

Research Article

A Comparative Morphometric Analysis of the Arteries Forming the Circle of Willis in Human Cadaveric Brains.

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Article History

Received: 10.11.2022

Revised: 21.11.2022

Accepted: 02.12.2022

Published: 15.12.2022

Citations:

Bhavani Prasad, B., Bage, N., & Rema Devi, R. A comparative morphometric analysis of the arteries forming the Circle of Willis in human cadaveric brains. *J Surg Radiol*, 2022; *J*(4):16-21

Abstract: **Introduction:** The present work has been undertaken in view of great importance of vascular supply to the brain. The knowledge of occurrence of variations in origin, course, branching pattern at the base of brain has a significant in neurosurgery. The anomalies of arteries forming the circle of Willis are very essential in performing the surgical procedure in infancy, childhood and in adults. **Materials & Methods:** The study was conducted on 50 embalmed human brains obtained from cadavers. A digital caliper, graduated to measure up to 0.1 mm, was used for all measurements. Arteries with a diameter of less than 1 mm were considered abnormal, whereas communicating arteries with a diameter of less than 0.5 mm were classified as abnormal. The length and external diameter of arteries contributing to the formation of the Circle of Willis were recorded. The anterior and posterior cerebral arteries were measured from their points of origin to the point where they were joined by the respective communicating arteries, while the entire course of the communicating arteries was measured. The basilar artery was measured from its origin to its termination at the bifurcation into the posterior cerebral arteries. This is a Cross sectional Descriptive study. **Results:** The left posterior communicating cerebral artery was absent in one specimen. The mean length of the posterior communicating artery was found to be 12.18 mm on the right side and 10.52 mm on the left side. The mean diameter of the posterior communicating artery was 1.54 mm on the right side and 1.28 mm on the left side. The length of the basilar artery ranged from 20.3 mm to 48 mm, while the diameter ranged from 2.6 mm to 3.5 mm. **Conclusion:** The most frequent variation was seen in the posterior communicating artery. The left posterior cerebral communicating artery and anterior cerebral communicating arteries showed higher values of coefficient of variation. A significant inverse relationship observed between the diameters of the posterior cerebral and posterior communicating arteries

Keywords: Basilar artery, posterior cerebral communicating artery, circulation, morphology

INTRODUCTION

The Researchers agree that the most important collateral circulatory system of the brain is the Circle of Willis. It was described by Thomas Willis in the year 1664. In his book *Cerebri Anatome: Nervorum Descriptio Et Usus*, he has mentioned an arterial ring present at the base of the brain called *Circulus Arteriosus Cerebri Willisii* (1). It is formed by branches from the cerebral part of the internal carotid artery and the basilar artery. The studies of the Fallopius (1523-62), Casserius (1561 -1616) and Vesling (1598 -1649) are helped to provide the complete depiction of cerebral arterial circle with its anastomotic nature (2). This polygonal shaped anastomosis brings down the velocity of the blood before it reaches the brain and plays a vital role in collateral circulation. The arterial pulsations will also make an impact on cerebrospinal fluid drainage in the interpeduncular cistern (3). Most of the variations are developed congenitally and these are 50% of the total population. Many studies evolved that the development of cerebro vascular diseases are mainly characterised by these variations (4).

Anatomical variants do not directly impair brain perfusion. However, they may increase the risk of

neurological diseases through two main mechanisms. First, they can affect collateral circulation, which may lead to complications during vascular or neurological surgery and increase the risk of cerebral infarction, migraine, or even certain psychiatric disorders. Second, the imbalanced branching geometry seen in some variants can create abnormal wall shear stress, which is associated with the development and rupture of intracranial aneurysms. (5). A whole ring of arteries with bilateral symmetry is a classic picture at the base of the brain. This typical configuration may vary. The calibre of vessels varies widely. They are often hypoplastic, duplicated or nonexistent (6). The present study is an effort to gather substantial knowledge and information about the normal pattern of the circle of Willis and the frequency of variations of the circle of Willis and to study the morphometric aspects of all the components of the circle of Willis separately. The inferences obtained from this study are also useful to anatomists, radiologists, and neurologists in enhancing their knowledge in teaching and investigative procedures.

