Human Anatomic Variations in the Formation of Circulus Arteriosus – A Dissection Method

[*]Dr.Mohammed Meraj Ahmed MD, [**]Dr.M.venkateshwar reddy MD , [***]Mr.venkatachary MSc, [****]Mr.Abdul Waheed MSc.

[*]Assistant professor, department of anatomy SVS medical college, Mahboobnagar, Telangana.
[**]Associate professor, Department of Anatomy, SVS medical College, Mahboobnagar, Telangana.

***Abstract*- Introduction & Objective:** The circulus arteriosus, exist between the internal carotid arteries and two vertebral arteries, that supplies the remainder. It slows down the blood before it reaches the brain and helps in collateral circulation. The knowledge of the CirculusArteriosus and its variations is essential in clinico –pathological conditions such as surgical hemorrhage, encephalomalacia, infarction of the brain and intra cranial aneurysms as it is one of the major collateral circulations ensuring the complete perfusion of the brain.

Methods: A total of 50 brain specimens were collected, cleaned and dissected. A careful examination of the specimens was done to check for variations in components of the CirculusArteriosus.

Dissection Method: The brains were removed en-mass by adopting the dissection procedures as given in the Cunninghams 'Manual of Practical Anatomy' Volume III: Head and Neck and Brain, 15th edition.

Results: The detail study of Circle of Willis along with morphology, shape, length, caliber, and anomalies were tabulated accordingly. In the present study all the components of the Circulus Arteriosus was studied and discussed in great detail and the variations were noted down.

Conclusion:- The posterior part of the circle was more anomalous than anterior part and the posterior communicating artery was the most anomalous segment when compared to all the segments of the arterial circle.

***Index Terms*-** Circulus Arteriosus, Circle of Willis

I. INTRODUCTION

Much of the brain is supplied by two internal carotid arteries and a central anastomosis, the circulus Arteriosus, exist between these and the two vertebral arteries, that supplies the remainder. This 'Circle' more polygonal than circular, is in the cisterna inter-peduncularis, surrounding the optic chaisma, the neural indundibular stem of hypophysiscerebri and other related neural structures in inter-peduncular fossa.[1]

Anteriorly the anterior cerebral arteries are joined by the anterior communicating artery; posteriorly the basilar artery divides into two posterior cerebral arteries, each joined to the ipsilateral internal carotid by posterior communicating artery. [1]

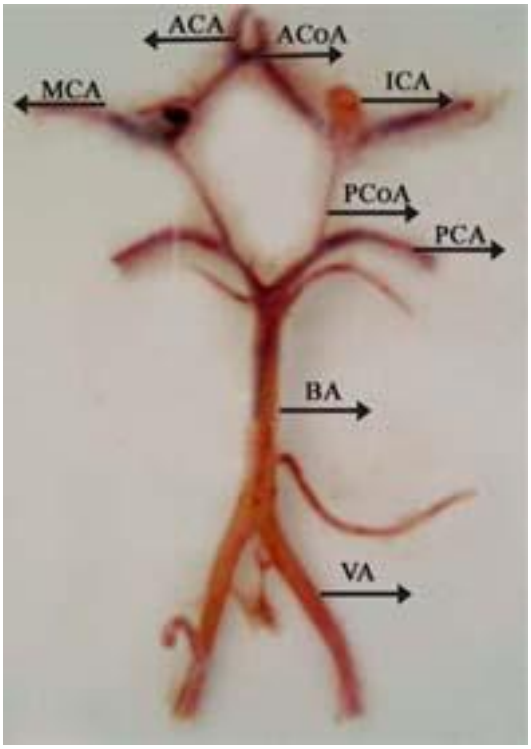

Fig.1 Showing Complete Circle of Willis.

