ORIGINAL ARTICLE

Variations in Cerebral Arterial Circle of Willis in Adult Pakistani Population

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ABSTRACT

Objective: To identify the anatomical variations in cerebral arterial circle of Willis.

Study Design: Descriptive study.

Place and Duration of Study: Department of Anatomy, University of Health Sciences, Lahore, from February 2009 to January 2010.

Methodology: Human brains were removed from fifty-one consecutive cadavers at the time of autopsy from Forensic Department, King Edward Medical University, Lahore, to observe anatomical variations in the cerebral arterial circle regarding its completeness, pattern and symmetry. The individual cerebral vessels were also noted for the presence, origin, caliber and symmetry. Pictures from each dissection, showing the complete circle were taken. The variations of the circle as whole and segmental variations were studied and described in percentage.

Results: Thirty-seven (72.5%) of the 51 (100%) cerebral arterial circles were complete; 15 subjects (29.4%) had typical configuration; 25 (49%) had symmetrical arrangement and 39 subjects (76.4%) had different types of variations in their component vessels. Variations were most common in the posterior communicating artery followed by anterior communicating artery, pre-communicating segments of the posterior cerebral and pre-communicating segments of anterior cerebral arteries. No circle was found with aneurysm.

Conclusion: Different variations in the formation of circle of Willis and in its component vessels are common in the local adult population of Pakistan. These should be taken into consideration during angiographic evaluation and neurosurgical procedures on the anterior circulation.

Key Words: *Cerebral arterial circle. Typical configuration. Symmetry. Variations. Anterior circulation. Circle of Willis.*

INTRODUCTION

The circle of Willis is a polygonal structure of blood vessels present at the base of brain which distributes oxygen-rich arterial blood to the cerebral mass.[1] It was described by Thomas Willis (1621 – 1675) in his book Cerebri Anatome in 1664. The history of arterial circle of Willis goes back to Hetrophilus, who discovered a structure which he called as 'rete mirabile'; later on, Galen mentioned that the carotid arteries run in the neck and enter the cranium forming 'rete mirabile' (wonderful net), giving two cerebral arteries to supply the brain. Fallopius (1523 – 62) gave the first reasonably correct description of basal arterial ramifications except for the posterior communicating artery which he thought to be indirectly connected with the internal carotid artery through a network of small arteries. Casserius (1561 – 1616) corrected this mistake unilaterally.[2,3] Twenty years later, Vesling (1598 – 1649) illustrated a complete posterior communicating artery but failed to demonstrate an unequivocal union of anterior cerebral arteries. Thomas Willis, assisted by Richard Lower and Christopher Wren, acknowledging the previous studies, provided the first complete illustration of cerebral arterial circle with its anastomotic nature.[2,3]

Complete circle of Willis consists of pre-communicating segments of right and left anterior cerebral arteries, joined by the anterior communicating artery; posteriorly, pre-communicating segments of right and left posterior cerebral arteries which are connected to the corresponding internal carotid arteries by posterior communicating arteries. The pattern of cerebral arterial circle of Willis is considered typical if all the component vessels (pre-communicating segments of anterior and posterior cerebral arteries and anterior and posterior communicating arteries) are present; they are not duplicated or triplicated; origin of the contributing vessels is from its typical source and the external diameter is not less than 1 mm.[4]

In the present study, this cutoff for hypoplasia at < 1 mm was chosen based on earlier reports from autopsy studies; in flow models, it was observed that significant flow reduction occurred below this diameter.[5] The paired vessels were considered asymmetrical if the vessel on either side was absent or there was a difference of one third in their diameter since this equals a cross-sectional area reduction of > 50%.[6,7]

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Ideal distribution of blood to the brain depends largely on the morphology and the presence and size of the component vessels of circle of Willis. Many variations have been reported in arteries forming the circle in their formation, development and size.[8] Different abnormalities such as absence, split, hypoplastic and accessory vessels had been observed.[9-13] This arterial circle is essential for the maintenance of a stable and constant blood flow to the brain and any changes in its morphology may lead to the appearance of variable severity of different syndromes of vascular insufficiency.

The variation in the arterial circle, which is associated with alteration of blood flow to the brain, enhances the problem in the vascular diseases of the brain.[14,15] So identification of such variations in a specific population is important in the evaluation of cerebral vascular morbidity for adequate treatment.

The objective of this study was to find the variations in the anatomy of the arterial circle of Willis in the adult Pakistani population.

