Vascular geometry of vertebrobasilar tree with and without aneurysm

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ABSTRACT

Aim To examine a possible relationship between the variable vascular geometry of vertebrobasilar joint angle and basilar bifurcation angle as well as the diameters of these blood vessels.

Methods The study included 60 adult patients, of both sexes, who were divided into two groups. One group (30) consisted of patients without aneurysm of vertebrobasilar tree, and another group (30) of patients with aneurysm. The patients were examined using Magnetic Resonance Imaging (MRI) and Computed Tomography Angiography (CTA) of head and neck.

Results In the group without aneurysm of vertebrobasilar tree, in 14 (46.6%) patients diameters of the right and the left vertebral artery were approximately the same. The average value of the angle of junctions of vertebral arteries was 65.43°, and the average angle of basilar bifurcation was around 94.53°. In the group with aneurysm of vertebrobasilar tree, in 12 (40%) patients diameters of the right and the left vertebral artery were also approximately the same. The average angle of junction of vertebral arteries was 68.46°, and the average angle of basilar bifurcation was 121.93°.

Conclusion Anatomic variations of the vertebrobasilar joint angle and basilar bifurcation angle, as well as the diameters of these blood vessels, are some of the factors in the increase of the incidence of aneurysm in this anatomic area.

Key words: vertebral artery, basilar artery, anatomy
INTRODUCTION

Vertebral artery, a branch of subclavia artery, passes among threads of brachial plexus in the neck region, and passing through the openings in the transverse processes of cervical vertebrae comes to the vertebral artery sulcus at the posterior arch of the atlas (1). It enters the cranial cavity through the foramen magnum of the occipital bone, connects at a sharp angle with the opposite one, usually under the post-pontine groove (67%), and forms a basilar artery (2). After a short course (25-35 mm), at the anterior part of the pons, the artery splits into its two terminal posterior cerebral arteries (3,4). Basilar artery may take a straight course (9.6%), be wrapped into the shape of the letter “S” (34.6%) or can take the arched course (55.8%) (5).

Basilar artery bifurcation angle ranges from 35°-175° (6). The mean diameter of the vertebral artery was 3.4 mm on the left and 2.9 mm on the right. The diameter of the basilar artery varied from 3-7 mm (mean of 4.3 mm) (3,7).

Cerebral aneurysm is an abnormal widening of the blood vessels in the brain. At the base of the brain there is a tangle of arteries that make up the so-called Circle of Willis, which is, in all its segments, subject to the anatomical variations (8) and which the arteries that supply the brain branch from. Bifurcations of these arteries are the most common places where aneurysms (9) arise. Cerebral aneurysm may occur due to a number of different factors (inheritance, polycystic kidney disease, infection, trauma, neoplasm, etc.). The most common type of brain aneurysm is saccular (berry) aneurysm in, in 85 to 95% of cases. The most frequent localization is the circulus arteriosus of Willis, more precisely, its anterior segment (85%). In their research in 2008, Bor et al. presented the hypothesis that the predilective place for the formation of aneurysm are bifurcation regions of large arteries with a sharp angle of bifurcation, and the reason is, they assumed, complex hemodynamic relationship in the blood vessels with subsequent development of atherosclerosis and weakening of the artery wall (10).

Atherosclerosis is a result of mutual and very complex interactions of blood, hemodynamic characteristics of the blood flow and geometric characteristics of the blood vessels, three entities known as Virchow’s Triad (11,12). Many studies have shown a high incidence of atherosclerotic lesions in the arterial bifurcation region (13,14). Variations of the vertebrobasilar joint angle and basilar bifurcation angle, as well as the diameters of these blood vessels most likely affect the condition of the blood vessel walls. Surgical approaches to this area are considered risky due to the presence of various important blood vessels and neural structures (4). The CT and MR angiographies allow a precise and detailed evaluation of vertebrobasilar circulation (15).

The aim of this paper is to examine a possible relationship between the variable vascular geometry of vertebrobasilar junctions and the angle of basilar bifurcation and subsequent aneurysm formation. Suggestions about the potential possibility of an aneurysm in the vascular area of vertebrobasilar joint angle as a result of specific vascular geometry, may help neurologists and neurosurgeons.

PATIENTS AND METHODS

The retrospective study included 60 consecutive adult patients, both sexes, treated at the Clinical University Centre of Tuzla during the period of four years, from 2008 to 2012. Data were gathered from institutional IMPAX Archive. Permission was obtained from the Ethics Committee of the Clinical Centre, University of Tuzla (02-09/2-112/12).

Patients were divided into two groups. One group consisted of 30 patients without aneurysm of the vertebrobasilar tree, which is formed of intracranial parts of the vertebral arteries (VAs), the basilar artery (BA) and their branches, and another group of 30 patients with aneurysm. Patients were observed using Magnetic Resonance Imaging (MRI) or Computed Tomography Angiography (CTA) of head and neck. In all patients the presence of joint angle of vertebral arteries (arteriavertebralis sinistra and arteriavertebralis dextra) was found and the basilar artery bifurcation angle, and the diameters of vertebral artery, basilar artery and posterior cerebral artery (0.5 cm below and above the vertebrobasilar joint, and 0.5 cm below and above the basilar bifurcation). We used CT and MRI software to rotate the angles and recorded the highest value we have measured in order to get the value of three-dimensional angles.
The statistical analysis of the collected data used descriptive statistics (determination of average values, standard deviations and standard errors), the correlation matrix, i.e. the test of the correlation between the measured values in which the correlation coefficient with statistical significance of $p<0.05$ was used, and the Student’s T-test to determine the significance of differences between the arithmetic average values.