Vessels of this 'circle' vary in calibre, being often maldeveloped, sometimes even absent.[1] The greatest variation in calibre between individuals occurs in the posterior communicating artery. Sometimes, the diameter of the pre-communicating part of the posterior cerebral artery is smaller than that of posterior communicating artery, in which case blood supply to the occipital lobes is mainly from the internal carotids via the posterior communicating arteries.[2]

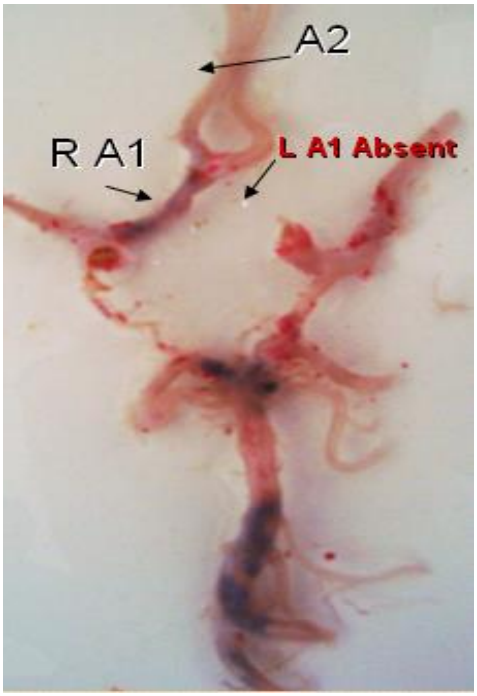

Fig.2. Showing incomplete Circle of Willis

Anatomic variations of Circle of Willis can also be the result of embryological anomalies.[3] Prematurity is associated with more complete Circle of Willis and fewer anatomic variation; more variations involved major arterial segment, but few variations occur in communicating arteries.[4] In some instances internal carotid artery provide the major supply to posterior cerebral artery.[5] Anomalies of the branches of internal carotid artery can lead to serious clinical conditions like stroke.[6]

Cerebral-vascular diseases present one of the leading problems of the modern mankind. They are followed by the risk of high mortality rate, and as such cause high level of disability with people who survive cerebral – vascular incident (stroke, apoplexy).[7] The knowledge of cerebro-vascular variantsis essential in education, training, diagnosis and treatment. After the occlusion of an internal carotid arterythe principal source of collateral flow is through the arteries of the circle of Willis, but the size and patency of these arteries are quite variable.

II. MATERIALS AND METHODS

Fifty randomly selected formalin fixed human brains were collected from the cadavers.The brains were removed en-mass by adopting the dissection procedures as given in the Cunninghams 'Manual of Practical Anatomy' Volume III: Head and Neck and Brain, 15th edition.Brain removal was done by sawing the calvaria manually 1 cm above the supra orbital margin anteriorly and external occipital protuberance posteriorly. Once the calvarium was removed, the dura was opened by making a cruciform incision. The brain was detached by retracting the brain backwards and cutting the falxcerebri from its attachment to frontal crest and crista galli, olfactory nerves, optic nerve, internal carotid artery, occulomotor and trochlear nerves as and when they were encountered. The attached margin of tentorium cerebella was incised to facilitate removal of brainstem and cerebellum intact with the cerebral hemispheres. While doing so, the remaining cranial nerves were cut as and when they were encountered. The vertebral arteries and spinal medulla were divided. The intact brains thus removed from the cranial cavity. Base of the brain was cleaned, circle of willis identified then numbered and photographed.

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. A careful study has been done to note the presence of any aneurysms, if present.

III. RESULTS

1. Circuls Arteriosus – Circle Morphology

In the present study of the CirculusArteriosus, the circle was complete in 43 of the cases (86.00%); out of the 43 complete circles 15 circles were symmetric and 18 asymmetric circles which accounted to 34.88% & 41.86% respectively. The circle was found to be incomplete in 7 of the 50 cases (14.00%).

Table No.1. Circuls Arteriosus – Circle Morphology

Circle Morphology	Complete 43 cases: 86.00%		Incomplete 7 cases: 14.00%
	Symmetric	asymmetric	
No. of cases	15	18	07
Percentage	34.88%	41.86%	14.00%

In the present study, the circle was incomplete in the anterior part in 2 of the 50 cases (4.80%). In specimen 7, the circle was incomplete due to the absence of A1 on the left side, A2 segments on both sides originate from ACA. In specimen 20, the circle was incomplete due the absence of A1 on right side, A2 segments on both sides originate from ACA.

