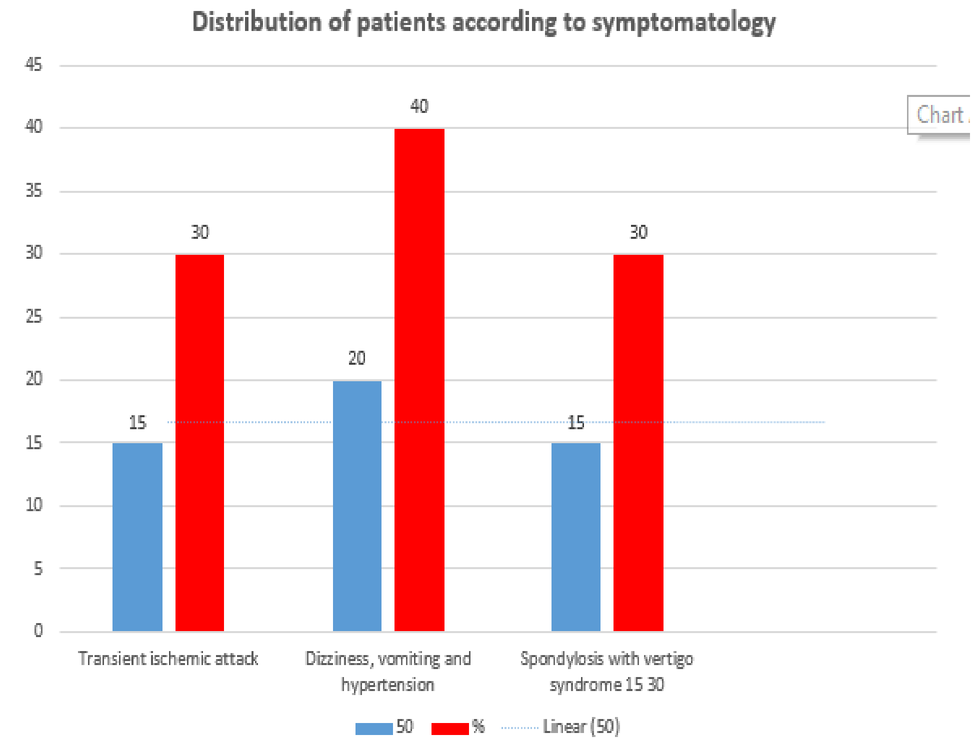


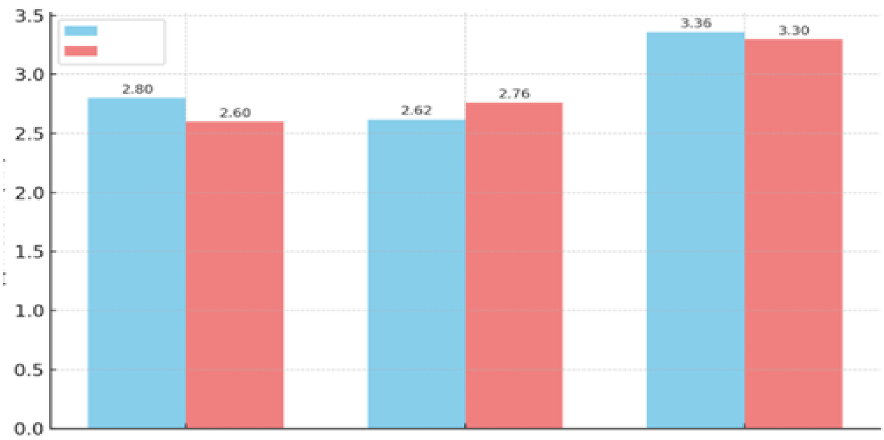
Table 3: distribution of patients according to symptomatology

Total number of patents	**50**	**%**
Transient ischemic attack	**15**	**30**
Dizziness, vomiting and hypertension	**20**	**40**
Spondylosis with vertigo syndrome	**15**	**30**



5. Results

Table 3. Dimensions of the Right Vertebral Artery (RVA) dimension of the Males = 2.70 mm, Women=2.65: Dimensions of the Left Vertebral Artery (LVA) of the Males = 2.62 while the Females = 2.80 (large and significant difference in diameters was observed for $p<0.001$.The dimensions of the basilar artery (AB) were: in men = 3.34 while in women = 3.30 without any significance.



Right V.A **Left V.A** **A.Basilaris**

Table 4: Dimensions of the vertebrobasilar arteries according to age

Our data showed that the average dimensions for: - Right Vertebral Artery in Men was = 2.80 mm while in Women was = 2.60 mm. Left Vertebral Artery in Men was = 2.62 mm while in Women was = 2.76 mm. Basilar Artery in Men was = 3.36 mm while in Women was = 3.30 mm. Compared with the world literature, these results are in accordance with their claims and that the vertebrobasilar arteries show variations between sexes and age which may be related to anatomical and hemodynamic factors (such as body size and greater need for circulatory perfusion) and that one artery is often dominant - usually the left which is also in accordance with the world literature.

