Original Article

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Morphological Variations of Circle of Willis: A Human Cadaveric Study

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Abstract

Background & Objectives: The Circle of Willis is a large arterial anastomosis in the base of the brain between carotid and vertebrobasilar system. There is considerable individual variation in the pattern and caliber of these vessels. Aim is to study the configuration of CW and its variations. *Materials and Methods:* This study was carried out in 50 brain specimens obtained from embalmed human cadavers. The CW was studied in detail in each specimen with reference to its formation and variations. *Results:* In this study, completeness of the CW was noted in 45 (90%) brai n specimens out of 50. The circle was found to be incomplete in 5 (10%) out of 50 specimens. Anterior part of the circle was incomplete in 4 brains (8%), whereas the posterior part of the circle was found deficient in 1 specimen (2%). Symmetry was seen in 27 (54%) of the 45 circles, the circle was found asymmetrical in 18 specimens (36%). Asymmetry was due to abnormal anterior part in 7 specimens (14%) and abnormal posterior part in 11 specimens (22%). Fetal PCA was found in 9 specimens (18%). PCoA was absent in 1 (2%), hypoplastic in 1 specimen (2%). Single median ACA was noted in 2 brains (4%). A1 was missing in 1 specimen (2%). ACoA was missing in 4 specimens (8%), double ACoA was observed in 2 circles (4%) and was plexiform in 1 brain (2%). *Interpretation & Conclusion:* Complete symmetrical CW was seen in 27 specimens (54%). The circle was incomplete in 5 specimens (10%), most frequently in the anterior part of the circle accounting for 8%. The circle was anomalous in 18 brains (36%), observed most frequently in the posterior part of the circle accounting for 22%. Variations noted were absence, hypoplasia and duplication of the vessels forming CW.

Keywords: Circle of Willis; Morphology; Symmetry; Anterior Cerebral Artery; Posterior Cerebral Artery; Communicating Arteries.

Introduction

Circle of Willis CW is a circle of arteries between internal carotid system and vertebrobasilar system that supply blood to the brain. The CW is a large arterial anastomosis which unites the internal carotid and vertebrobasilar systems. It lies in the subarachnoid space within the interpeduncular cistern and surrounds the optic chiasma and infundibulum. The carotid arteries and their branches (referred to as the anterior circulation) supply the anterior portion of the brain while the vertebrobasilar system (referred to as the posterior circulation) supplies the posterior portion of the brain. Arterial circle is formed anteriorly by the two ACA derived from the ICAs are linked by the small ACoA, posteriorly by the two PCA formed by the division of the basilar artery, they are joined to the ipsilateral ICA by a PCoA. It is not truly a circle but a polygon [8].

From the arterial circle and the principal cerebral arteries, two types of branches arise, central and cortical forming two distinct systems. Every cerebral artery has evolved from a primitive vascular network enveloping the brain. From this net, channels have become enlarged in response to the demands of the parts they supply.

Materials and Methods

This study was carried out in 50 brain specimens obtained from embalmed human cadavers. The brains

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were removed en-mass and gross examination of the arterial circle was done. Magnifying lens was used wherever necessary. Drawings were made for each specimen for further correlation.

The CW was studied in detail in each specimen with reference to its formation and variations. The completeness, symmetry, presence and absence of the components of the circle, other variations like doubling, fenestration etc. were noted.

Results

Circle Morphology

Completeness

In the present study, completeness of the CW was noted in 45 (90%) brain specimens out of 50. The circle was found to be incomplete in 5 (10%) out of 50 specimens [Chart 1].

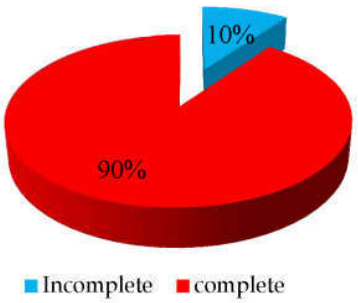

Chart 1: Completeness of CW

Incomplete CW

Anterior part of the circle was incomplete in 4 brains (8%), whereas the posterior part of the circle was found deficient in 1 specimen (2%) [Chart 2].

