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Research article

VERTEBROBASILAR VARIANTS AND THEIR BASIC CLINICAL IMPLICATIONS

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ABSTRACT

Objectives: Cerebrovascular diseases are the leading illness affecting the modern world with a high mortality rate. The posterior circulation of the brain consists of vertebrobasilar system, shows a high incidence of anomalies in the form of hypoplasia, fenestrations and asymmetry of the vessels, which precipitate the development of vertebrobasilar insufficiency and posterior circulation stroke. A detailed knowledge of the vertebrobasilar variants is essential in the diagnosis, treatment as well as in educating the patients suffered from posterior circulation stroke. The present study is aimed to analyze the size, asymmetry and anomalies of the vertebrobasilar system and their implications in posterior circulation infarcts. Materials and methods: Fifty adult brains were studied during routine dissection of the cadavers. The base of the brain with intact vertebral, basilar and posterior cerebral arteries were dissected, preserved in 10% formalin and analyzed for the variations in the size, length and asymmetry in the configuration. The dimensions of the vessels were measured using graduated calipers. Results: Anomalies of the basilar artery were found in 14% of the brains, in the form of hypoplasia, fenestration and terminal expansion at its bifurcation. The vertebral arteries showed asymmetry with right vertebral were hypoplastic in majority of the brains. Conclusions: The variations of the vertebrobasilar system increase the risk of vertebrobasilar insufficiency and posterior circulation stroke. Anomalies of the vertebrobasilar arteries were also found to be associated with aneurysms. The right vertebral artery has been frequently hypoplastic and there was no consistent correlation between the left vertebral dominance and right handedness of the person. Hypoplastic vessels were frequently associated with vertebrobasilar territory ischemic stroke.

Keywords: Hypoplasia, Fenestration, Dolichoectasia, Asymmetry, Dimensions, Infarction.

INTRODUCTION

Cerebrovascular disorders are one of the leading ailments affecting the modern mankind with high incidence of mortality rate; with high levels of disabilities among those who survive cerebrovascular accidents[1]. Vertebrobasilar system constitutes the posterior circulation of the brain, supplies brainstem, cerebellum and occipital lobes of the cerebrum, shows a high incidence of anomalies. Anomalies of the vertebrobasilar system may precipitate the

development of cerebrovascular diseases viz., stroke and aneurysms. Variations in the form of hypoplasia and duplications are often prevalent. Asymmetry of vertebral arteries is quite common, but the amount of blood reaches the basilar artery remains constant due to the contra lateral large vertebral artery[2]. Vertebral artery hypoplasia or asymmetry is frequently associated with posterior circulation stroke (PCS) [3, 4]. The basic knowledge of vertebrobasilar variants is essential in diagnosis, treatment as well as in educating and training the patients suffered from posterior circulation stroke. In the cases of occlusion of an internal carotid artery, the principal source of blood supply is through the vertebrobasilar system, but the size and patency of these arteries are quite variable. The vertebral asymmetry can cause insufficiency in the posterior circulation, which results in vertebrobasilar ischemia. Asymmetrical vertebral arteries are also considered to be one of the risk factors for pontine infarction. Various types of anomalies exist in different populations, but the anomalies of the vertebrobasilar complex in Indian population have been reported only by few authors previously, based on cadaveric analysis. So the objective of the present study is to analyze the size, asymmetry and anomalies of the vertebrobasilar system and their implications in posterior circulation infarcts. The surgical importance lies in its application during the exposure of the vertebrobasilar territory and a thorough knowledge of the vascular variants will increase the success of the procedure. The inference obtained from this work is also useful for the sonologists in improving their diagnostic skills and for anatomists in enhancing their knowledge in teaching.

MATERIALS AND METHODS

Fifty adult brains were studied from the regular dissection hall cadavers over a period of Jan 2008-2013. The cadavers were obtained by following the procedures in accordance with the ethical standards of experimentation. The bases of the brain including the brain stem with intact vertebral, basilar and posterior cerebral arteries were fixed in 10% formalin for 10 days. The intra cerebral portion of the vertebral, basilar and the proximal posterior cerebral arteries were dissected carefully under water, dried and painted with fevicryl red colour. The sub-arachnoid portions of the vertebral and basilar arteries were then analyzed for the variations in the size, length and any asymmetry in the configuration. The dimensions of the component vessels were measured using graduated calipers (sensitivity: 0.1 mm). We focused on the basilar artery and the upper segment of the vertebral artery. The results obtained were recorded and tabulated.

