

## Research Article

# Study of Variations in Anterior Circulation of Polygon of Willis in Dissected Human Brains of Eastern Indian Population

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**Abstract: Background:** The knowledge of anatomy of anterior circulation of Polygon of Willis, which is accessible from the basal aspect of brain is utmost important from the surgical point of view, as it plays a critical role in anterior cerebral circulation aneurysms. Racial and gender variations, difference in materials and methods and several other factors had made systematic description of this vascular variations complicated. Aim of the current study was to thoroughly observe and describe the anatomical vascular variations in anterior circulation of Polygon of Willis and compare the findings with previous studies. **Methods:** 200 intact cadaveric human brains irrespective of age or sex, without any obvious intracranial pathology or gross brain destruction were recruited as study samples in unpreserved form as forensic autopsy cases and as formalin preserved donated bodies. All the brains were dissected carefully, observed thoroughly, labelled and photographed to find out the vascular variations in anterior circulation. **Results:** The most common variation found in the current study was aplastic Anterior Communicating Artery (AComA) seen in 3% of the brain samples (6/200) followed by hypoplastic AComA 2% (4/200), duplicated AComA 2% (4/200) and plexiform AComA in 1% (2/200) of the samples. The most frequent variation found in Anterior Cerebral Artery (ACA) was triplicated A2 segment or Persistent Median Artery of Corpus Callosum in 2% of the samples (4/200) followed by unilateral aplastic A1 segment 1.5% (3/200), unilateral hypoplastic A1 segment 1% (2/200) and bihemispheric ACA seen in 1% (2/200) of the samples. **Conclusion:** The most common variation had been aplastic Anterior Communicating Artery (AComA) and the least common variation had been plexiform AcomA. The findings of the present study can be compared to the incidence of neuromuscular accidents occurring in the sample population. The knowledge of the study can be utilised for treatment and prognosis purpose.

**Keywords:** Anterior Circulation, Polygon of Willis, Anterior Communicating Artery, Anterior Cerebral Artery, Variations

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## INTRODUCTION

Polygon of Willis is an anastomotic polygon, formed at the base of the brain, as the internal carotid and vertebral arterial systems anastomose around the optic chiasma and infundibulum of pituitary stalk in the suprasellar cistern. The Anterior Cerebral Artery (ACA) and Anterior Communicating Artery (AComA) are two key arteries forming the Anterior circulation of polygon of Willis. There are four segments of ACA namely A1 or Horizontal or Pre-communicating part defined by from origin of ACA from ICA to origin of AComA, A2 or vertical or post communicating defined by from origin of AComA to commencement of callosomarginal artery [1]. Almost all the classification systems of segmentation of ACA acknowledge this definition [2]. The central and terminal branches which arise from A1 and A2 segments of ACA at the basal aspect of brain are Medial striate arteries, Lenticulostriate arteries and Recurrent Artery of Heubner [3]. These branches supply anterior perforated substance, caudate lobe, septal nuclei, part of orbital cortex, medial orbital gyrus and gyrus rectus and comprise an important vascular territory of ACA [4]. Variations in the A1 or A2 segment of ACA might cause vascular compromise to the anatomical regions supplied by them.

The segments of ACA approachable from base of the brain are A1 and a part of A2 segment and AComA. These very components are specifically known for significant anatomical variations and associated clinical manifestations. Cadaveric dissection method and Imaging study methods such as Computed Tomography angiography (CT angiography) and Magnetic resonance angiography are most used methods to assess the variations in anterior circulation of Polygon of Willis. Angiographic studies yield better outcome regarding functionality of the vessels and presence of aneurysms whereas can be considered only in patients and might not be applicable to all the subjects as it is an expensive tool for study. Implication of the knowledge of different types of anastomoses among the two A1 segments through AComA is of crucial important for surgeons and angiographers for diagnosis and treatment of medical conditions as well as for prevention of complication [5].

Various study methods had been used in different time frames and study settings to observe the variations in anterior circulation of Polygon of Willis and thereafter correlate the findings with different clinical conditions, among

various races, in different genders or in different age groups. It had been clearly noticed that the study results varied depending on whether it was an angiographic study or a cadaveric study. Percentages of the same variation in different studies performed on a particular race differed; given the sample size and study method had been different. This way it is utmost important to obtain race and region-specific information about anatomical variations of anterior circulation of Polygon of Willis. The aims and objectives of this study were to investigate the variations in symmetry of origin, diameter and branching pattern of A1 segment of ACA, part of A2 segment of ACA and AComA which is accessible from the basal aspect of brain; in Eastern Indian population to provide specific data about different variations to surgeons, clinicians or researchers as particular information about the same is scanty at hand.

## MATERIAL AND METHODS

The present study was an observational, descriptive and cross-sectional study was conducted in the Department of Anatomy and Department of Forensic and State Medicine bearing the facility of R. G. Kar Police Mortuary in R.G. Kar Medical college and Hospital, Kolkata, from August 2015 to August 2016.

