A cadaveric study of variations in the vertebrobasilar system

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Received: 18th June, 2018 **Accepted:** 12th July, 2018

Abstract
Introduction: The intracranial part of vertebral artery, basilar artery, and their branches together form the veretebrobasilar system. Identification of anomalies or variations in the vertebrobasilar system can be useful in diagnosing associated aneurysms, and in preventing complications during endovascular treatment.
Materials and Methods: The study was conducted in 60 randomly selected brain specimens obtained from the cadavers used for dissection by the undergraduate medical students in the department of anatomy. The length of the basilar artery, variations in its course, level of formation and termination were noted. The variations in the caliber of right and left vertebral arteries and their symmetry were noted. Photographs were taken to document the variations. The results obtained were then tabulated.
Results: In the present study variations in the origin of basilar artery was noted in 25% of specimens. Other variations like fenestration and button hole formation was also noted. Asymmetry of vertebral arteries were present in 14% of specimens. Hypoplasia of vertebral artery was also noted.
Conclusion: Knowledge of variations in the vertebrobasilar system is helpful for the neurosurgeons to plan and execute surgeries for treatment of stenosis, aneurysms, and arteriovenous malformations in the posterior cranial fossa.

Keywords: Vertebrobasilar system, Variations, Hypoplasia, Asymmetry, Posterior circulation, Vertebrobasilar ischemia.

Introduction
The intracranial part of vertebral artery, basilar artery, and their branches together form the veretebrobasilar system. The vertebrobasilar system, also known as posterior circulation is an important vascular network that supplies blood to the posterior part of the cerebral hemispheres including occipital lobes and posterior portion of temporal lobes, cerebellum and brainstem. The vertebral arteries of both sides unite to form a basilar artery, a large median vessel, at the pontomedullary junction. It runs over the ventral surface of pons in a shallow median groove and terminates at the upper border of pons by dividing into right and left posterior cerebral arteries, which pass ventral to the respective oculomotor nerves.[1]

Anomalies and variations in the vertebrobasilar system has been reported in the previous studies. Normal morphology of the basilar artery is an essential component of cerebral circulation since the hindrance of blood supply due to any cause, even for a short duration (7-8 minutes) would cause severe and irreversible damage to brain cells. Anatomical variations in the morphology of the basilar artery is thought to be an aetiological factor for many clinicopathological conditions such as atherosclerosis, infarcts, arteriovenous malformations, transient ischemic attacks, and certain syndromes including wallenberg's syndrome, medial medullary syndrome and weber's syndrome.[2]

Fenestrations in the vertebrobasilar system is a factor which increases the incidence of aneurysms in this region. Ten percent of saccular aneurysms are located at the posterior circulation.[3]

Asymmetry of vertebral arteries are quite common, but the amount of blood reaching the basilar artery remains constant due to contralateral large vertebral artery.[4] The hypoplasia / asymmetry of vertebral arteries are frequently associated with posterior circulation stroke. Identification of anomalies or variations in the vertebrobasilar system can be useful in diagnosing associated aneurysms, and in preventing complications during endovascular treatment.[5,6]

The aim of the present study is to find out variations in the origin and termination of basilar artery as well as variations in the size, shape and position of both intracranial part of vertebral and basilar arteries.

Materials and Methods
The study was conducted in 60 randomly selected brain specimens obtained from the cadavers used for dissection by the undergraduate medical students in the department of anatomy. Those specimens with gross pathological lesions of the brain were excluded. The specimens were then numbered and fixed in 10% formalin for 10 days in the department of anatomy. The arachnoid mater was removed carefully. The basilar and vertebral arteries were dissected. The specimens were then dried and the vessels were painted using wet eosin pencil. The external diameter of the arteries were measured using a graduated calipers to record hypoplasia of the vessels (external diameter <2mm). The length of the basilar artery, variations in its course, level of formation and termination were noted. The variations in the caliber of right and left vertebral arteries and their symmetry were noted. Photographs

were taken to document the variations. The results obtained were then tabulated.