OBSERVATIONS

Basilar artery: The basilar artery was normal in 43 circles (86%). Anomalies were found in 7 cases (14%). Progressive narrowing of the basilar artery was seen in two circles (4%) [Fig-1.A]. A cobra-hood like terminal expansion at its bifurcation was found in 4 circles (8%) [Fig-1.B]. Partial duplication of the basilar artery in the form of fenestration, in its proximal part was found in one circle (2%) [Fig-1.C]. In this circle the proximal segment of the basilar artery duplicated immediately into two unequal divisions. The larger division (thickness 2.8 mm) occupied the basilar sulcus, while the smaller one (thickness 1.6mm) deviated slightly to the right and ran forwards for a short distance, and then joined the main division 6mm away from its origin. The rest of the basilar artery showed progressive narrowing. The vertebral arteries in this case were unequal in size. The origin of basilar artery was at the ponto-medullary junction in 35 circles (70%). In 13 circles it was 1 cm below ponto-medullary junction (upper medulla) and in 2 circles it was 1cm above the ponto-medullary junction. The basilar artery terminated opposite to the ponto-mesencephalic junction in 32 circles (64%). It bifurcated at the upper pons in 16 circles and in 2 circles at the

level of mammillary bodies. The length and diameter of the basilar artery was given in Table-1

Vertebral artery: Bilateral symmetrical vertebral arteries were encountered in 28 circles in this series (56%). Asymmetry was observed in 22 circles (44%). The left vessel was larger than the right in 14 circles and the right larger than the left in 8 circles. Hypoplastic vertebral arteries were seen in 5 brains (10%). The left vertebral artery was hypoplastic in 2 brains (4%) [Fig-1.D] and the right one was narrow in 3 brains (6%) [Fig-1.E]. The average diameter of the vertebral artery was given in Table-1.

Table: 1. Average dimension of vertebral and basilar arteries

Name of the vessel	Length (mm)		Diameter (mm)	
	Range	Average	Range	Average
Basilar artery	18-37	30	2.8-5.1	3.9
Vertebral artery	-	-	1.6-3.9	2.1

Table: 2. Average dimensions of basilar and vertebral arteries as reported in literature

Name of the author	Length of the basilar artery		Diameter of basilar artery		Diameter of vertebral artery	
	Range (mm)	Average (mm)	Range (mm)	Average (mm)	Range (mm)	Average (mm)
Pai et al[22]	24 - 35	24.9	3 - 7	4.3	3.4 (L) & 2.9 (R)	3.15
Idowu et al[19]	20 - 40	31.42	2.5 - 5.5	3.82	-	2.98
Present study	18 - 37	30	2.8 - 5.1	3.9	1.6 - 3.9	2.1