MATERIALS AND METHODS

A prospective observational study was conducted in the The study was done in the department of anatomy, NRI medical College, Mangalagiri, Andhra Pradesh. The study was started by undertaking the institutional ethical clearance. After it was continued at Pondicherry Institute of Medical Sciences, Pondicherry. The circle of willis was studied on 50 formalin-preserved brains of human cadavers. The cadaveric bodies from which brains removed were of unknown age and unknown cause of death. The approximate age was 40–60 years. The specimen obtained was washed with tap water and placed in a labeled container having 10% formalin solution. After fixation, the base of brain in each specimen was

cleaned and cerebral arterial Circle of Willis was identified. The arachnoid mater was removed from the arteries and areas around it. The circle of Willis was then analysed with special reference to the following factors - whether the circle is complete or incomplete, any asymmetry in the configuration and variations in the size, and number of the component vessels, and absence, duplication or triplication of any of the vessels. The Length and diameter of all the components forming the Circle of Willis were measured by using digital vernier calliper. The arteries with a diameter of less than 1 mm were considered abnormal where as the communicating arteries with a diameter of less than 0.5 mm were considered as abnormal. Morphological variations were well photographed.

RESULTS

The circle of willis was incomplete in one specimen where posterior communicating cerebral artery was absent. It was on the leftside. The posterior cerebral artery showed abnormal diameter on right side in the five specimens and one specimen on the leftside. The posterior cerebral communicating artery showed abnormal diameter predominantly on left side (6 specimens) than right side (1 specimen). The anterior cerebral artery showed one abnormal diameter variation on both sides. The long basilar artery was observed, where the formation of the basilar artery takes place at the lower end of the medulla oblongata. The anterior communicating arteries showed fenestration in two specimens. The double anterior communicating artery was noticed in two specimens.

Table1: the arteries with abnormal diameter observed in the present sample.

Name of the Artery	Right side	Left side	Total
Posterior cerebral artery	5	1	6
Posterior communicating cerebral artery	1	6	7
Anterior cerebral artery.	1	1	2

The morphometric average values of the posterior cerebral artery length was 5.38 ± 1.75 mm on right and 5.37 ± 1.46 mm on left and diameter of 2.03 ± 0.64 mm in right and 2.09 ± 0.52 on left. The posterior cerebral communicating artery average length was 12.18 ± 2.74 mm on right and 10.52 ± 2.44 mm on left and the diameter of the same vessel on the right was 1.54 ± 0.73 mm and on the left was 1.28 ± 0.57 mm. The average length of anterior cerebral artery on right side was 12.75 ± 2.29 mm and on leftside was 11.28 ± 1.41 mm. The average diameter of anterior cerebral artery on right side was 2.15 ± 0.43 mm and on left side was 2.22 ± 0.66 mm. The average length of anterior cerebral communicating artery was 2.20 ± 0.91 mm and the diameter was 1.15 ± 0.57 mm. The basilar artery length was 25.61 ± 4.86 mm and the diameter was 3.23 ± 0.23 mm.

Table 2: Average length and External Diameter of arteries of the sample

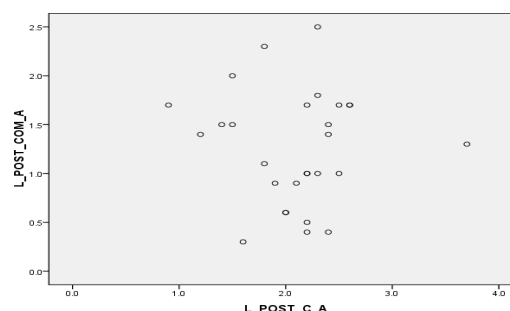
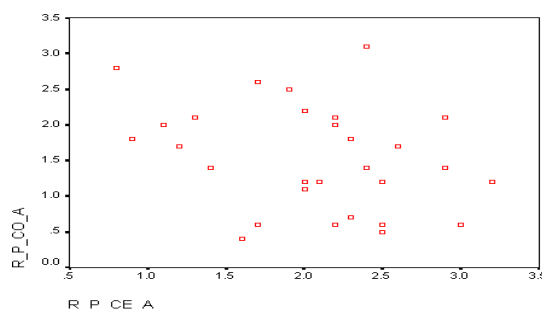
Name of the Artery	Length (in mm)		Diameter (in mm)	
	Right	Left	Right	Left
Posterior cerebral	5.38 ± 1.75	5.37 ± 1.46	2.03 ± 0.64	2.09 ± 0.52
Post. Cere. Communicating	12.18 ± 2.74	10.52 ± 2.44	1.54 ± 0.73	1.28 ± 0.57
Anterior cerebral	12.75 ± 2.29	11.28 ± 1.41	2.15 ± 0.43	2.22 ± 0.66
Anterior cere. Communicating	2.20 ± 0.91		1.15 ± 0.57	
Basilar Artery	25.61 ± 4.86		3.23 ± 0.23	

The greatest and smallest values of vessels forming circle of willis was observed. The left posterior cerebral communicating artery and anterior cerebral communicating arteries showed higher values of coefficient of variation(CoV).

Table 3: Greatest and smallest length and diameter values and Coefficient of Variation of dimensions of the arteries forming the circle of willis.