Results and Discussion

Basilar Artery: Basilar artery is a large median vessel formed by the union of right and left vertebral arteries at the pontomedullary junction. It runs along the median sulcus in the cisterna pontis over the ventral surface of pons and on reaching the ponto mesencephalic junction bifurcates into right and left posterior cerebral arteries. (Fig. 1)

The diameter of the basilar artery varied from 2-8mm with a mean of 4.6mm. The length of the basilar artery varied from 25mm–45mm with a mean of 30.3mm. In no specimens hypoplasia or aplasia was noted. The variations in the level of origin and terminal bifurcation of basilar artery were looked for in all the 60 specimens. It was noted that origin was at the pontomedullary junction in 45 specimens (75%) (Fig. 1); above the pontomedullary junction in 7 specimens (11.7%) (Fig. 2) and below the ponto medullary junction in 8 specimens (13.3%) (Fig. 3) and in no specimens hypoplasia or aplasia or complete duplication of the basilar artery was noted. In one specimen, a button hole formation was seen in the artery close to its origin (Fig. 2). In another specimen, a partial duplication of the artery was noted immediately after its formation at the pontomedullary junction (Fig. 5). The termination of basilar artery was noted at the pontomesencephalic junction in 53 circles (88.3%) (Fig. 1) and at the mammillary bodies in 7 circles (11.7%) (Fig. 4). Variations in the course of basilar artery was also noted. There are 3 types of courses of basilar artery reported in the literature- bent / curved course, straight & 'S' shaped course. In the present study the straight and curved course were noted. The curved course was noted in 26 specimens (43.3%) (Fig. 3). In no specimen 'S' shaped course was found.

Vertebral Artery: The vertebral artery enters the cranial cavity through the foramen magnum, close to the anterolateral aspect of the medulla. They converge medially as they ascend the medulla and unite to form the midline basilar artery at the pontomedullary junction. It could be dissected out intact only in 50 specimens. Out of this, the arteries were found to be symmetrical in 43 specimens (86%) (Fig. 1) and asymmetrical in 7 specimens (14%) (Fig. 6) among the asymmetrical arteries, the right vertebral artery was found to be larger than the left in 4 specimens (8%) and left vertebral artery was found to larger than the right in 3 specimens (6%). Hypoplasia of the vertebral artery was observed in one specimen on the left side (Fig. 6). No non union or fenestration or absence of vertebral artery was noted.

Table 1: Comparison study of level of formation of basilar artery

Author (Year)	Origin		
	PM Jn	**Above PM Jn**	**Below PM Jn**
Wojtowicz et al (1989)[21]	44.4%	15.1%	40.4%
Akar et al (1994)[22]	36.4%	54.5%	9.1%
Shongur et al (2008)[3]	20%	12%	67%
Padmavathi et al (2011)[2]	44.4%	16.7%	38.9%
Wankhede et al (2014)[17]	62.50%	29%	12.50%
Kushwaha et al (2017)[19]	38.46%	38.46%	23.07%
Present study	75%	11.7%	13.3%

Table 2: Comparison study of level of termination of basilar artery

Author (Year)	Termination		
	Ponto mesencephalic Jn	**Mammillary body**	**Upper pons**
Wojtowicz et al (1989)[21]	56%	32.9%	11.1%
Saeki et al (1977)	88%	2%	10%
Wankhede et al (2014)[17]	50%	32.50%	17.50%
Kushwaha et al (2017)[19]	53.84%	38.46%	7.69%
Present study	88.3%	11.7%	Nil

Table 3: Comparison study of course of basilar artery

Authors (year)	Straight course	Curved course	'S' shaped course
Pai et al (2007)[18]	48%	52%	nil
Mehinovic et al (2014)[24]	30%	46.6%	23.3%
Wankhede et al (2014)[17]	55%	37.5%	5%
present study	56.7%	43.3%	nil

Table 4: Variations of vertebral artery as observed by other workers

Author (Year)	Symmetrical	Asymmetrical	
		RT>LT	LT>RT
Stopford 1915)[25]	8%	41%	51%
Akar et al (1994)[22]	36.4%	45.4%	18.2%
Pai et al (2007)[18]	53.3%	40%	6.7%
Present study	86%	8%	6%