The posterior part of the circle was incomplete in (specimen No.2,10,26,28,37) 5 cases (10.00%). In specimen 2, PCoA& P1 absent on the left side,BA bifurcates unequally. In specimen 10, PCoA absent on the right side P1 absent on the right side.In specimen 26, PCoA& P1 absent on the right side.In specimen 28, PCoA absent on the right side & P1 absent on the left side.Rest of the components of PCoA, P1, and BA normal in their size and origin. In specimen 37, PCoA& P1 absent on the right side.

2. Circulus Arteriosus Shape:-

In the present study, the shape of the Circle in most was a nonagon found in 37 cases (74.50%) and in 6 cases the circle was a polygon (12.00%).

Table No. 2. Circulus Arteriosus Shape:-

Shape of circle	No.of cases	Percentage
Nanogon	37	74.50%
Polygon	06	12.00%

3.Criculus Arteriosus – Anomalous Circle:

In the present study the anterior part of the circle was complete & normal in 39 of the 50 cases (78.00%); the posterior part of the circle was complete in 44 of the 50 cases (88.00%). In the present study the anterior part of the circle was anomalous in 6 cases (22.00%); the posterior part was more anomalous than anterior which was seen in 11 cases (12.00%).

Table No.3. Circulus Arteriosus – Anomalous Part:

	Normal/ Complete	Anomalus
Anterior part	88.00%	12.00%
Posterior part	78.00%	22.00%

A) ACoA–ACA Complex: (Anterior Communicating Artery:)

The size of the anterior communicating artery was found to be comparatively less variant than any components of the circle. the average size of the artery was found to be 2 ± 0.17 mm in its external diameter and 4.2 ± 0.23 mm in its length. although, ACoA was absent in 15.00% of the cases, a complete absence of ACoA was found only in 2.00 % of the cases and in 7.00% of the cases, an azygous ACA was found.

B) Anterior Cerebral Artery (A1-Segment):

The artery was found to be hypoplastic in one case on the right side (2.00%); azygous ACA or median trunk formation was seen in 3 cases (6.00%). The artery was missing in one case on the right side (2.00%) and the A2 segment of both the side arose from the contralateral ACA (2.00%).

C) Posterior Communicating Artery [PCoA]:

The average length of the artery was found to be 14.02 ± 0.56 mm on t he right side and 14.58 ± 0.53 mm on the left. The average external diameter of the artery was found to be 1.07 ± 0.14 mm on right side and 1.10 ± 0.15 mm on the left.

Both PCoA were hypoplastic in 12.00% of the cases. HypoplasticPCoA-R was seen in 17.00 % and hypoplasticPCoA-L was seen in 5.00%. In 2.00% of the cases, each of the PCoA continued as PCA proper on the ipsilateral side. PCoA arising from basilar artery was seen in 2.00%.

D) Posterior Cerebral Artery (P1segment):

The average length of the P1 segment in the present study was found to be 8.08 ± 0.49 mm on right side and 8.11 ± 0.54 mm on the left. In the present study, the artery was hypoplastic in two cases, one oneach side.

The artery originated from the terminal bifurcation of the basilarartery in 46 (92.00%) cases. In 4 cases (8.00%) the artery originated fromICA, 2 cases on each side accounting for 4.00% each.

IV. DISCUSSION

In this present study entitled “a study of anomalous pattern of Circle of Willis - a dissection method”, the Circle of Willis was studied in 50 specimens of intact brain for its components forming the Circulus Arteriosus. The findings were compared with the previous workers on this subject.

I) Circle Morphology: Completeness

In the present study, out of 50 brain specimens, it was found that the Circle of Willis as complete in 86.00% of the cases and incomplete in 14.00% of the cases. The circle was symmetric and normal in 34.88%. Most of the workers have reported that the normal CirculusArteriosus is present in only 50% or less of the cases.