Name of the Artery	Length (in mm.)			Diameter (in mm.)		
	Greatest	Smallest	CoV	Greatest	Smallest	CoV
Right Posterior Cerebral artery	9.3	2.3	32.53	3.2	0.8	27.19
Left Posterior Cerebral artery	10.6	2.6	31.53	3.7	0.9	24.88
Right Posterior Commu.artery	20.2	8.2	22.5	3.1	0.4	23.19
Left Posterior Commu. artery	15.5	5.2	47.4	2.5	0.3	51.82
Right Anterior Cerebral artery	18.5	8.3	17.96	2.9	1	12.5
Left Anterior Cerebral artery	15.4	8.9	20	3.5	1	29.73
Anterior Cerebral Communi.artery	4	0.8	41.36	2.5	0.5	49.57
Basilar artery	48	20.3	18.98	3.5	2.6	7.12

The scattergram of the right and left posterior cerebral artery and posterior cerebral communicating artery was observed. An inverse relationship was observed between the diameters of the posterior cerebral and posterior communicating arteries of the same side. The results were subjected to statistical analysis and found to be highly significant. Right side $r = -0.306$, $P < 0.001$. Left side $r = -0.051$, $P < 0.001$.



DISCUSSION

The present study demonstrated a postoperative wound Alpers et al.,(7) Riggs and Rupp(8), Jain et al. (9), and Kapoor et al.(10) reported that hypoplasia of the arteries is the most common anomaly observed in the Circle of Willis. The findings of the present study are in agreement with these previous reports, as hypoplasia was also identified as the most frequent variation in the Circle of Willis.

Sande et al.(11) reported that about 80% of the examined specimens demonstrated a symmetrical configuration of the Circle of Willis, whereas 20% showed asymmetry. Their study also indicated that anatomical variations were more frequently observed in the posterior part of the circle compared to the anterior portion of the hexagonal arterial ring. Hypoplasia or complete absence of certain segments were commonly identified in the posterior circulation. In contrast, variations such as duplication and fenestration were more often found in the anterior segments of the Circle of Willis. The

observations in the present study are in agreement with the findings reported by Sande et al.

Saha et al.(12), Eftekhari et al.(13), and Ardakani et al(14). conducted studies on the posterior communicating artery and reported that variations were more frequently observed on the right side than on the left. Among the various anomalies, hypoplasia of the posterior communicating artery was found to be the most common variation. In the present study, hypoplasia of the posterior communicating artery was also observed as a common anomaly. However, in contrast to the findings of the above-mentioned authors, the variations in the present study were more frequently observed on the left side than on the right side.

Gunnal S.A. et al(15) reported that the mean length of the posterior communicating artery (PCoA) was 15.9 mm on the right side and 15.3 mm on the left side. They also observed that the mean diameter of the PCoA was 2.1 mm on the right side and 1.9 mm on the left side. In

the present study, the mean length of the posterior communicating artery was found to be 12.18 mm on the right side and 10.52 mm on the left side. The mean diameter of the posterior communicating artery was 1.54 mm on the right side and 1.28 mm on the left side. Thus, the measurements obtained in the present study are comparatively lower than those reported by Gunnal S.A. et al.

Pai et al.(16) reported that the length of the posterior communicating artery ranged from 8 mm to 18 mm on both sides. In the present study, the length of the posterior communicating artery was observed to range from 5.2 mm to 20.2 mm. Pai et al. also noted that in certain cases the P1 segment of the posterior cerebral artery was larger than the posterior communicating artery, while in other instances the posterior communicating artery was larger than the P1 segment of the posterior cerebral artery.

In the present study, an inverse relationship was observed between the diameters of the posterior cerebral artery and the posterior communicating artery on the same side. Statistical analysis revealed that this relationship was highly significant, with a correlation coefficient of $r = -0.306$ ($P < 0.001$) on the right side and $r = -0.051$ ($P < 0.001$) on the left side. This negative correlation indicates that when the diameter of the posterior communicating artery increases, the diameter of the P1 segment of the posterior cerebral artery tends to decrease, and vice versa. This finding supports the concept of compensatory variation within the posterior part of the Circle of Willis, which helps maintain adequate cerebral blood flow.