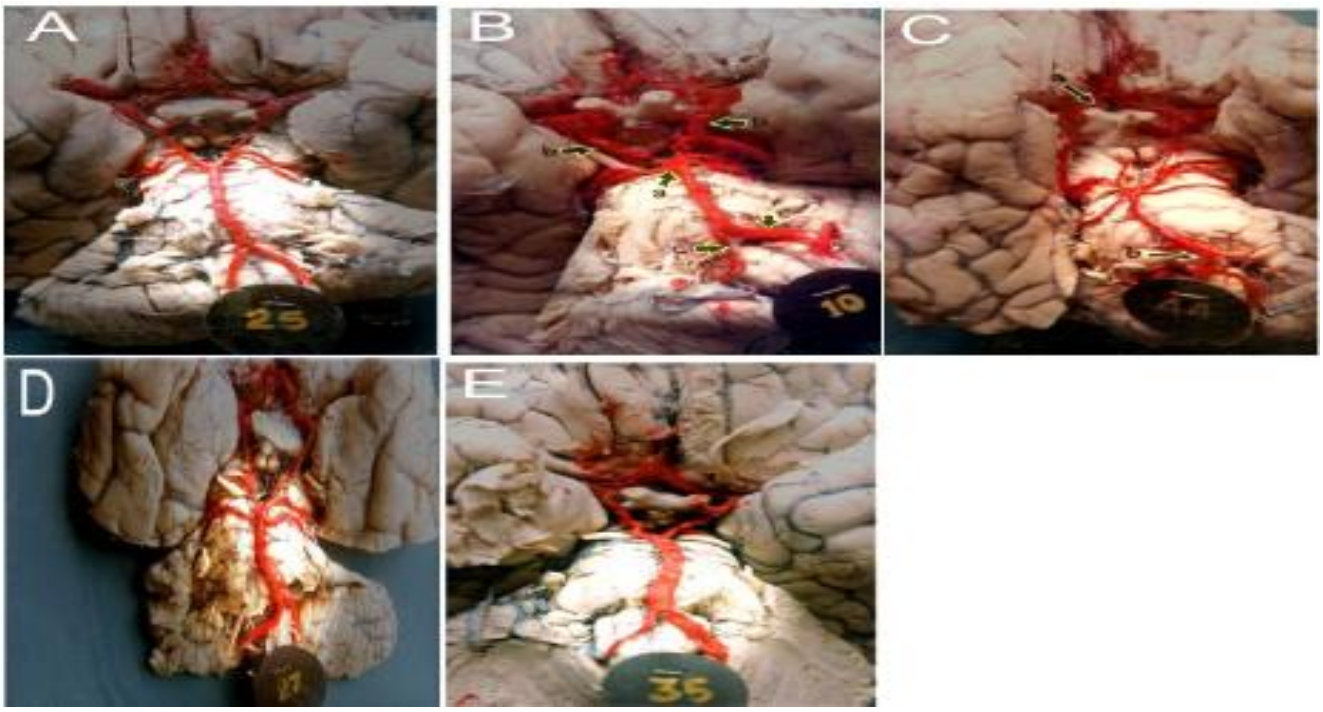

Fig.1: A-Progressive narrowing of (hypoplastic) basilar artery, **B**-Cobra-hood like terminal expansion of the basilar artery at its bifurcation, **C**-Partial duplication (Fenestration) of the basilar artery at its proximal portion, **D**-Hypoplastic left vertebral artery & **E**-Hypoplastic right vertebral artery.

DISCUSSION

In the present study 86% of the brains displayed a normal basilar artery with a uniform diameter throughout its length. Anomalies of the basilar artery were rare and include duplication or fenestration, rarely hypoplasia, segmental aplasia and plexiform channels[5]. An unusual anomaly in the form of a fenestration in the proximal part of basilar artery was noted in 2% of the brains. The proximal portion of the vessel was divided into two unequal divisions. The larger division (2.8mm) lies in the basilar sulcus and the narrow smaller division (1.6mm) deviates slightly to right and then fuses with main division with a fenestration window of about 6mm. There was no associated aneurismal dilatation in these cases. The occurrence of this anomaly can be explained on the basis of embryological development. During the development of the intracranial arteries, two bilateral, longitudinal vascular channels differentiate along the ventral surface of the hind brain from a plexus fed by intersegmental and transitory pre-segmental branches of the dorsal aorta and its forward continuation. These longitudinal channels are later connected cranially with the terminal branches of the internal carotid arteries and caudally with the vertebral arteries through the first cervical intersegmental arteries. Fusion of these two longitudinal channels results in the formation of the basilar artery. The incomplete fusion of two longitudinal vascular channels in its proximal portion may result in the formation of this anomaly. This type of anomaly seemed to be reported rarely in the literature reviewed. Dodevski et al[6] reported two cases of fenestrations of the basilar artery out of the 50 patients analyzed under computed tomography angiography (CTA), an incidence of 4%. The fenestration windows in these cases were 3.68 mm and 8 mm. There were no associated aneurysms in these cases. Sanders et al[7] in their retrospective review of 5190 cerebral angiograms, reported 37 patients with 38 fenestrated arteries viz., 16 basilar, 10 vertebral, 9 middle cerebral and 3 anterior cerebral arteries. The angiographic incidence of basilar artery fenestration was 0.3%. In 5 cases the fenestration was at the proximal basilar artery, in 7 cases in the mid basilar artery and in 4 cases in the distal part of the basilar artery.

Fenestration is the partial/complete duplication of a part of a vessel with or without a common adventitial layer. It appears in different forms, with a small mass of vascular tissue separating the two lumens to the actual duplication of a part of the affected vessel[7]. Fenestration of the basilar artery was most frequent, followed by vertebral and middle cerebral artery duplications[8]. The reported incidence of basilar artery fenestrations range from 0.02% to 0.6% in angiographic series, 2.0% on magnetic resonance angiography and from 1.3% up to 6.0% in autopsy studies. The reason for the wide range in the incidences can be explained by the fact that in some cases the duplication is not complete and in others it is not angiographically evident. The commonest site of basilar fenestration was in its proximal part close to the junction of the vertebral arteries. Basilar fenestration was commonly found associated with aneurysms. There were local defects in the medial walls of the duplicated segment at proximal end of the fenestration. The tunica media was deficient with discontinuity of the elastic fibers. These structural changes in the proximal end of the fenestration are similar to those seen in arterial bifurcations and were consistent with the causes of intracranial aneurysms[6].