RESULTS

In this study, in the group of patients without aneurysm, basilar arteries took the following courses: arched course in 14 (46.6%), “S”-shaped course in 7 (23.3%) and straight in 9 (30%) patients. In the group of patients with aneurysm, artery basilaris took these courses: arched course in 13 (43.33%), “S”-shaped in 6 (20%) and straight in 11 (36.66%) patients.

In patients without aneurysm of the vertebrobasilar tree in the joint area of right and left vertebral arteries with the basilar artery, the average diameter of the right vertebral artery was 2.43 mm and the average diameter of the left vertebral artery was 2.83 mm. Diameters of the right and left vertebral arteries were approximately the same in 14 (46.6%) patients. Caudal part of the basilar artery in the vertebral artery joint area had an average diameter of 3.8 mm, and the rostral part, in the area of bifurcation, 3.43 mm. The initial part of the right posterior cerebral artery had an average diameter of 2.5 mm, while the initial part of the left posterior cerebral artery had an average diameter of 2.46 mm. The bifurcation angle of vertebral arteries averaged at 65.43º, and the average angle of the basilar artery bifurcation was 94.53º (maximal angle 166º, minimal angle 84º).

In patients without aneurysm of the vertebrobasilar tree, the measured diameter values for right vertebral arteries showed statistically significant positive correlation with measured diameter values of the posterior cerebral arteries on the same side ($r=0.37$).

Statistically significant positive correlation was also shown by diameter values of vertebral artery and posterior cerebral artery on the left side ($r=0.44$). In the same group of patients, the basilar artery rostral part diameter values (in the bifurcation area) showed a statistically significant positive correlation with the values of diameters.

In the patients with aneurysm of the vertebrobasilar tree, in the joint area of both vertebral arteries with the basilar artery, the average diameter of the right vertebral artery was 3.61 mm and the left vertebral artery 3.94 mm. Diameters of the right and left vertebral arteries were approximately the same, in 12 (40%) patients ($r=0.563$). Caudal part of the basilar artery, in the vertebral artery joint area, had an average diameter of 5.08 mm, and the rostral part, in the area of bifurcation 4.57 mm. The initial part of the right posterior cerebral artery had an average diameter of 2.62 mm, while the initial part of the left posterior cerebral artery had an average diameter of 2.52 mm. The bifurcation angle of vertebral arteries averaged at 68.46º, and the average angle of the basilar artery bifurcation was 121.93º (maximal angle 166º, minimal angle 84º).

In patients without aneurysm of the vertebrobasilar tree, the measured diameter values for right vertebral arteries showed statistically significant positive correlation with measured diameter values of the posterior cerebral arteries on the same side ($r=0.37$).
of the left posterior cerebral arteries (r=0.38). Also, in this group of subjects, the basilar artery rostral part diameter values (in the bifurcation area) showed a statistically significant positive correlation with the values of diameters of the right posterior cerebral arteries (r=0.48). The biggest correlation factor in this group of patients was between the diameter values of the basilar artery at the caudal and rostral end and it was (r=0.69). In the group of patients with the aneurysm in vertebrobasilar tree, values of the measured diameters of all blood vessels that build the tree were interacting in a positive statistical correlation (r=0.56) between the diameters of the left and right vertebral artery, and the highest correlation factor (r=0.93) between the diameters of the caudal and rostral parts of the basilar arteries. The angle values of the vertebral into basilar artery junction, as well as the bifurcation angles of the basilar arteries were not in the statistically positive correlation either in the group of patients without an aneurysm or in the group of patients with aneurysm in the vertebrobasilar tree area. Average diameter values of the vertebral artery at the junction into the basilar artery, were significantly higher in patients with aneurysm in the vertebrobasilar tree area than in the group without an aneurysm (p=0.000008 on the right side and p=0.000351 on the left side). Average values of joint angles of vertebral arteries in the group of patients with aneurysm were not statistically significantly different from the average values of the joint angles of vertebral arteries in the group of patients without aneurysm of the vertebrobasilar tree area.

Average diameter values of the basilar arteries at the caudal and rostral part were statistically significantly higher in patients with aneurysm than in the group of patients without aneurysm in the vertebrobasilar tree area (p=0.000105 at the caudal part, p=0.000300 at the rostral part). Average diameter values of posterior cerebral arteries in the group of patients with aneurysm in the vertebrobasilar tree area, were not statistically significantly different from the average values of the diameters of posterior cerebral arteries in the group of patients without aneurysm. Basilar artery bifurcation angles are on average statistically significantly higher in the group of patients with aneurysm than in the group without aneurysm in the vertebrobasilar tree area (p=0.000215).