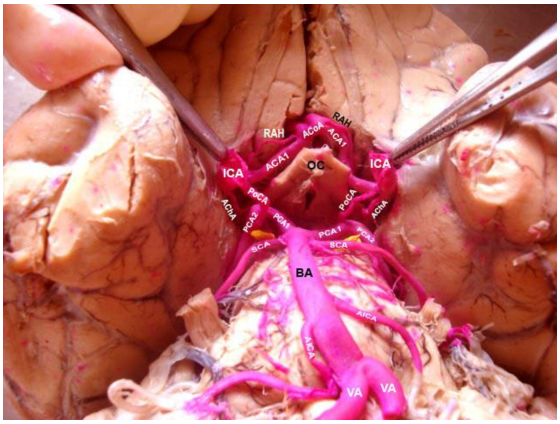

Fig. 1: Base of brain showing origin of basilar artery at pontomedullary junction and termination at pontomesencephalic junction. (BA – Basilar artery, VA-Vertebral artery, PCA1-Precommunicating segment of posterior cerebral artery, SCA-Superior cerebellar artery, AICA-Anterior imnferior cerebellar artery, PCA2-Postcommunicating segment of posterior cerebral artery, ICA -Internal carotid artery)

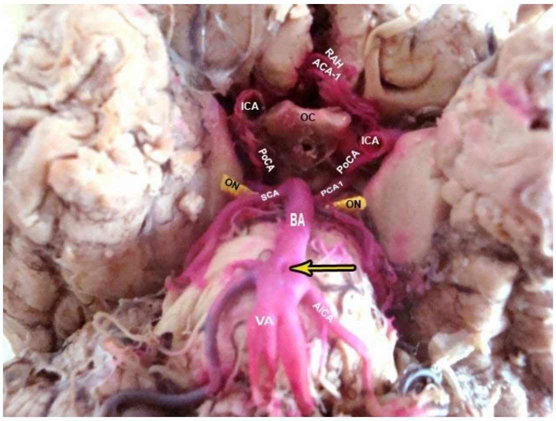

Fig. 2: Base of brain showing origin of basilar artery above the pontomedullary junction. Arrow is showing a button hole formation in the proximal part of basilar artery

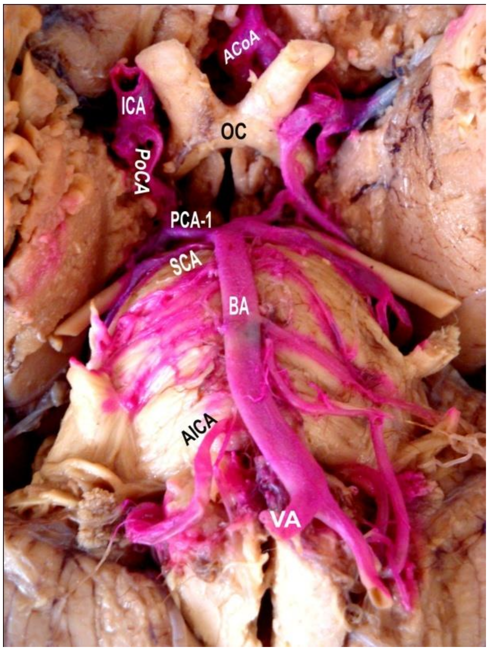

Fig. 3: Base of brain showing origin of basilar artery (BA) below the pontomedullary junction and a curved course of basilar artery

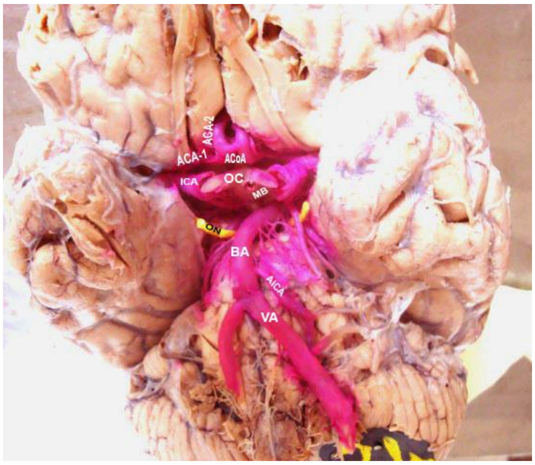

Fig. 4: Base of brain showing termination of basilar artery (BA) at mammillary bodies

Fig. 5: Base of brain showing a fenestration at the proximal part of basilar artery