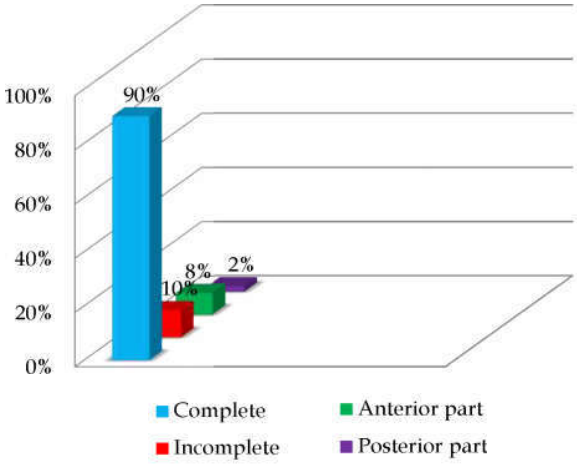

Chart 2: Circulus Arteriosus

Symmetry

Symmetry was seen in 27 (54%) of the 45 complete circles, the circle was found asymmetrical in 18 specimens (36%) [Table 1].

Table 1: Symmetry of CW

Symmetry	No. of specimens	%
Asymmetrical	18	36
Symmetrical	27	54
Total	45	90.0

Asymmetric CW

- Asymmetry was due to abnormal anterior part in 7 specimens (14%)
- Asymmetry was due to abnormal posterior part in 11 specimens (22%) [Table 2].

Table 2: Asymmetric CW

Asymmetric CW	Specimens	%
Anterior part	7	14
Posterior part	11	22

Types of CW found in the study

Typical Pattern

Of the 50 specimens examined, 27 (54%) conformed to the aforementioned typical pattern being symmetrical and complete [Figure 1].

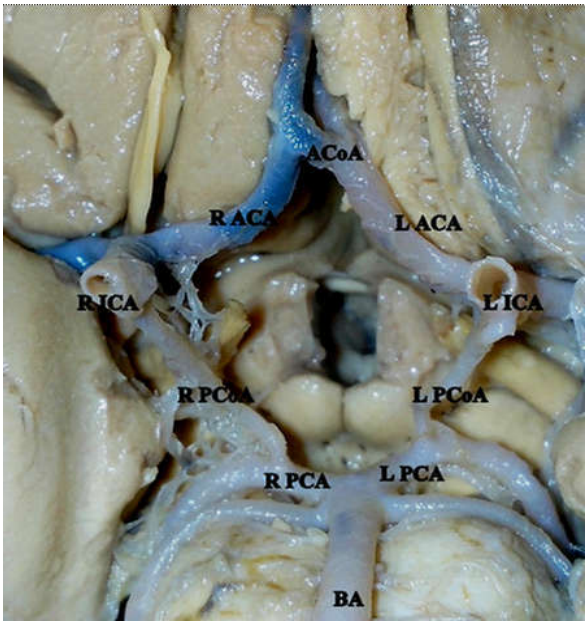

Fig. 1: Complete and symmetrical circle

Deficient Circle

The CW was said to be deficient if there was complete absence of a component vessel breaking the continuity of the circle.

In the present study the circle was deficient in 5 instances (10 %).

It was due to absence of

i. ACoA in 3 specimens (6%);
   - It was due to single median ACA in 2 brains (4%)
   - Due to communicating ACA walls in 1 specimen (2%)

ii. Proximal part of an ACA up to its union with ACoA in 1 instance (2 %);

iii. PCoA in 1 specimen (2 %). [Chart 3]

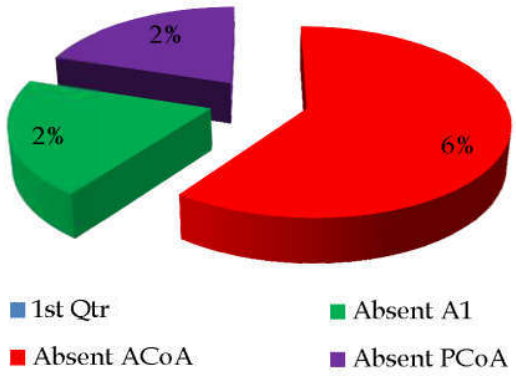

Chart 3: Deficient circle

PCA: It was present in all 50 specimens on both the sides. It was found abnormal in 9 specimens. Embryonic type of PCA was found in all cases (4 on right side, 2 on left side and 3 bilateral). The proximal part of the PCA was abnormal and the distal part was normal, which was the continuation of PCoA. The PCoA on the affected side was larger than normal. [Figure 5, 7]

PCoA: It was found in 49 specimens out of 50 specimens examined. It was absent bilaterally in one brain specimen (2%) thus providing no communication between the carotid and basilar systems. It was hypoplastic in 1 specimen (2%). [Figure 6]

ICA: They were present universally in all specimens examined both on right and left side.

