FOLIA MEDICA CRACOVIENSIA
Vol. LX, 3, 2020: 75–84
PL ISSN 0015-5616
DOI: 10.24425/fmc.2020.135797

Coexistence of posterior cerebral circulation anatomical variations and basilar artery aneurysms: Case-control study

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Abstract: Background: The anatomy of arteries supplying blood to the brain often varies among the population. It applies particularly to posterior cerebral circulation. The impact of its anatomy variabilities on the formation of intracranial aneurysms has not been determined yet. The aim was to find out if posterior cerebral circulation anatomy variations coexist with basilar artery aneurysms (BAAs). We retrospectively analyzed 27 patients with BAA and a group of 30 patients matched by gender and age but without BAA. In both groups together most (66.67%) of patients were female and the average age was 59.75 ± 10.91. All of the patients had Computed Tomography performed. We assessed the occurrence of BAA, basilar artery (BA) diameter, vertebral artery (VA) diameter, posterior cerebral artery (PCA) diameter, and if patients had hypoplastic VA or PCA.
Results: The presence of right VA hypoplasia significantly increased the risk of BAA occurrence (48.15% vs. 16.67%; p = 0.011). The occurrence of hypoplastic VA on either side was significantly associated with the risk of BAA formation (59.26% vs. 26.67%; p = 0.013). Patients with BAA had slightly larger left PCA diameter 1cm after division (1.96 ± 0.51 vs. 1.64 ± 0.42; p = 0.014) in comparison to those without BAA. Additionally, hypoplastic right PCA occurred more often in patients with BAA (22.22% vs. 0%; p = 0.022).
Conclusions: We can conclude that the anatomy of PCA and VA affects the occurrence of BAA. Hypoplastic VA, the presence of wider left PCA and hypoplastic right PCA may be factors that coexist with BAA occurrence.

Keywords: anatomical variations, aneurysm, basilar artery, cerebrovascular disease, posterior circulation.

Submitted: 08-Aug-2020; **Accepted in the final form:** 27-Nov-2020; **Published:** 30-Nov-2020.

Introduction

The anatomy of arteries supplying the brain, especially in the posterior area, is very inconstant in the population [1]. Both, right and left vertebral arteries (VA) are equal in only 25% of cases, while the left one is dominant in 65% of cases [2, 3]. Such inconstancy also applies to the presence of hypoplastic vessels in the posterior circulation of the brain. What is more, VA is a vessel that often appears to be hypoplastic. Vertebral artery hypoplasia (VAH) has been mentioned for the first time in the 19th century [4, 5]. There are many definitions of VAH, but this phenomenon is most commonly described in the literature as a VA with a diameter of less than 2–3 mm in the entire course, or with an asymmetry ratio equal or greater than 1:1.7 (Fig. 1) [6–9].

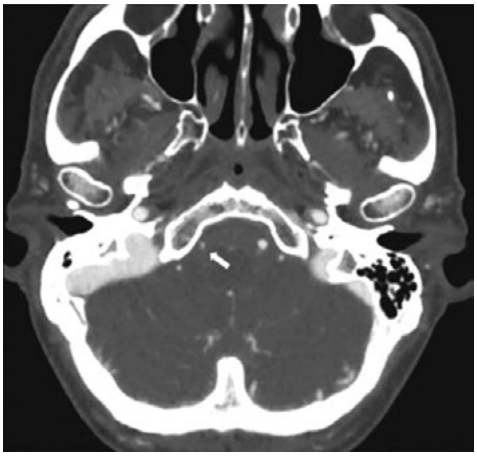

Fig. 1. 2D Axial Computed Tomography image presenting right VAH (indicated with an arrow). VAH — vertebral artery hypoplasia.

Depending on the criteria used, its prevalence in the population varies between 2% and 26% [10]. What is more, VAH has been associated with a higher incidence of stroke, VA dissection and VA aneurysms (Fig. 2) [10, 11]. Furthermore, VAH has been reported to predispose to migraine with aura and vestibular neuronitis [9, 12].