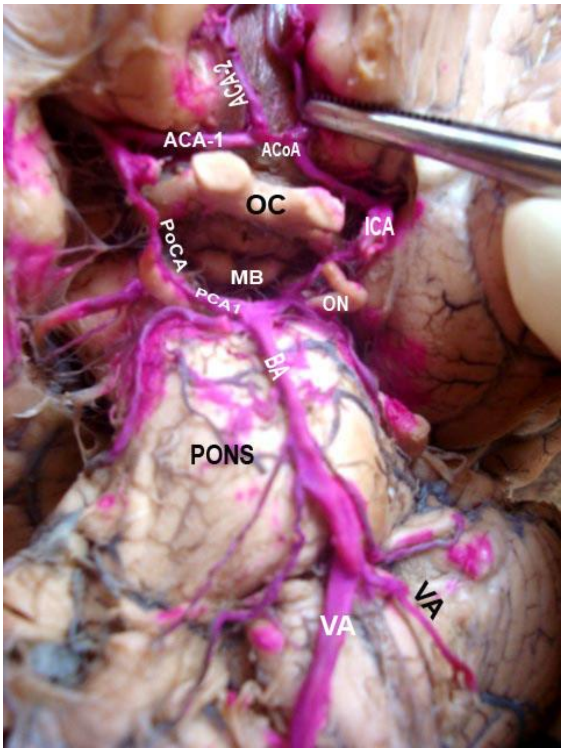

Fig. 6: Base of brain showing asymmetric vertebral arteries with hypoplastic vertebral artery (VA) on the left side

Discussion

Anomalies of basilar artery are rare and include most commonly duplication or fenestration and so rarely hypoplasia, segmental aplasia, plexiform appearance etc.[7] In the present study there was no basilar artery hypoplasia noted.

In the present study, basilar artery duplication was noted in 1 specimen in the lower half immediately after the union of vertebral arteries. The incidence of duplication / fenestration of basilar artery ranges from 1.3 to 5.26% in postmortem studies and from 0.022 to 0.6% in angiographic reports. It occurred most commonly in the lower half of the vessel.[8,9]

In 2002 Masanori Tsutsumushi et al reported a case of duplication of distal part of basilar artery.[10] Tran Dinh et al (1991) noted duplication of basilar artery at the union of two vertebral arteries and partial duplication in the upper portion of the artery.[11]

Complete duplication of basilar artery, with each vertebral artery continuing separately to form a posterior cerebral artery has been described previously by Adachi (1928)[12] and Yasargil (1982).[13] Ten percent of saccular aneurysms are located in the posterior circulation. Fenestration /duplication in the vertebrobasilar system is a factor which increases the incidence of aneurysms in this region. Anatomic hemodynamic changes at the proximal ends of fenestrations may cause intracranial saccular aneurysms.[14]

Basilar artery hypoplasia was not noted in the present study. Basilar artery is said to be hypoplastic if its diameter is less than 2mm. Hegedius (1985) opined that hypoplasia of the basilar artery is rarely encountered variation of the vertebrobasilar system and frequently accompanied by hypoplastic vertebral Artery. He demonstrated autopsy findings of 3 cases of entire basilar artery hypoplasia associated with vertebral artery hypoplasia in which two of the deceased had neurological symptoms characteristic of insufficiency in the vertebrobasilar system.[15]

According to Chathurvedi et al (1999) hypoplastic vertebrobasilar vessels should be considered among the potential causes of cerebral ischemia in young adults.[16]

The data on the length and diameter of the basilar artery is important for interventional radiologist to perform various endovascular procedures and also to the neurosurgeons to get proper approach to the surgery.[17] In the present study the diameter of the basilar artery varied from 2-8mm with a mean of 4.6mm and the length of the basilar artery varied from 25mm–45mm with a mean of 30.3mm. Pai et al (2007) reported that the diameter of basilar artery varied from 3-7mm (mean 4.3 mm) and the length varied from 24-35mm (mean 24.9mm).[18] Kushwaha et al (2017) reported that the length of basilar artery varied from 24 -40mm and the mean length was 29.72mm and an overall mean diameter of 4.3mm.[19] Idowu et al (2010) observed that the diameter of basilar artery was relatively constant throughout its course with few minor variations.[20]

Variation in the level of origin and termination of basilar artery has been noted by previous workers. In the present study, basilar artery most commonly arose at the pontomedullary junction (PM Jn) and terminated at the level of pontomesencephalic junction. Basilar artery arose above the pontomedullary junction (PM Jn) in 11.7% cases and below the junction in 13.3% cases. Its termination at the level of mammillary body in the interpeduncular fossa was observed in 11.7% cases.