ACA: Single median or azygous ACA was seen in 2 specimens (4%). A1 segment was absent in 1 specimen (2%). ACA walls were communicating in 1 brain (2%) in the absence of ACoA. [Figure 2, 3, 4]

ACoA: It was absent in 4 specimens (8%). Duplication was seen in 2 specimens (4%). Plexiform ACoA was seen in 1 brain (2%). [Figure 2, 5, 8]

Thus the CW was mostly complete and symmetrical. Incompleteness of CW was found commonly in the anterior part. Asymmetric or anomalous circle was frequent in the posterior part of CW.

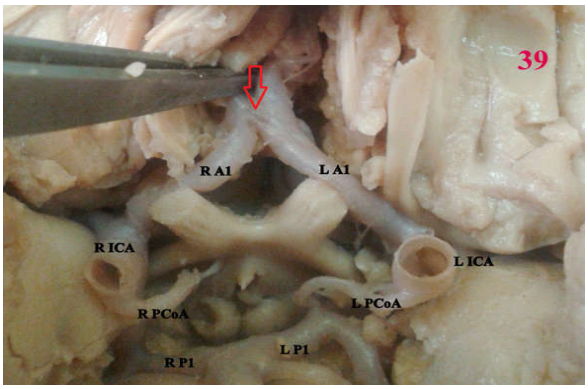

Fig. 2: Absent ACoA

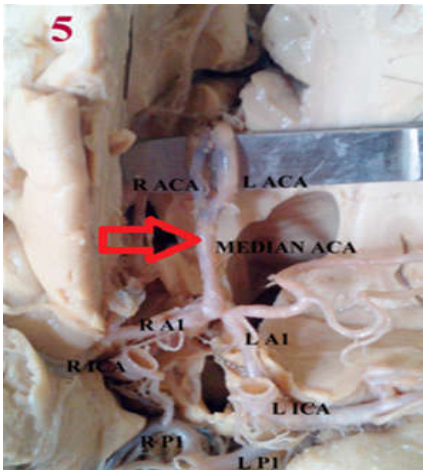

Fig. 3: Single median ACA

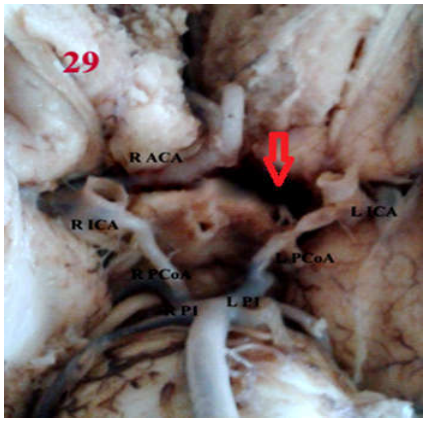

Fig. 4: Absent L A1 segment

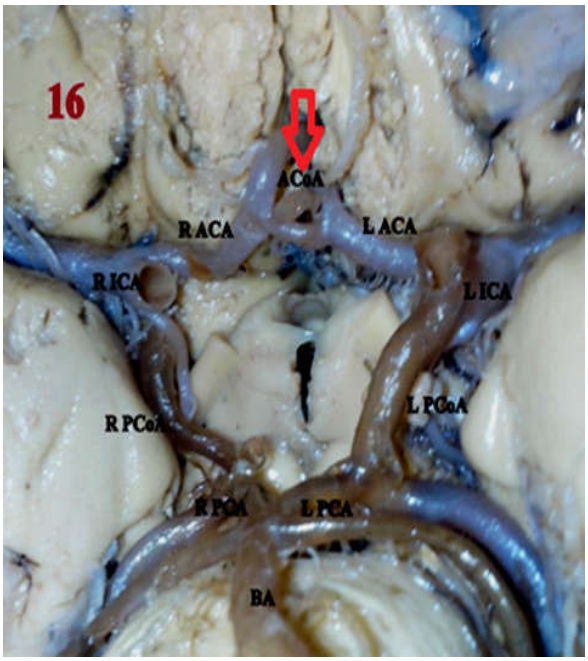

Fig. 5: Double ACoA and Fetal PCA

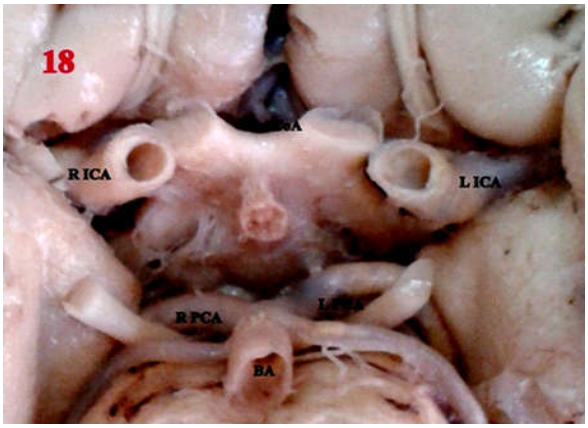

Fig. 6: Bilateral absence of PCoA

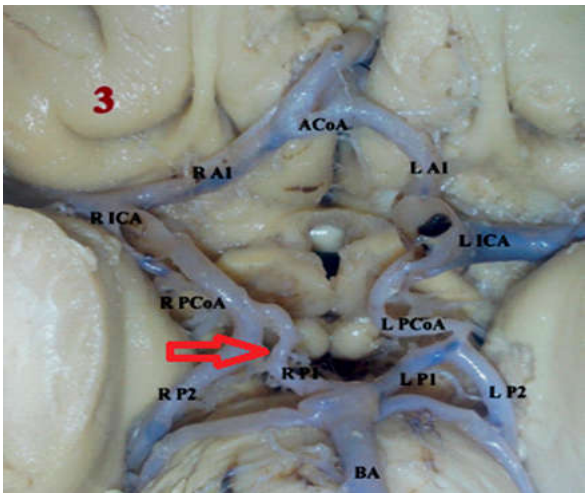

Fig. 7: Fetal R PCA

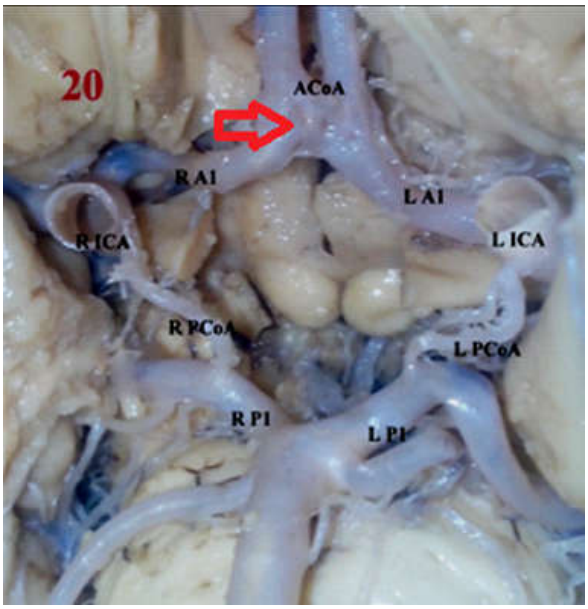

Fig. 8: Plexiform ACoA

Discussion

Circle Morphology: Completeness

Kapoor et al examined 1000 specimens, noted complete in 96.8%, 452 (45.20%) confirmed to be aforementioned typical pattern and was found deficient in 32 instances (3.20%) [2]. In a study conducted by Fawcett, it was complete in 673 cases (96.1%) and incomplete in 27 cases (3.8%) out of 700 [3]. Eftekhar et al., reported 31.5% of cases where the CW was normal [4]. Windle in 1887 reported that 59.5% circles had normal arrangement of arteries in the CW [5]. Ghanbari et al. noted the anatomical patterns of CW in 100 male east Azarbaijanian individuals, they found complete CW in 89% and incomplete CW in 11% [6]. In a study done by Roopashree et al., out of 30 brain specimens, it was found that the CW was complete in 76.66% of the cases and incomplete in 23.34% of the cases. The circle was symmetric and normal in 33.33% [7]. [Chart 4].

In the present study, 45 specimens (90%) were complete CW and 5 specimens (10%) were incomplete CW.

Incomplete CW

Kapoor et al. has reported that incomplete circle (3.20%) was due to absence of

i. ACoA in 18 specimens (1.80%);