**DISCUSSION**

Anatomic variations of the vertebrobasilar joint angle and basilar bifurcation angle, as well as the diameters of these blood vessels, can be a factor in the increase of the incidence of aneurysm in this anatomic area (16). The intracranial vascular anatomical variations, although rare, represent an interesting field of research, since many anomalous variants are possible and in most cases they remain asymptomatic (17). In the population, in general, basilar arteries can have three different anatomic courses: arched course, the “S”-shaped course and straight course (1).

The results of our research did not demonstrate a significant difference between the percentages of the courses taken by the basilar arteries in patients with (43.33%, 20% and 36.66%, respectively) and without aneurysm (46.66%, 23.33% and 30%, respectively). Our results do not quite match the results found in a Japanese study (5), where the percentages of the courses were 55.8%, 34.6% and 9.6%, respectively.

The angle of bifurcation of the basilar artery, in this study, ranged from 84° – 166° with an average of 121.93° in patients with basilar artery aneurysm, or 46° – 174° with an average of 94.53° in patients without aneurysm. Zurada et al. showed similar values, where the average angle of bifurcation of the basilar artery was 117.7°, with the angles ranging from 30.93°–172.2° (18). In other study (6) average angle of bifurcation of the basilar artery was 107°, ranging from 35°–175°.

The results of our study have shown that the average value of the basilar artery bifurcation angles was significantly higher (121.93°) in patients with aneurysm, which was generally placed on the bifurcation, than in patients without aneurysm (94.53°) of the vertebrobasilar tree. This result was opposite to the result of another study suggesting arterial bifurcation region with a sharp angle of bifurcation as predilective place for aneurysm (12). The angle of the basilar artery bifurcation is thought to influence the risk of the development and rupture of aneurysms in this anatomic place (19).

In our study, the diameter of the right vertebral artery varied from 2–4 mm and left from 1–4 mm in patients without aneurysm, whereas in patients with aneurysm it was 2–7.6 mm, and 2–8.1 mm,
respectively. The diameter of the basilar artery at the caudal part varied from 3 – 5mm, and at the rostral part 2 – 4 mm in patients without aneurysm, and in patients with aneurysm it varied from 2.8 - 9.9 mm and from 2.3 - 8.7 mm respectively. According to the results of other studies (20), the right and left vertebral arteries had different diameters in almost 60% of the patients.

Nishijima et al. have reported the average maximum and minimum exterior diameter of the basilar artery of 3.93 +/- 0.76 mm and 3.14 /- .58 mm, which is slightly different from the values in our study, especially for diameters in patients with aneurysm of the vertebrobasilar tree (5).

The average values of the measured parameters of the vertebrobasilar tree vascular geometry showed statistically significant differences and higher values in the group of patients with aneurysm compared to those without aneurysm, in all of the measured values, except for the diameters of posterior cerebral arteries and vertebral arteries joint angles. This means that the diameters of vertebral arteries at joining the basilar artery, as well as the basilar artery diameters at both ends, and the basilar artery bifurcation angles, are on average statistically significantly higher in patients with aneurysm. These results confirm the hypothesis of the potential role of vascular geometry and its variations as one of the factors of the aneurysm of the vertebrobasilar tree.

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**COMPETING INTERESTS**

None to declare.

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SAŽETAK

Cilj Ispitati moguće varijacije vertebro-bazilarne geometrije, te utvrditi eventualnu vezanost varijabilne vaskularne geometrije uglavnom vertebro-bazilarne arterija i ugla basilarne bifurkacije, kao i dijametre ovih krvnih sudova.

Metode Istraživanje je obuhvatio 60 konsekvatnih pacijenata, odraslih osoba, oba pola, koji su bili podijeljeni u dvije grupe. Jednu grupu (30) sačinjavali su pacijenti bez aneurizme bazilarne arterije, a drugu grupu (30) pacijenti s aneurizmom. Pacijenti su obrađeni metodom magnetne rezonancije i kompjuterizovane tomografske angiografije u sklopu pregleda vrata.

Rezultati U grupi ispitanika bez aneurizme vertebro-bazilarne arterije, kod 14 (46,6%) ispitanika dijametri desne i lijeve arterije vertebralis bili su približno isti. Ugao spoja vertebro-bazilarne arterije bio je u prosjeku 65,43°, a prosječan ugao bifurkacije arterije basilaris bio je 94,53°. U grupi ispitanika sa aneurizmom vertebro-bazilarne arterije, kod 14 (46,6%) ispitanika dijametri desne i lijeve arterije vertebralis, iste su bili približno isti. Ugao spoja vertebro-bazilarne arterije iznosio je u prosjeku 68,46°, a prosječan ugao bifurkacije arterije basilaris 121,93°.

Zaključak Varijacije uga vertebro-bazilarne arterije i ugla basilarne bifurkacije, kao i dijametri ovih krvnih sudova, jedan su od faktora u nastanku aneurizme ovog područja.

Ključne riječi: arterija vertebralis, arterija basilaris, anatomija