The position of termination of basilar artery also determines the type of approach to be taken for the treatment of aneurysms of the basilar apex and those involving the posterior cerebral arteries, as efforts need to be made to minimize or prevent damage to nearby important structures such as the mammillary body or optic chiasma.[2]

Regarding the course of basilar artery, normally it has a straight course. Other than that a curved and an 'S' shaped course also has been reported in the previous literature. In the present study in 56.7% of specimens basilar artery had a straight course and in 43.3% of specimens it had a curved course. No 'S' shaped course was noted. In the present study, a button hole on the proximal part of basilar artery was observed in one case. Stopford (1915) and Blackburn (1907) reported cases with a small foramen immediately above the origin of basilar artery.[25,26]

Vertebral Artery: The vertebral arteries were observed for any asymmetry, hypoplasia and fenestration. The paired arteries are said to be asymmetric if one of them is twice the diameter of the opposite artery.

In the present study, vertebral arteries were symmetrical in 86% of cases and asymmetrical in 14% of cases. It was noted that the right vertebral artery is frequently larger than the left vertebral artery. Akar et al (1994) also observed right vertebral artery larger than the left.[22] Paksoy et al (2004),[27] Jeng et al (2004),[28] Kazui et al (1989)[29] reported that left vertebral artery was usually larger than the right vertebral artery.

It has been reported that unequal diameters of the Vertebral Arteries cause insufficiency in the vertebrobasilar circulation, which in turn results in vertebrobasilar ischemia. Asymmetry of the intracranial parts of vertebral arteries is common and vertebral artery asymmetry leads to basilar deviation.[27]

Congenital Vertebral artery hypoplasia is an uncommon embryonic variation of the posterior circulation. The frequency of the hypoplasia has been reported to range from 2% to 6% based on autopsy studies and angiograms.[28]

The definition of vertebral artery hypoplasia has not been precisely stated. Vertebral arteries less than 2mm diameter are accepted as hypoplastic in pathoanatomic studies. In ultrasonographic studies, frequency of hypoplasia was reported as 1.9% considering the vertebral artery diameter less than 2mm as hypoplastic and 6% in the cases that have a cut off value of 3mm diameter.[30]

In the present study, hypoplasia of vertebral artery was noted (<2mm) in 4% cases. It was not associated with the hypoplasia of basilar artery.

Park et al (2007) reported that hypoplastic vertebral artery is frequent in patients with posterior circulation stroke. People with hypoplastic vertebral artery may have a high probability of posterior circulation stroke, with atherosclerotic susceptibility and ipsilateral lesions in the vertebral artery territory.[5]

Uzmansel et al (2009) reported a case of hypoplastic left vertebral artery accompanying an aneurysm at the distal end of basilar artery.[30] Chuang et al (2006) reported that hypoplastic vertebral artery might cause a decrease in the net flow volume which conditions the development of ischemic stroke in posterior cerebral circulation.[31] In addition hypoplastic vertebral artery with additional risk factors such as hypertension, hyperlipidemia, diabetes, and smoking was also reported to contribute to ischemic brainstem stroke, even in young patients.[32]

Fenestration or non-unions of Vertebral Arteries were not observed in the present study. Stopford (1915)[25] and Tran Dinh et al (1991)[11] reported cases of Fenestrations of vertebral artery in their study.

Conclusion

In the present study the origin of basilar artery was observed in 13.3% of specimens below the pontomedullary junction and in 11.7% of the specimens above the pontomedullary junction. In no specimens hypoplasia or aplasia or complete duplication of the basilar artery was noted. In one specimen a button hole formation was seen in the basilar artery close to its origin. In another specimen a partial duplication of the artery was noted immediately after its formation at the pontomedullary junction. In 11.7% of cases the termination of basilar artery was noted at the mammillary bodies. The vertebral artery was noted to be asymmetrical in 14% of the specimens. Most commonly the right vertebral artery was larger than the left. The artery was observed to be hypoplastic in 4% of cases. Unequal diameters of the Vertebral Arteries cause insufficiency in the vertebrobasilar circulation, which in turn results in vertebrobasilar ischemia. Knowledge of variations in the vertebrobasilar system is helpful for the neurosurgeons to plan and execute surgeries for treatment of stenosis, aneurysms, and arteriovenous malformations in the posterior cranial fossa.

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How to cite this article: Narayanan S, Geetha GN. A cadaveric study of variations in the vertebrobasilar system. Indian J Clin Anat Physiol. 2018;5(4):553-558.