METHODOLOGY

Fifty one unclaimed adult human brains of either gender between 20 – 70 years of age were obtained at autopsy from Forensic Department of King Edward Medical University, Lahore after due ethical permission from February 2009 to January 2010. The cadavers were kept in the cold storage room at +2°C to +4°C until the time of autopsy. For autopsy the human cadaver was put in a supine position on the autopsy table. A wooden block was placed under the back of the head so that it was elevated and positioned appropriately for the autopsy. A sharp scalpel was used to incise the layers of the scalp from behind the ear of one side, carrying it over the top of the head and to behind the ear of the other side. The front flap was pulled forward over the cadaver's face, thus exposing the top and front of the skull. The back flap was pulled backwards over to the nape of the neck. The cap of the skull was removed with the circumferential incision one centimeter (1 cm) above the supraorbital margin anteriorly and external occipital protuberance posteriorly, using a saw. A hammer was used to separate the skull cap when the inner table was reached. The skull cap was removed and the dura mater was incised from frontal crest and crista galli anteriorly, extending backwards to the internal occipital protuberance, on either side of superior sagittal sinus. The occipital lobes were supported with one hand while the other hand was used to free the brain from the cranial fossae. First, the olfactory nerves were gently cut by elevating frontal lobe from anterior cranial fossa, using light pressure on the underside of the brain. Next, the optic nerves were cut, followed by cutting both internal carotid arteries, infundibulum and oculomotor nerves. Both the temporal lobes were freed from middle cranial fossae with the fingers. The attached margin of tentorium cerebelli, on both sides, was incised along the posterior clinoid processes, superior borders of petrous part of temporal bone, and the margins of the grooves for transverse sinuses on the occipital bone, using a long and pointed knife. Falx cerebelli was also cut from the margins of the groove for occipital sinus. The cerebellum was gently pushed back. A long, thin knife was then used to incise the rest of the cranial nerves; the medulla oblongata was incised at the level of foramen magnum and the brain was then gently lifted out of the cranium. The specimen obtained was washed with tap water and placed in a labeled container having 10% formalin solution. The specimens were transported to the Department of Anatomy, University of Health Sciences, Lahore.

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, to facilitate the accurate measurements. The specimens were duly numbered. The cerebral arterial circle was studied in detail in each specimen with reference to parameters.

Completeness, pattern, variations and symmetry of circle of Willis; presence, origin, external diameter and number of component vessels of circle of Willis and the presence of any aneurysm.

The external diameter of all the arteries forming the circle of Willis was measured using sliding vernier calipers. Magnifying lens was used to observe the vessels closely. The arteries were wiped using filter paper followed by acetone. The arteries were coloured using red enamel paint. Each specimen was photographed using a digital camera with different magnifications for better clarity of the variations noticed.

RESULTS

From a total of 51 subjects included in present study, forty one were males and ten were females. The time lapse between death and autopsy was 12 – 72 hours. Different types of variations like asymmetrical paired vessels, unilaterally or bilaterally absent and hypoplastic posterior communicating arteries, absent, split or double anterior communicating arteries etc. were found in 39 subjects. Continuity and symmetry of the arterial circle was maintained in 37 and 25 brains respectively (Figures 1 and 2). No circle was found with aneurysm.

Single pre-communicating segment of anterior cerebral artery was present in 100% subjects on either side with its typical origin and diameter of more than 1 mm (Table I).

Anterior communicating artery was present in 98.0% subjects with its typical origin. It was hypoplastic in 13.7% subjects. The artery was single in 82.3%, double in 5.8%, and split in 9.8% subjects (Figure 3).

Single pre-communicating segment of posterior cerebral artery was present in 98% with its typical origin and external diameter > 1 mm and absent in 1.9% on right side.

Table I: Showing the different variations in component vessels of circle of Willis.

Artery	Side	Present n (%)	Absent n (%)	Typical origin n (%)	Atypical origin n (%)	Hypoplastic n (%)	Single n (%)	Double n (%)	Split n (%)
ACA	Rt	51 (100)	0 (0)	51 (100)	0 (0)	0 (0)	51 (100)	0 (0)	0 (0)
	Lt	51 (100)	0 (0)	51 (100)	0 (0)	0 (0)	51 (100)	0 (0)	0 (0)
Acom		50 (98.03)	1 (1.96)	50 (100)	0 (0)	7 (14)	42 (84)	3 (6)	5 (10)
PCA	Rt	50 (98.03)	1 (1.96)	50 (100)	0 (0)	0 (0)	50 (100)	0 (0)	0 (0)
	Lt	51 (100)	0 (0)	51 (100)	0 (0)	0 (0)	51 (100)	0 (0)	0 (0)
Pcom	Rt	43 (84.31)	8 (15.68)	43 (100)	0 (0)	17 (39.53)	43 (100)	0 (0)	0 (0)
	Lt	43 (84.31)	8 (15.68)	43 (100)	0 (0)	17 (39.53)	43 (100)	0 (0)	0 (0)

Pre-communicating segment of anterior cerebral artery, ACA; anterior communicating artery, Acom; pre-communicating segment of posterior cerebral artery, PCA; posterior communicating artery, Pcom; posterior communicating artery, right, Rt; left, Lt.