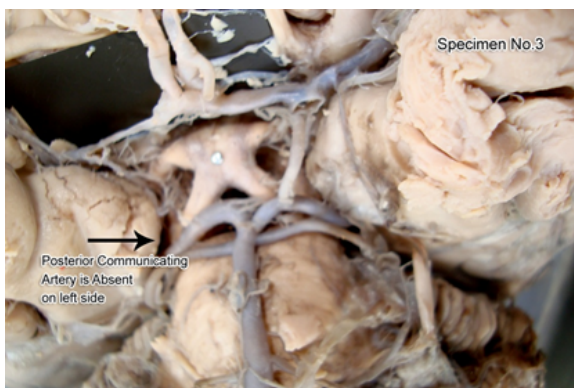
Sultana et al (17) , Kalaivanan (18), and Padmavathi et al (19) have reported that the basilar artery is formed at various sites, with the pontomedullary junction being the most common, followed by formation below the pontomedullary junction. Formation above the pontomedullary junction and at the lower end of the medulla oblongata was less frequently observed. In the present study, the majority of basilar arteries were also formed at the pontomedullary junction, consistent with

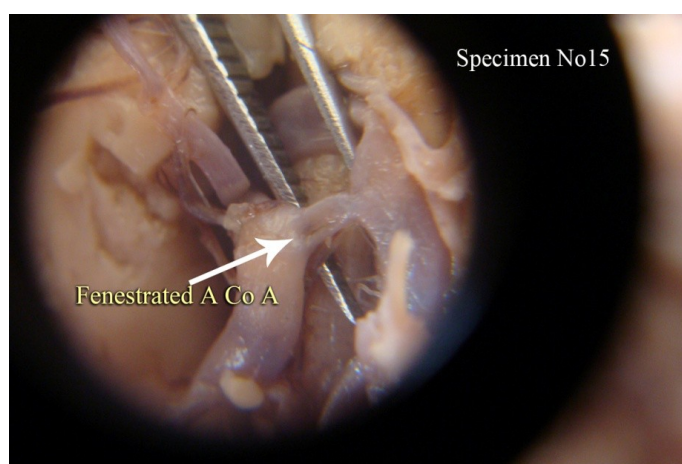
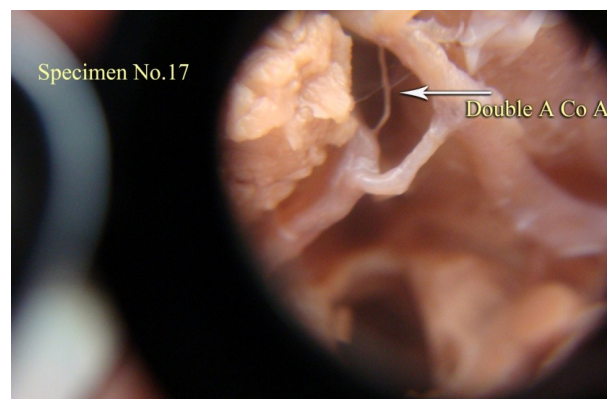
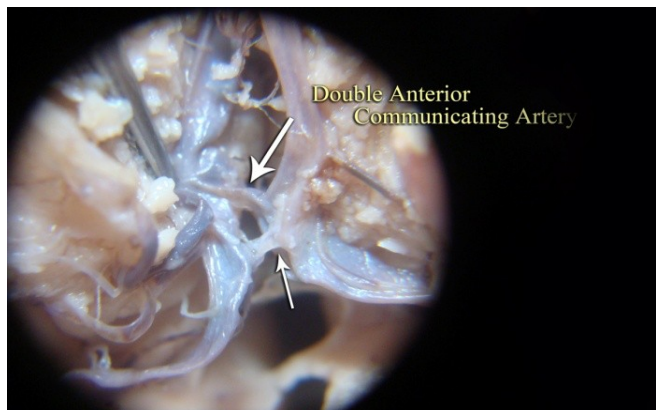
previous reports. However, in one specimen, the basilar artery was found to be formed below the lower end of the medulla oblongata, highlighting the anatomical variations that may occur in the site of basilar artery formation.

Patel et al (20) reported that the length of the basilar artery ranges from 20.1 mm to 42.02 mm, with a diameter between 2.02 mm and 4.45 mm. Vijaykumar et al (21) observed that the average length of the basilar artery was 31 mm, with an average diameter ranging from 3.6 mm to 3.9 mm. In the present study, the length of the basilar artery ranged from 20.3 mm to 48 mm, while the diameter ranged from 2.6 mm to 3.5 mm. The mean length and diameter in the current study were 25.61 mm and 3.23 mm, respectively. These findings are largely consistent with previous reports, although the present study observed a slightly greater maximum length and a marginally lower mean diameter compared to some earlier studies, reflecting the natural anatomical variability of the basilar artery.

Conclusion

One incomplete circle was observed i.e. due to absence of Posterior communicating artery. The double or fenestrated types of anterior communicating arteries were observed. Unilateral string or hypoplastic arteries are more common than bilateral. The coefficient of variation for the length and diameter was greatest for the posterior communicating artery, followed by the posterior cerebral artery. Abnormal narrow diameter observed in 15 arteries. The most frequent variation was seen in the posterior communicating artery. A significant inverse relationship observed between the diameters of the posterior cerebral and posterior communicating arteries.





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