Sanders et al[7] found a 7% incidence of aneurysm in basilar fenestration. In all intracranial fenestrations, the overall incidence of aneurysms at the fenestration site was 3%. A majority of aneurysms arises at the proximal junction of the fenestration. So in patients with vertebrobasilar aneurysms, the associated fenestrations should always be looked for. The basilar artery fenestrations may sometimes misinterpreted for dissecting aneurysms or thrombosis in patients with stroke leading to incorrect diagnosis and mismanagement[8]. Vertebrobasilar artery

fenestrations may also found to be associated with brain stem ischemia or infarctions. Collateral branches may arise from the limbs of the fenestrated vessels. These findings should be analyzed in detail and the fenestrations should be differentiated from aneurysm before surgery in order to prevent inadvertent clipping of a limb of the fenestration including these branches[6].

The cause of the basilar hypoplasia is still not known as other arterial abnormalities. Embryologically, the posterior circulation begins as two paired plexiform longitudinal neural arteries and they start to fuse to form the basilar artery at 5 weeks of gestation, while the trigeminal artery begins to involute[9.] The size of an artery depends on the area that ultimately irrigates and an artery becomes unnecessary during development if the area undergoes regression. Therefore basilar artery hypoplasia is believed to be the consequence of the persistent primitive trigeminal artery (PPTA)[10]. It has also been suggested that large posterior communicating artery, which was commonly seen in these cases, may show the persistent flow from carotid to vertebrobasilar circulation and this may cause vertebrobasilar hypoplasia. In addition, malformations, injuries that effect acting either in the perinatal period (such as basal meningitis, arteritis and arterial occlusion) or in the early childhood trauma, may impede the normal reproduction of the smooth muscle cells in the media from maintaining the capacity of the artery to grow with the brain, have been suggested in development of hypoplastic arteries[11]. When associated with persistent primitive trigeminal artery, basilar artery hypoplasia occurs commonly at proximal part of the vessel and usually associated with vertebral artery hypoplasia[12.]

Previous studies of stroke in young adults have not so far included hypoplastic cerebral vessels among the potential causes of cerebral ischemia. Chaturvedi et al[13] had suggested that hypoplastic basilar artery might be a predisposing factor for ischemic stroke and the mean age of all cases was 49.8 out of 4000 cases he has examined. Szdzuy and Lehmann[14] described angiographic findings of incomplete fusion of the distal part of the basilar artery associated with vertebral artery hypoplasia in two cases presented with symptoms of brain stem ischemia and termed this condition as distal hypoplasia. It was speculated that poor retrograde flow due to hypoplastic distal basilar artery might make easy occurrence of infarction. Demonstration of these hypoplastic narrowing is also of importance since atherosclerotic disease may also appear at an earlier age if the native vessel is hypoplastic and would become stenosed sooner than a large vessel[15.] Moreover, embolic occlusions tend to involve the distal basilar segment and usually result in fatal consequences. It has been recently concluded that magnetic resonance angiography (MRA) can demonstrate entire/partial hypoplasia of the basilar system. Moreover, the demonstration of these hypoplastic vessels may be clinically important, since it has been suggested that hypoplastic vertebrobasilar vessels should be considered among the potential causes of cerebral ischemia in young adults[13.] In reviewing the literature, symptomatic entire basilar artery hypoplasia has been described only in 13 cases by three previous reports[11, 13, 14.] Hypoplastic basilar arteries were encountered in 4% of circles in this series. We conclude that hypoplastic basilar arteries as a predisposing factor should always be investigated in posterior circulation stroke patients, and MRA as a non-invasive tool, should be considered in diagnosis of these basilar abnormalities.