Posterior cerebral artery (PCA) diameter has been reported to vary as well. PCA variations and anomalies have several clinical implications, including the effect on clinical signs of a stroke [13]. The correlation of the presence of cerebral aneurysms and differences in PCA diameter has been reported [14]. The hypoplastic PCA is commonly defined as PCA of fetal origin. In embryonic life PCA is a branch of the internal carotid artery (ICA). As the brain develops, it starts to receive blood from the vertebrobasilar system and in adults PCA becomes a branch of the basilar artery. In

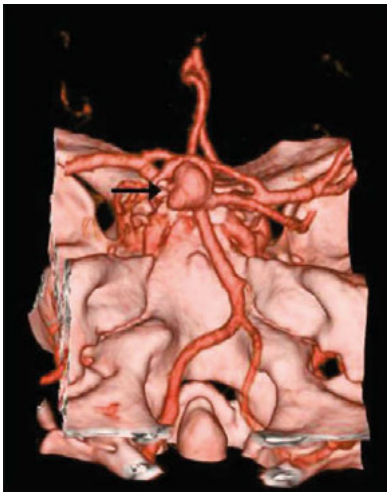

Fig. 2. 3D Computed Tomography image presenting basilar artery aneurysm with coexisting VAH (indicated with an arrow). VAH — vertebral artery hypoplasia.

some cases, blood flow from the ICA is still dominant and PCA becomes hypoplastic as a result [15]. This variant may predispose to ischemic episodes [16].

Basilar artery aneurysms (BAAs) and PCA aneurysms may constitute up to 30% of intracranial aneurysms [17]. Basilar tip aneurysms can press the midbrain, pons, or third oculomotor nerve, which may lead to limb paresis or eye movement disorders [18]. These aneurysms are clinically dangerous, because when ruptured, they can cause severe subarachnoid hemorrhage (SAH), which mortality can reach up to 50% [19]. VAH correlation with BAA occurrence is still undefined.

The aim of this study was to assess if hypoplastic variants of cerebral arteries diameter correlate with the presence of BAA.

Materials and Methods

Study group

In this retrospective, single-center study we analyzed patients with single BAA hospitalized in The University Hospital in Cracow, between 2015 and 2018. 27 patients met the study inclusion criteria. Patients included into the study group had never had any invasive head surgeries or interventions. We excluded patients with radiological data of low quality or any registered movements which influenced Computed Tomography (CT) image. The control group was matched for age and gender. It included 30 patients that had CT imaging performed for causes different than BAA, at the same period of time and in the same medical center.

An appropriate control group was found with a successful gender and age match for the BAA group (p-value for differences in gender and age >0.05). In both groups together most (66.67%) patients were female and the average age was 59.75 ± 10.91 (Table 1).

Table 1. Differences between patients with and without BAA. BAA — basilar artery aneurysm, SD — standard deviation.

	BAA present	Control group	p-value
Age ± SD	59.89 ± 10.50	59.63 ± 11.44	0.931
Female sex [%]	62.97%	63.33%	0.977

Computed Tomography Angiography Method and Image Evaluation

CT angiography was performed using a 64-row computed tomography scanner (GE Optima CT 660; GE Healthcare, Chicago, IL, USA). A volume of 70 ml of a nonionic contrast agent iomeprol (Iomeron 350; 350 mg iodine/mL; Bracco Imaging, Milan, Italy) was injected. After the bolus reached the common carotid artery at a level of C3-C4, the scanning procedure was started automatically. The imaged region ranged from the aortopulmonary window to the cranial vertex. The scanner setting was: 120 kV, 200 mA, 64 × 0.625-mm slice collimation. Axial 0.625-mm slices at an increment of 1.25 mm were reconstructed with a matrix of 512 × 512, applying a standard kernel.

Data was analyzed on a dedicated workstation (Advantage Workstation AW4.5; GE Healthcare, Chicago, IL, USA) equipped with software for 3D volume-rendering post-processing of images. All scans were reconstructed using a setting of volume-rendering opacity of 45 to 300 HU and evaluated visually.