Fawcett & Blackford in 1905 documented 96.1% of complete Circle of Willis. The circle was symmetrical and normal in 73.4% and was incomplete in 3-8%.[8]

Bergmann mentions that textbook description of normal and symmetrical Circulus Arteriosus is true in only 34.5% of the cases.[9]

II) Circle Morphology: Shape

In present study out of the 86.00% of complete circles it was found that the circle was nonagon in 74.50% and in the rest it was polygonal in shape 12%. Osborn mentions that arterial polygon specially a nonagon having ten components & nine segments.[10]

III) Circle Morphology: Anomalous

Previous workers have found that the anomalies of the circle are more common in the posterior part. Jain et.al, in his study shows anterior and posterior parts of the Circle of Willis to be having anomalies in 29.16% and 51.38% cases respectively.[11]

Hartkamp demonstrates that the posterior part of the Circulus Arteriosus is more anomalous in older subjects in 47% of the subjects than the anterior in 68% of the subjects.[12]

Van Raamt et.al, showed that the complete anterior part of circle was seen in 71% of cases and a complete posterior part in 19%.[13]

In the present study, it was found that the posterior part of the circle was most anomalous in 10.00% cases which are approximately similar to the findings of the other workers.

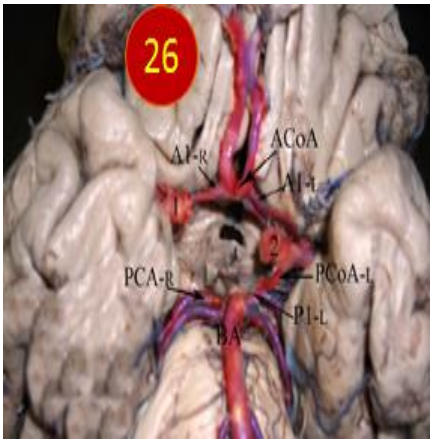

Fig.3. Showing the absence of PCoA and P1 on the right side. (26th specimen)

IV) ACOA-ACA COMPLEX:

1.Anterior Communicating Artery:

In the present study, the size of the anterior communicating artery was found to be comparatively less variant than any components of the circle. The average size of the artery was found to be 2 ± 0.17 mm in its external diameter and 4.2 ± 0.23 mm in its length. Although, ACoA was absent in 4.88% of the cases, a complete absence of ACoA was found only in 2.00% of the cases and in 7.00% of the cases, an Azygous ACA was found.

According to Luzsa's illustrations, the average length of ACoA ranges between 0.75 - 2.75 mm.[14] KamathS reported 2.5 ± 1.8 mm as the average length of ACoA and 1.9 ± 9 mm as the average external diameter.[15] Orlandinialso gives the mean values for arterial segments of the components of Circulus Arteriosus and documents the mean value for ACoA to be 2.8 ± 1.8 mm.[16]

Bergmann et.al, in their illustrations state that the average length of ACoA is 2 - 3 mm that may vary from 0.3 mm to 7 mm in length. They also reported that the percentage of the artery with a diameter of 1.5 mm was <44% and the diameter of 1.0 mm was found in <16%.[9]

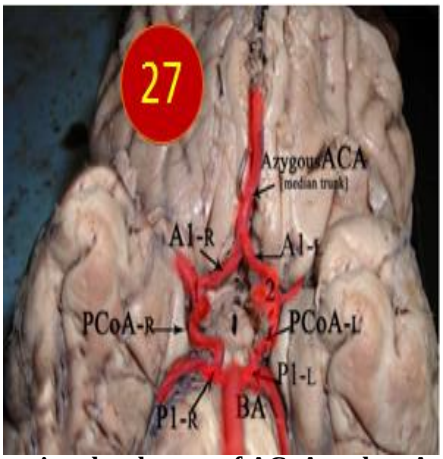

Fig.4. Showing the absence of ACoA and an Azygous ACA is fromed by the union of A1 Segments of both sides. (27th Specimen)

2. Anterior Cerebral Artery (A1-Segment):

In the present study, the pre-communicating anterior cerebral artery (A1 segment) was present in 92.00%; the average length of the A1 segment was found to be 14.5 ± [0.53-r; 0.18-l] mm for both sides although the average external diameter differed for right & left; for right it was 1.96 ± 0.08mm left 2.07 ± 0.08 mm respectively.