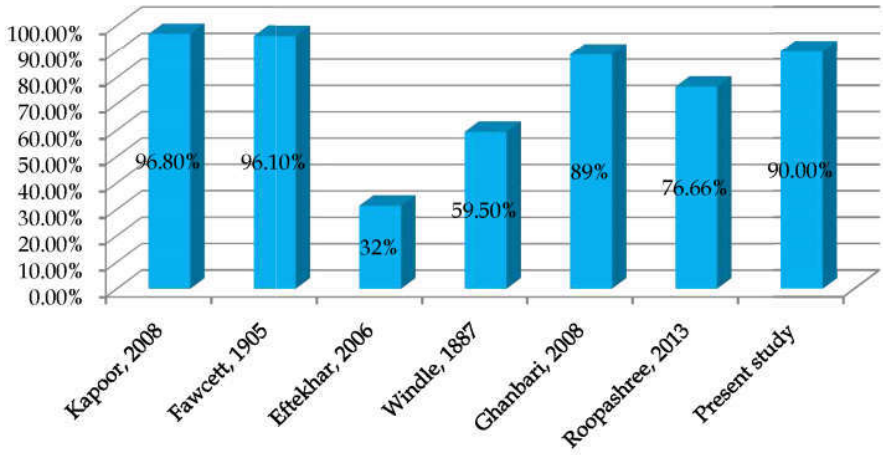

Chart 4: Comparison of completeness of CW Kapoor 2008 Present study

ii. Proximal part of an ACA up to its union with ACoA in four instances (0.40%)

iii. PCoA in 10 specimens (1%) [2].

In the present study, anterior part of the circle was incomplete in 4 brains (8%), whereas the posterior part of the circle was found deficient in 1 specimen (2%).

It was due to absence of ACoA in 3 specimens (6%) single median ACA in 2 brains (4%) and communicating ACA walls in 1 specimen (2%), absence of proximal part of an ACA up to its union with ACoA in 1 instance (2 %) and absent PCoA in 1 specimen (2 %). [Chart 5].

Symmetry of CW

Fawcett 1905 found symmetrical CW in 514 (73.4%) and asymmetrical in 186 cases (26.5%) out of 700.[3] In the present study, CW was symmetrical in 27 specimens (54%) and was asymmetrical in 18 specimens (36%) [Chart 6].

Anomalous CW

Previous studies have found that the anomalies of the circle are more common in the posterior part. Kapoor et al in 2008 documented in their study, that anterior half was abnormal in 234 (23.4%) and posterior half was found abnormal in 314 (31.4%) [2]. Saeki et al. in 1977 reported the anomalies of the posterior part of the circle as 49% of the cases [8]. Out of 35 circulus arteriosus, anomalous formation was found in 3 cases, 8.6% by Poudel et al. [9]. The posterior part of the circulus arteriosus was incomplete in 16.66% by Roopashree et al in 2013 [7].