Measurements

All measurements were performed in CT angiography 2D images. The following parameters were assessed: diameters of basilar artery (BA) (1 cm before division into PCAs), VAs (1 cm before the formation of BA), and PCAs (1 cm after branching from BA) (Fig. 3). PCA's and VA's diameters were recorded separately for both sides in every patient. We also assessed if patients had hypoplastic VA or PCA. VA hypoplasia was defined as a diameter less than 2 mm in the entire visible course of an artery. PCA hypoplasia was defined as a diameter less than 1 mm in the entire course of an artery. Radiological data was collected by two researchers and the mean was calculated out of their measurements.

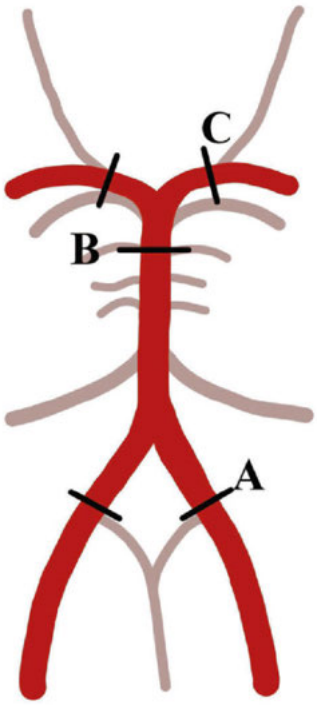

Fig. 3. Scheme of posterior arterial brain circulation with measured diameters. A — place of vertebral artery diameter measurement, B — place of basilar artery diameter measurement, C — place of posterior cerebral artery diameter measurement.

Statistical analysis

Statistical analysis was performed with Statistica 12.5 software (StatSoft Inc., Tulsa, OK, USA). Statistical significance was set at p-value <0.05. Pearson's chi-square test was applied to categorical variables, while independent two-sample t-Student's test and Mann–Whitney U were applied to continuous variables.

Results

Statistical analysis revealed that the right VA hypoplasia presence significantly increased the risk of BAA occurrence (48.15% vs. 16.67%; p = 0.011). Other sided VA hypoplasia did not show similar, statistically significant differences (14.81% vs. 13.33%; p >0.05).

The occurrence of hypoplastic VA on either side was evaluated and statistical analysis showed that it was significantly associated with BAA formation risk (59.26% vs. 26.67%; p = 0.013).

Differences in left and right diameters of VA in patients with and without BAA did not reach statistical significance (left: 2.40 ± 0.78 vs. 2.19 ± 0.54; p >0.05, right: 1.93 ± 0.77 vs. 1.89 ± 0.56; p >0.05).

Patients with BAA had slightly larger diameter of left PCA 1 cm after division (1.96 ± 0.51 vs. 1.64 ± 0.42; p = 0.014) in comparison to those without BAA. What is more, hypoplastic right PCA was found to occur more often in patients with BAA (22.22% vs. 0%; p = 0.022), in opposite to hypoplastic left PCA that was present more often in patients without BAA (3.70% vs. 6.67%; p >0.05), but it was not statistically significant.

The presence of hypoplastic PCA on either side was estimated and dissimilarity between the groups was observed. Patients with BAA had at least one hypoplastic PCA more often than patients without BAA (22.22% vs. 6.67%; p = 0.191), but the statistical significance level was low.

Diameters of all measured arteries are present in Table 2.

Table 2. Comparison of posterior circulation measurements in patients with and without BAA. BA — basilar artery, BAA — basilar artery aneurysm, diam — diameter, PCA — posterior cerebral artery, VA — vertebral artery, SD — standard deviation.

	BAA Present	Control Group	p-value
BA 1 cm prior to division (diam; mm) ± SD	2.79 ± 0.56	2.66 ± 0.47	>0.05
Left PCA 1cm after division (diam; mm) ± SD	1.96 ± 0.51	1.64 ± 0.42	<0.05 (0.014)
Right PCA 1cm after division (diam; mm) ± SD	1.80 ± 0.61	1.64 ± 0.30	>0.05
Left VA prior to connection (diam; mm) ± SD	2.40 ± 0.78	2.19 ± 0.54	>0.05
Right VA prior to connection (diam; mm) ± SD	1.93 ± 0.77	1.89 ± 0.56	>0.05
Left hypoplastic VA (percent)	14.81	13.33	>0.05
Right hypoplastic VA (percent)	48.15	16.67	<0.05 (0.011)