On left side, single pre-communicating segment of posterior cerebral artery was present in all subjects with its typical origin and diameter of > 1 mm (Table I).

Posterior communicating artery was the most frequently absent and hypoplastic vessel in present study. Either the right or left sided vessel was hypoplastic in 33.3% (Table I). It was absent unilaterally in 15.6% and bilaterally in 7.8% of subjects (Figure 3).

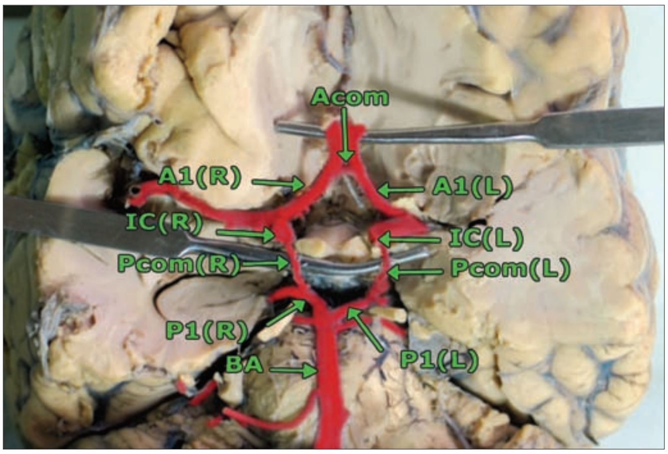

Figure 1: Photograph showing the painted red complete cerebral arterial circle of Willis (2x). A1 (R): Pre-communicating segment of right anterior cerebral artery, A1 (L): Pre-communicating segment of left anterior cerebral artery, Acom: Anterior communicating artery, IC (R): Right internal carotid artery, IC (L): Left internal carotid artery, Pcom (R): Right posterior communicating artery, Pcom (L): Left posterior communicating artery, P1 (R): Pre-communicating segment of right posterior cerebral artery, P1 (L): Pre-communicating segment of left posterior cerebral artery, BA: Basilar artery.

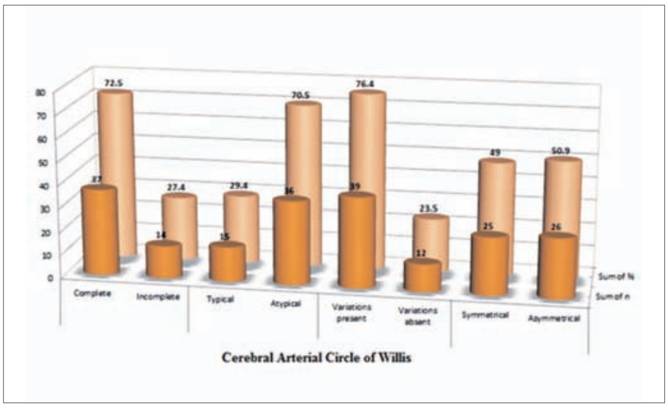

Figure 2: Different types of cerebral arterial circle of Willis found in the present study. The brown cylinders give the actual proportion of the studied population while the pink cylinders present the data in percentages.

Regarding the asymmetry of paired vessels, posterior communicating artery was asymmetrical in 23.5% followed by the asymmetry of posterior cerebral (7.8%) and anterior cerebral arteries (5.8%, Figure 4). None of the arteries was bearing any aneurysm.

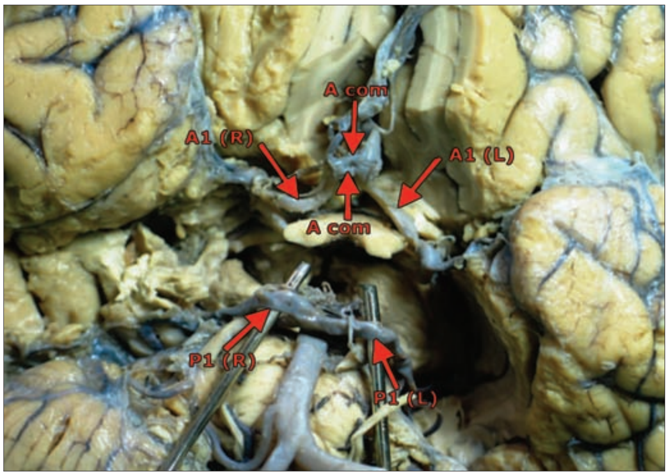

Figure 3: Photograph shows that posterior communicating arteries are absent on both sides whereas anterior communicating artery is split in cerebral arterial circle. A1 (R): Pre-communicating segment of right anterior cerebral artery, A1 (L): Pre-communicating segment of left anterior cerebral artery, Acom: Anterior communicating artery, P1 (R): Pre-communicating segment of right posterior cerebral artery, P1 (L): Pre-communicating segment of left posterior cerebral artery.