6. Discussion

In general, the percentage of anatomical variations in the vertebrobasilar system, according to most international studies, is estimated to be between 20-40% of the general population. These data highlight the importance of studying this system in detail, especially for diagnostic and surgical purposes, since variations can significantly affect the distribution of blood flow in the hindbrain and be associated with clinical manifestations such as dizziness, syncope or vertebrobasilar ischemia. Anatomical variations of the vertebrobasilar system represent an aspect of particular importance in the assessment of posterior cerebral circulation, since they can affect brain perfusion, contribute to the formation of pathological changes and have clinical significance during neurovascular interventions. According to the world literature, these variations are quite common and the percentage of their occurrence varies depending on the study method (autopsy, MRI, MRA, CT scan) as well as the characteristics of the population analyzed. Knowledge Comprehensive knowledge of the anatomy and variations of the vertebrobasilar system provides an important basis for the diagnosis and treatment of neurological diseases. Vertebrobasilar disease accounts for 20% of all ischemic events. others. Anatomical variations of the vertebrobasilar system have important clinical implications, particularly in the context of interventional and surgical procedures, as well as in their diagnosis and management. Improved outcomes for these patients are associated with early detection (using magnetic resonance imaging or computed tomography) and early treatment to restore blood flow to the affected areas[27,28]. Several risk factors predispose patients to vertebrobasilar insufficiency (VBI), particularly those that exacerbate atherosclerosis, include: smoking, hypertension, age, sex, family history, genetic predisposition, hyperlipidemia, systemic hypercoagulable states, and patients with a history of coronary artery disease or peripheral artery disease. [29]. Circulation in the left vertebral artery may aberrantly arise from the aorta in 2.4–5.8% of patients due to a failed anastomosis between the sixth and seventh intersegmental arteries. Such variants have an increased incidence of vertebral artery dissection, cerebrovascular events, and iatrogenic injury during carotid artery procedures. [30,31] Asymmetry in VA size is common, and over 50% of individuals have a larger VA, but the left vertebral artery is larger in size and diameter and has a more irregular shape. In approximately 10% of cases, PICA arises from the extradural V3 segment rather than the intracranial V4 portion of the VA, most commonly in the non-dominant VA. Other VA aberrations include double or accessory arteries, fenestrations, twists, tortuosity, elongation, hypoplasia, and aplasia. [32,33] Although most VA abnormalities are asymptomatic, any changes along the course of the VA may increase the risk of occlusion, dissection, and even increase the risk of Alzheimer's disease [34,35,36]. Symptoms of IVB tend to be recurrent and brief, rarely resulting in cerebral infarction. For hemodynamic ischemia to occur, there must be occlusion in both vertebral arteries or within the basilar artery. There must also be an incomplete contribution from the carotid circulation via the posterior communicating artery to the circle of Willis. [37,38] Although vertebral artery injury is an uncommon complication of spinal cord injury, special care should be taken to avoid further damage to the SVB because such injury leads to permanent neurological damage or death in 10% of cases (during massive brain hemorrhages)[39,40]. Transient partial ischemia of the posterior circulation due to decreased blood flow to the VB is known as VB insufficiency and may be classified as a transient ischemic attack if symptoms resolve within 24 hours. Vertigo is often the only symptom of VB insufficiency, although patients may also develop diplopia or suffer from drop attacks (sudden falls without loss of consciousness).[41] Diagnostic evaluation of the VB system can be performed using several imaging modalities. Doppler ultrasonography was the initial technique used to assess the patency of extracranial segments of VAs, although it is unable to visualize the origin of VAs in some patients.[2] Currently, computed tomography or magnetic resonance angiography, and digital subtraction angiography (DSA) are the diagnostic modalities of choice in the evaluation of the vertebral and basilar arteries.[42,43] Hemodynamic changes from vascular variants may predispose to the formation of aneurysms within the VB system. Other vascular anomalies include arteriovenous malformations (AVMs), dural AV fistulas (DAVFs), and sometimes persistent primitive carotid-vertebrobasilar communications. Although microneurosurgery remains a gold standard in their management, other modalities such as radiotherapy and endovascular modalities also play a key role in the selection and planning of an accurate therapeutic algorithm in many of them.[44,45]

7. Conclusion

Overall, a deeper understanding of the anatomical variations of the SVB improves the prevention, diagnosis and treatment of cerebrovascular disorders and reduces the risks for patients; The development of new minimally invasive techniques in neurosurgery in the future will allow improved outcomes and prognosis in patients with vascular disorders. In conclusion, we can say that the anatomical variations of the SVB are not only anatomical curiosities, but are also key elements for the diagnosis and prevention of the vertebrobasilar system and its pathological disorders. Disorders in the circulation of the VB or interruption of blood flow can have catastrophic neurological consequences for people or patients. Anatomical variations in these vascular structures increase the incidence of thrombi and aneurysms in patients.Thus, a thorough understanding of the anatomy and clinical significance of the VB system is critical for the evaluation of neurological syndromes and preoperative neurosurgical planning. One of the most severe neurological manifestations, the lock-in syndrome, results from thrombosis of the proximal and middle portions of the BA, sparing the pontine tegmentum. The clinical manifestations of the lock-in syndrome include almost complete paralysis of all voluntary muscles except eye blinking and vertical eye movements, with preserved consciousness and cognitive function. On the other hand, distal BA embolism may present with superior basilar syndrome, resulting in ischemia of the upper brainstem and thalamus.

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