Orlandini et.al, gives the mean length of the ACA on the right to be 14.1 ± 2.7mm. And on the left as 13.6 ± 2.8 mm.[17]

In the present study the cerebral artery A1 segment was found to be hypoplastic in one case on the right side (2.00%); Azygous ACA or median trunk formation was seen in 3 cases (6.00%). The artery was missing in one case on the left side (2.00%) and the A2 segment of both the side arose from the contralateral ACA (2.00%).

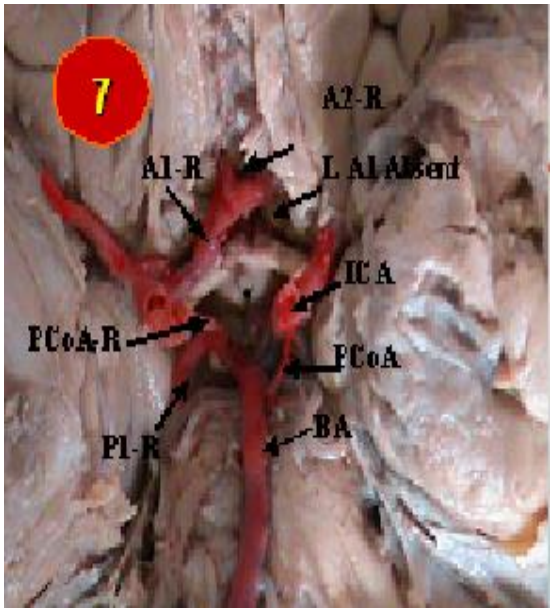

Fig.5. Showing the absence of A1 segment on the left side.(7th Specimen)

Windle reports the absence of the artery in 1%.[21] Luzsa report statesthe absence of the artery in 0.7 - 11% and hypoplasia in 8 - 15%.[14] Arthur reports 9.61% each of aplasia & hypoplasia of A1 segment[18]. Osborn states the absence of the A1 segment in 1 - 2%.[10] Vohra from his study inferred the range to be 0.5 - 2.5 mm.[19]

3. Posterior Communicating Artery [PCoA]:

In the present study, the artery was found to be present in 87.50% and the average length of the artery was found to be 14.02 ± 0.56 mm on the right side and 14.58 ± 0.53 mm on the left. The average external diameter of the artery was found to be 1.07 ± 0.14 mm on right side and 1.10 ± 0.15 mm onthe left.

According to Pedroza et.al the external diameter of the PCoA was 1.5 ± 0.8 mm on the right side; 1.6 ± 0.6 mm on the left side and the total length of the PCoA was12.7 ± 3.2 mm on the right and 12.5 ± 1.7 mm on the left side.[20] Orlandini et.al, mentions mean values for the length of PCoA to be 13.7 ± 3.5 mm in the right and 13.3 ± 3.5 mm in the left. [16]

In the present study both PCoA were hypoplastic in 12.00% of the cases. Hypoplastic PCoA-R was seen in 17.00 % and

hypoplastic PCoA-L was seen in 5.00%. In 2.00% of the cases, each of the PCoA continued as PCA proper on the ipsilateral side. PCoA arising from basilar artery was seen in 2.00%.