Dolichoectasia is the dilated, elongated and tortuous vessels affecting vertebrobasilar systems. It is also known by other names such as megadolichoectasia, fusiform aneurysms or tortuous vertebrobasilar system. It may compress the cranial nerves, causes ischemia, subarachnoid hemorrhage (SAH) and sometimes obstructive hydrocephalus. On reviewing literature, the incidence of VBD was to be 4.4%, and it usually affects women. The basilar trunk was commonly involved (40%), followed by vertebral arteries. VBD is caused by either a congenital

vasculopathy of the tunica intima or hypertensive stress on the vessel wall deranging the collagen and elastin meshwork of the media and downgrades the vessel. Neurological symptoms manifest in 10% of the patients, in the form of ischemic stroke, temporary/permanent motor deficits, hydrocephalus, cerebellar dysfunction and brain stem compression, which may be mild to severe. The most frequent clinical picture is due to cranial nerve compression or brain stem ischemia or intracranial bleeding[16,17]. Tomoyuki Nishizaki et al[18] reviewed 23 patients with VBD and found seven cases (30%) of intracranial aneurysms. It was in the form of fusiform as well as multiple and giant aneurysms. Rupture of the dolichoectatic basilar artery is considered unlikely and rarely presented with cerebellar hemorrhage. In our studies we have found a cobra-hood like terminal expansion of the basilar artery at its bifurcation in 8% of the circles. Idowu et al[19] also observed that the diameter of the basilar artery was relatively constant throughout its course except for the widening at its terminal bifurcation. These terminal widenings/expansions were probably in the form of minor variants of the above mentioned dolichoectasia. And we are not sure about the antemortem history of these patients with regard to hypertension or any other congenital malformations of the vasculature to explain the above anomalies, since our specimens were randomly collected from the dissection hall cadavers.

The basilar artery terminates at the ponto-mesencephalic junction in 64% of the cases. In 32% of the brains the vessel bifurcated at the upper pons and in the remaining 4% of the cases, opposite to the mammillary bodies. Stopford[20] found that the basilar artery had bifurcated at the upper border of pons in 97.5% of the specimens and below this level, ie, at the upper pons in the remaining 2.5% of the cases. Sacki and Rhoton[21] have reported that the vessels had bifurcated opposite to the interpeduncular fossa in 88% of the specimens, at the upper pons in 10% of the brains and in the remaining 2% of the cases, the bifurcation has indented the mammillary bodies. Idowu et al[19] stated that the basilar artery extends from the lower to the upper border of the cisterna pontis in 98% of the brains; and early bifurcation at the mid pontine region in 2% of the cases. It terminates at the ponto-mesencephalic junction by running a straight course in 60% of the cases, convex to the right in 18% and convex to the left in 18% of the cases and forming a loop in 4% of the cases. The dimensions of the basilar artery were compared with that of other workers in Table-2. Our measurements were more or less coincides with that of other workers.

Asymmetrical vertebral arteries were commonly encountered and were found in 44% of the brains in this series. The left vertebral artery was larger in diameter than the right in 28% of the cases and the right vessel was larger in 16% of the brains. Cloud and Markus[23] concluded that the left VA was dominant in approximately 50%; the right in 25% and only in the remaining quarter of cases was the two vertebral arteries of similar caliber. Seydel[24] found that the vertebral arteries were asymmetrical in 39.79% of the specimens and further reported that the left vessels was larger than the right in 26.53% and the right vessels was larger in 13.26% of the cases. Stopford[20] gave the ratio of left to right vertebral arteries was 51:41 for diameter predominance and stated that it was equal on both sides in only 8% of the cases, out of the total 150 specimens they have examined. Gillilan[25] also stated without giving any figures, that the cranial vertebral arteries were frequently unequal in size, the right being more often smaller. Kirgis et al[26] have reported a case of congenitally small vertebral artery and a relatively large contra lateral vertebral artery and further added that the discrepancy in the caliber of the vertebral arteries was not uncommon and there was no consistent correlation between the asymmetry of these arteries and the asymmetry of the circle of Willis. So from the present observation as well as from the findings of others, it is inferred that the cranial vertebral arteries are usually unequal in size, the left vessel is generally larger than the right. There was no

clear cut reason for the existence of this asymmetry. But the development of this asymmetry was related to vascular requirements of the brain. Numerous authors had investigated the correlation between the dominance of the left vertebral artery and right handedness and vice versa. But there is no definite evidence to correlate the vertebral dominance and handedness. So based on the findings of the present study and also from others' observations, it is inferred that there seems to be a possibility of a greater flow on the left side in the cranial vertebral arteries and there is no consistent relation between the asymmetry of these arteries and the asymmetry of the circle of Willis.