At least one hypoplastic VA (percent)	59.26	26.67	<0.05 (0.013)
Left hypoplastic PCA (percent)	3.70	6.67	>0.05
Right hypoplastic PCA (percent)	22.22	0.0	<0.05 (0.022)
At least one hypoplastic PCA (percent)	22.22	6.67	>0.05

Discussion

Studies regarding the prevalence of VAH present inconstant values. For example, Kulyk *et al.* [10] research showed that VAH was present in 19.7% of patients with ischemic stroke, while another study found VAH in 15.1% of cases of patients with a suspected stroke [20]. When it comes to patients with posterior circulation aneurysms, VAH was reported to be present in 52% of cases [11]. In our study, the prevalence rate of VAH equals 59.3% in patients with BAA. This small, but yet present disparity may be a result of differences in measurement techniques (VAH can be diagnosed using CT angiography, duplex ultrasonography, magnetic resonance angiography or autopsy), distinct sample size, and characteristics of studied groups. The main problem in comparison of our study to other VAH studies is that there is no universal VAH definition and there has not been any established gold standard method to diagnose such anomaly. In our research, we defined VAH as it is defined in most of the recent studies [10, 11, 20].

In our study, right-sided VAH was found to be more frequent than a left-sided one. Thierfelder *et al.* [20] and Park *et al.* [21] studies also reported such correlation. Researchers suggested an explanation in VA's anatomy and its origin from the left subclavian artery (LSCA). LSCA derives directly from the aortic arch, which may lead to increased wall shear stress (WSS) in VA during its development. High WSS may result in the domination of left VA over the right VA and in more frequent right-sided occurrence of VAH [22].

In our study, the diameter of PCA in both groups was smaller than it was measured in previous studies which may be a result of different measurement methods [23]. A study by Diogo *et al.* [24] exposed the opposite result to our research. Their research associated the absence of fetal-type PCA with an increased risk of basilar tip aneurysms. Such disparity in the results proves that posterior cerebral circulation hemodynamics requires more research to provide data associated with the impact of its defects on vascular disorders.

Our study revealed that the presence of the right hypoplastic VA significantly increases the risk of BAA appearance. Although our research is the first to expose such a result, VAH was reported to elevate the risk of basilar artery stenosis when accompanied by posterior cerebral circulation stroke [10]. Stenosis of the aforementioned artery may influence the risk of its intracranial aneurysms. Zhan *et al.* [25] stated that in the intracranial artery stenosis patients, the possibility of the occurrence of the aneurysm is much higher than in the general population.

Study limitations

Digital subtraction angiography (DSA) is the gold standard for intracranial vascular imaging, but in our study, we used CT angiography as it is faster, less invasive, and more available. The retrospective type of study and small size of group means that our findings require further validation by larger follow-up studies. Despite our limitation, this is the first study that shows the association between VAH and BAA. Our study is also one of only a few ones that covers influence of diameter of PCA on BAA.

Conclusions

We found out that the anatomy of PCA and VA affects the occurrence of BAA. Hypoplastic VA, presence of wider left PCA and hypoplastic (fetal-type) right PCA may be factors that coexist with BAA occurrence. Our findings suggest that hemodynamics of posterior cerebral circulation is very prone to any vascular abnormalities as they appear to increase the risk of aneurysm formation on BA.

Acknowlegdements, Funding and Disclosures

A.U., J.P. and P.B. were responsible for study idea. M.C. with J.P. collected data and created database. M.F., K.C., P.G. and J.P. were responsible for data analysis and its interpretation. M.C., K.C. and M.F. wrote manuscript. M.C. and M.F. prepared visual data and final article draft. All authors read and approved final manuscript.

Funding — none.

Conflict of interest — none declared.

Abbreviations

BA — basilar artery
BAA — basilar artery aneurysm
DSA — digital subtraction angiography
ICA — internal carotid artery
PCA — posterior cerebral artery

SAH — subarachnoid hemorrhage
VA — vertebral artery
VAH — vertebral artery hypoplasia
WSS — wall shear stress

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