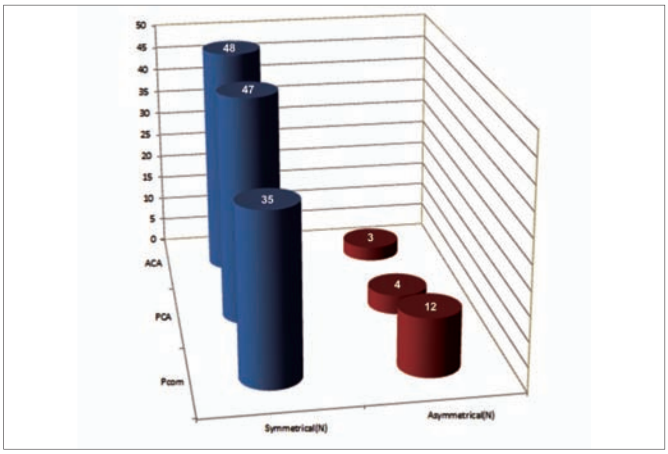

Figure 4: Symmetry of paired pre-communicating segments of anterior cerebral artery followed by pre-communicating segment of posterior cerebral and posterior communicating artery. ACA: Anterior cerebral artery, PCA: Posterior cerebral artery, Posterior communicating artery: Posterior communicating artery.

DISCUSSION

It has been postulated that the arterial circle of Willis is essential for the maintenance of a stable and constant blood flow to the brain and any change in its morphology produces different syndromes of variable vascular insufficiency in adults.[12] A thorough knowledge of the variations in cerebral arterial circle has grown in importance with the increasing number of procedures like aortic arch surgery, carotid endarterectomy and microsurgical clipping of anterior communicating artery aneurysms; its variations are common and the textbook picture of symmetrical, large, approximately equal sized vessels were present only in 30% subjects.[11,16-18]

Incomplete cerebral arterial circle of Willis may be due to absence of one or more of the component vessels thus breaking the continuity of the arterial circle. In present study, 72.5% had complete while 27.4% subjects had incomplete cerebral arterial circles and 49% of arterial circles were symmetrical while 50.9% were asymmetrical. However, in a study performed by Alpers and Berry, using 136 cases of cerebral haemorrhage of verified hypertension reported normal circles in 66% of the cases.[9] The difference in results could be due to difference in population and specimen selection, different type of method of investigation and different criteria of the normal circles.

Nevertheless, large variations in the percentages of circles with a complete configuration are found in literature, it ranges from 21% to 52% in autopsy studies.[10,19] Contrary to this study, Fawcett found only 3.8% incomplete and 26.5% asymmetrical circles.[20] In 1959, Alpers performed another study on the cerebral arterial circle of Willis in normal brains and found 52.3% normal circles and only 0.6% of the circles were incomplete. Rest of the circles were with one or the other type of variations.[19] Fisher studied brains of 414 unselected autopsies and found only 30% subjects with textbook picture of cerebral arterial circle of Willis however, Al-Hussain *et al*. observed 20% circles of typical type.[11,21] Krabbe-Hartkamp *et al*. observed 42% entirely complete circle.[22] In study performed by Kapoor *et al*. on 1000 specimens, 96.8% of cerebral arterial circles were complete and 42.2% were of typical pattern.[4] However, in this study, 29.4% of subjects had typical pattern of cerebral arterial circles. So the present observations accordingly stand at variance regarding the completeness and symmetry of cerebral arterial circle when compared with the studies reported earlier.

In a cross-sectional study, visualizing the circle of Willis with magnetic resonance angiography in patients with internal carotid artery occlusion, the presence of posterior communicating artery was associated with the absence of border zone infarcts.[23] In an autopsy study including 49 infarcted and 88 non-infarcted brains, 27% of brains in first group and 17% of brains in second group were found with variations.[24] Another autopsy study described more variations associated with infarcted brains than the brains without infarct.[25]

The hypoplasia of posterior communicating artery (33.3%) is the most frequent variation found in the present study followed by the absence of this vessel (15.6%). These results were in accordance with the previous reports.[4,10,12,19] Anterior communicating artery was hypoplastic in 13.7%, split in 9.8% and duplicated in 5.8% of subjects in the present study. Fawcett (1905) found the duplicated anterior communicating artery as the most common variation (7.5%).[20]

CONCLUSION

The results of present work emphasize the effects of variations in cerebral arterial circle of Willis in producing hypoxia of brain in many clinical conditions and provides the relevant data on these variations for its possible implications. This may have special utility to neurosurgeons as well who perform advance procedures while maintaining constant blood supply to the brain.

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