Hypoplasia of vertebral artery (HVA) is not rare in normal population, but is more frequent in patients with posterior circulation stroke (PCS). Congenital variations in the size of the vertebral arteries were frequently encountered ranging from asymmetry to severe hypoplasia of one vertebral artery. In reviewing the literature most of the workers agreed, that the external diameter of 2mm or less was considered to be hypoplastic[15]. Other workers with the help of the colour duplex ultrasonography defined the HVA with flow volume less than 30-40 ml/min in the vertebral artery. The absence of uniform description of HVA is due to the lack of studies on the healthy individuals, smaller size of sample groups and inadequate sonographic findings to support HVAs. In the more recent observations using colour coded ultrasonographic studies, a diameter of less than 2.2mm was considered hypoplastic, which was mainly based on hemodynamic changes and supported by ipsilateral flow resistance, contralateral diameter and flow volume[27.] In our study we fixed that the external diameter of less than 2mm was considered hypoplastic. On reviewing the literature, we found that about 1.9% to 35.2% of the brains have unilateral HVA and makes little contribution to basilar artery flow. It is also worthwhile to mention that in all the above works the right vertebral artery was more hypoplastic than the left vessel. Hypoplastic vertebral artery was found in 10% of the total 50 brains analyzed in our study. Hypoplasia was commonly observed on the right side (6%), which was consistent with findings of other workers.

Chaturvedi et al[13] suggested that a hypoplastic vertebrobasilar system was considered to be a predisposing factor in the posterior circulation ischemia. Ipsilateral hypoplasia of vertebral artery was more frequent in patients with lateral medullary syndrome and concluded that HVA conferred an increased probability of ischemic stroke[3.] In the studies conducted by other workers, HVA was significantly more frequent in posterior territory ischemic stroke compared with healthy subjects or patients with anterior circulation stroke[3, 4, 28]. Chuang et al[28] examined 191 acute ischemic stroke patients in the age group 55.8 ± 14.0 years, with the help of the magnetic resonance angiogram (MRA) and duplex ultrasonography and confirmed the overall increase in the incidence of a unilateral congenital HVA in the cases of brainstem / cerebellar infarction. They also postulate that hypoplastic VA might cause a decrease in the net flow volume which conditions the development of ischemic stroke in posterior cerebral circulation. In addition, HVA with additional risk factors such as hypertension, hyperlipidemia, diabetes and smoking was also reported to contribute to ischemic brainstem stroke, even in young patients[29.]

Watanabe et al[30] correlated asymmetry of vertebral artery and pontine infarction in Japanese population and concluded that patients with small diametric VA of the right side significantly had infarctions in the same side of the pons and suggest that VA asymmetry is considered to be one of the risk factors of pontine infarction and that MRA can be useful in the examination of the cerebral artery as a valuable and non-invasive screening method. The average diameters of the vertebral artery were compared with the values of other authors in Table 2.

The end results of the anomalies of the vertebrobasilar system in this study was not a

true reflection of the general population in the frequency of the vertebrobasilar anomalies, because our data were limited to only 50 adult cadaveric brains without any neurological diseases. In addition our sample group was so small and Indian origin, it may also limit generalizations of these anomalies based on our study results. The inference of this study will inform neurosurgeons, sonologists and patients about the potentially vulnerable vertebrobasilar circulation and further autopsy, angiographic, and magnetic resonance imaging analysis were needed to augment these clinical implications.

CONCLUSION

Cerebrovascular diseases are one of the leading problems in modern medicine with high incidence of mortality rate. The vertebrobasilar system which supplies one fourth of the brain shows a high incidence of variations in the form of hypoplasia, fenestrations and asymmetrical configuration. These variations increase the risk of vertebrobasilar ischemia and posterior circulation stroke. Our study was conducted to analyze the size, asymmetry and anomalies of the vertebrobasilar system, using fifty adult cadaveric brains. The common variations encountered were hypoplasia of vertebrobasilar arteries, fenestrations of basilar artery and asymmetrical vertebral arteries. The role of these anomalies was discussed in causing the posterior circulation stroke. The left vertebral artery was significantly larger in diameter than the right and there seems to be more blood flow on the left side than on the right half of the brain and there was no consistent correlation between the vertebral dominance and handedness. Hypoplastic vertebral artery was frequently common in the normal population and there was a high incidence of its association with vertebrobasilar territory ischemic stroke.

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ABBREVATIONS

CT: Computerized tomography, CTA: Computed tomography angiography, MRA: Magnetic resonance angiography, PPTA: Persistent primitive trigeminal artery, MRI: Magnetic resonance imaging, VBD: Vertebrobasilar dolichoectasia, VA: Vertebral artery, HVA: Hypoplasia of vertebral artery, SAH: Subarachnoid hemorrhage

Conflict of Interest: Nil

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