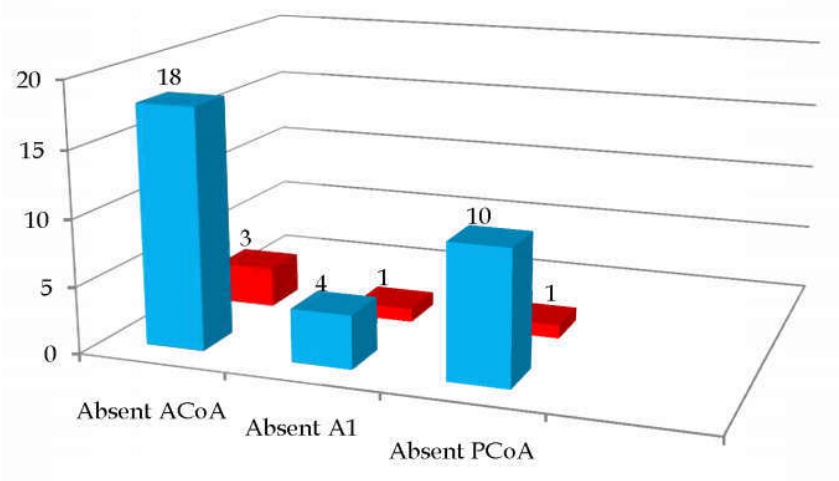

Chart 5: Comparison of specimens with incomplete CW

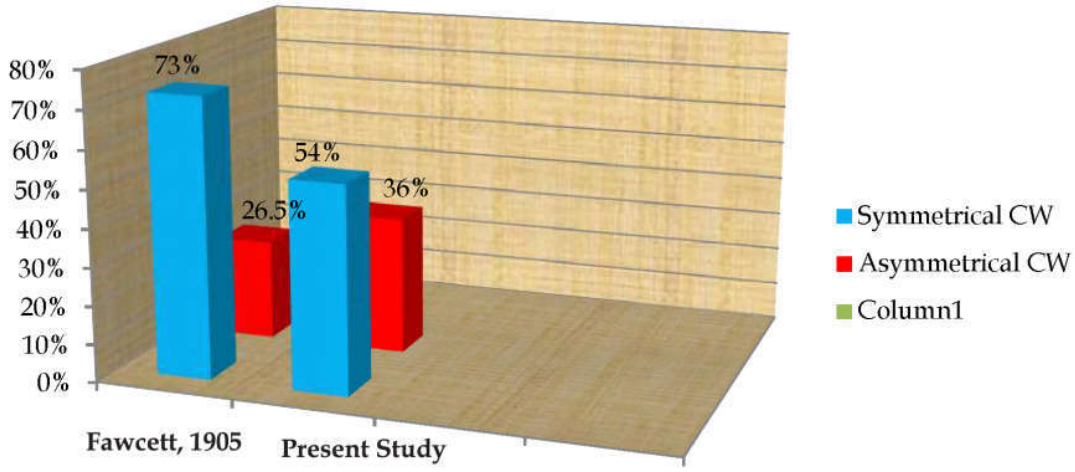

Chart 6: Comparison of symmetry of CW

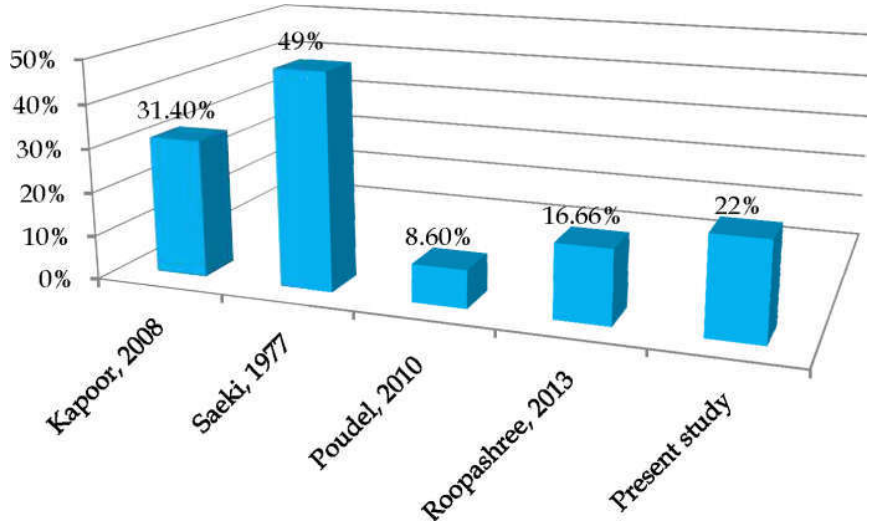

Chart 7: Comparison of anomalous posterior part of CW

In the present study anomalous circle was noted in 18 specimens (36%). Posterior part accounted for major anomalies being found in 11 specimens (22%) followed by anterior part which was abnormal in 7 specimens (14%) [Chart 7].

Altered cerebral blood flow has been demonstrated in regions supplied by variant CW vessels. Their central hypothesis was that CW anomalies correlate with alterations in cerebral hemodynamics and contribute to migraine susceptibility and ischemic complications of migraine. Dysregulation of cerebral blood flow may allow relative ischemia to develop in the setting of increased metabolic demand related to neuronal hyperexcitability, may trigger cortical spreading depression, and may predispose individuals with migraine to ischemic lesions and stroke [10].

Conclusion

Completeness of the CW was noted in 45 (90%) brain specimens out of 50. The circle was found to be incomplete in 5 (10%) out of 50 specimens. Complete and normal circle was found in 27 (54%) and complete anomalous circle in 18 specimens (36%). Thus the CW was mostly complete and symmetrical. Incompleteness of CW was found commonly in the anterior part. Asymmetric or anomalous circle was frequent in the posterior part of CW.

In the study variations like

- Deficient circles due to absence of ACoA, A1 segment, PCoA
- Hypoplastic communicating arteries
- Fetal PCA
- Double ACoA etc.. were observed.

The knowledge of such variations, anomalies and its significance in causing cerebrovascular accidents will be of great importance for the physicians, neurologists, neurosurgeons, radiologists in arriving at a diagnosis and managing the patient accordingly.

List of Abbreviations Used

ACA- Anterior Cerebral Artery

ACoA - Anterior Communicating Artery

A1- Anterior Cerebral Artery before ACoA

A2 - Anterior Cerebral Artery after ACoA

BA- Basilar Artery

CW- Circle of Willis

ICA - Internal Carotid Artery

L- Left

PCoA - Posterior Communicating Artery

PCA - Posterior Cerebral Artery

R - Right

Acknowledgement

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