Windle reported the vessel to be absent in 15% of the cases; bothPCoA were absent in 1.5%; 4.5% involving the right and 6.5 % on left side and the vessel was hypoplastic in 3.5 % of the cases.[21]

Fawcett & Blackford reported that the vessel was absent in 0.4% on both sides; absent on the rightside in 1.8% and on the left side in 1.4% of the cases.[8] Jain et.al reports indicated that the artery presented maximum anomalies in 50% of the cases.[11]

Stephen & John mentions 23% the PCoA missing on one side.[22] Macchi et.al, hypoplasia of the PCoA was noted in 21% of the cases.[23] Osborn mentions hypoplasia orabsent PCoA in 25-33%.[10]

4. Posterior Cerebral Artery (P1 – Segment):

In the present study, the pre-communicating artery (P1 segment) was present in 44 of the cases (88.00%) and absent in 6 cases (12.00%). Out of the 6 cases, 4 cases on right side and 2 cases on left side accounted for 12.00% and 4.00% respectively. The average length of the P1 segment in the present study was found to be8.08 ± 0.49 mm on right side and 8.11 ± 0.54 mm on the left. Similarly the average external diameter of the P1 segment was found to be 2.0 ± 0.09 mm on the right side and 2.2 ± 0.17mm on the left.

Luzsa illustrates the average length of P1 segment ranging from 1.2 - 2.2 mm similar to the present study finding where the average length was found to be 2 mm.[14] According to Kamath s the average length on the right side for P1segment is 6.8 ± 2.7 mm and on the left 6.9 ± 3.1 mm. The average external diameter is 2.1 ± 0.7 mm on the right and 2.2 ± 0.6 mm on the left.[15]

Orlandini also mentions mean values for P1 segment on the right being 7.7 ± 2.6mmand 8.1 ± 2.9 mm on the left.[16]

In the present study, the artery was hypoplastic in two cases, one on each side. The artery originated from the terminal bifurcation of the basilar artery in 46 (92.00%) cases. In 4 cases (8.00%) the artery originated from ICA, 2 cases on each side accounting for 4.00% each.

Windle study shows an anomalous P1 segment in 13.5%; PCA originating from ICA on the right in 5.5% of the cases and left in 2% of the cases.[21] Fawcett & Blackford study indicates that the artery had an abnormal origin, arising from ICA in 0.14%; 0.85% on the right and 0.57% on the left.[8]

Riggs' study showed that the unilateral hypoplasia of P1 present was present in16% of the cases. Vare & Bansal studies show 25% P1 segment anomalies having an abnormal origin from ICA and 5.7% of the cases had both P1segments arising from the ICA; 13.7% on the right and 5.7% on the left.[24]

V. CONCLUSION & SUMMARY

The present study on the Circle of Willis involved the components of the circle and its variations. The Circulus Arteriosus was complete in 86.00%. In 74.50% the circle was found to be a nonagon. Normal and complete anterior part of Circulus Arteriosus was observed in 96.00% of the cases and posterior part in 90.00%.

Anomalous anterior part of the Circulus Arteriosus was more common in posterior part (10.00 %) than in the Anterior part (4..80 %).In spite of careful study, associated aneurysms were not seen in any of the segments of the Circulus Arteriosus.

The posterior part of the circle was more anomalous than anterior part and the posterior communicating artery was the most anomalous segment when compared to all the segments of the arterial circle.

Abbrivations:

1- Right Internal Carotid Artery
2 - Left Internal Carotid Artery
R – Right
L – Left
ACA - Anterior Cerebral Artery
ACoA- Anterior Communicating Artery
A1 - Anterior Cerebral Artery before ACoA.
A2 - Anterior Cerebral Artery after ACoA
PCoA-Posterior Communicating Artery
PCA - Posterior Cerebral Artery
P1 - Posterior Cerebral Artery before PCoA
BA - Basilar Artery

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AUTHORS

First Author – Dr.Mohammed Meraj Ahmed MD, Assistant professor, department of anatomy SVS medical college, Mahboobnagar, Telangana.
Second Author – Dr.M.venkateshwar reddy MD , Associate professor, Department of Anatomy, SVS medical College, Mahboobnagar, Telangana.
Third Author – Mr.VenkataChary MSc, tutor, Department of Anatomy, SVS medical College, Mahboobnagar, Telangana.
Fourth Author – Mr.Syed Abdul Waheed MSc. Associate tutor, Department of Anatomy, SVS medical College, Mahboobnagar, Telangana.