### Inclusion and Exclusion Criteria

For the purpose of study, 43 human brains were collected from embalmed cadavers from the Department of Anatomy and 157 human brains were collected from fresh corpses undergoing autopsy from the Department of Forensic and State Medicine at R.G. Kar Medical college and Hospital, Kolkata. Human brain samples irrespective of age, sex and socio-economic status were included into the study excluding those with gross injury, massive laceration in the basal aspect of brain, obvious intracranial pathology or improper preservation.

### Ethical Statement

Permission was taken from Institutional Ethics Committee as a part of thesis submission.

### Methods of Dissection and Measurements

Sample size for the study was calculated by non-probability sampling procedure. Simple and usual study tools for dissection such as 10% formalin solutions, large glass container, forceps, scissors, gloves, bone saw, and other instruments were used. For detailed examination, measurement of specimen and record keeping, magnifying glass, scale, measuring tape, thread and fine malleable copper wire, 5X zoom 14.1 Megapixel Canon digital camera, record form / record room and autopsy room were used. No additional resources or human resources were required for this study. The unpreserved brain samples collected from Forensic autopsy cases were dissected by Virchow's technique in which cranium was opened without damaging the brain matter and its vascular structures [6]. Brains were removed intact from meninges and cranial cavity, washed properly and observed thoroughly. The formalin preserved brain samples collected from human cadavers were dissected according to the description given in Cunningham's Manual of Practical Anatomy [7].

### Statistical Analysis

Data were stored in the MS Office Excel and analyzed. Findings were described by descriptive statistics by calculating percentage of each variation.

## RESULTS

The study group consisted of 200 adult human brains irrespective of age and sex. Total number of variations found in the Anterior communication of Polygon of Willis have been described in Table 1.

### Anterior Communicating Artery

The most common vascular variation found in the study was aplastic AComA (in 3% of the subjects) (Figure 3, Table 2). The other vascular variations found in this study were hypoplastic ACoMA (in 2 % of the subjects), duplication of AComA

Table 1: Variations of the Anterior Communicating Artery (AComA) and Anterior Cerebral Artery (ACA)

| Variations of AComA      | Variations of ACA             |                       |
|--------------------------|-------------------------------|-----------------------|
|                          | A1 Segment                    | A2 Segment            |
| Aplasia (6/200)          | Aplasia right side (2/200)    | Triplication (4/200)  |
|                          | Aplasia left side (1/200)     | Bihemispheric (2/200) |
| Hypoplasia (4/200)       | Hypoplasia right side (1/200) |                       |
| Duplication (4/200)      | Hypoplasia left side (1/200)  |                       |
| Plexus formation (2/200) | Total (11/200)                |                       |
| Total (16/200)           |                               |                       |

Table 2: Comparison of Variations Observed in Anterior Circulation of Polygon of Willis in Different Ethnicity and by Different Study Methods

| Variations        | Cadaveric Studies             |                                |                               |                   |                          | Imaging Studies          |                  |
|-------------------|-------------------------------|--------------------------------|-------------------------------|-------------------|--------------------------|--------------------------|------------------|
|                   |                               |                                |                               |                   |                          | CT Angiography           | MRA              |
|                   | Kapoor et al, North India (%) | Iqbal et al[8] South India (%) | Present study, East India (%) | Alpers et al, USA | Khamlichi et al, Morocco | Krzyżewski et al, Poland | Qiu et al, China |
| Aplastic AComA    | 1.8                           | -                              | 3                             | 2                 | -                        | 19.7                     | 18.34            |
| Hypoplastic AComA | 2.1                           | 4                              | 2                             | 2.8               | 11                       | 5.35                     | 0.62             |
| Duplicated AComA  | 10                            | 6                              | 2                             | -                 | -                        | 0.49                     | 8.28             |
| Plexiform AComA   | 0.4                           | -                              | 1                             | -                 | -                        | -                        | 0.13             |
| Aplastic ACA      | 0.4                           | -                              | 1.5                           | -                 | -                        | 4.62                     | 2.11             |
| Hypoplastic ACA   | 1.7                           | 4                              | 1                             | 2                 | 4                        | 7.3                      | 4.59             |
| Triplicated ACA   | 2.3                           | 4                              | 2                             | -                 | -                        | 0.97                     | 6.95             |
| Bihemispheric ACA | 0.9                           | -                              | 1                             | -                 | -                        | 0.97                     | 27.74            |

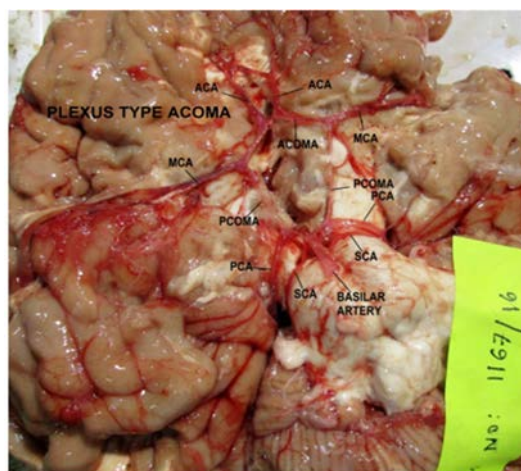


Figure 1: Duplicated AComA

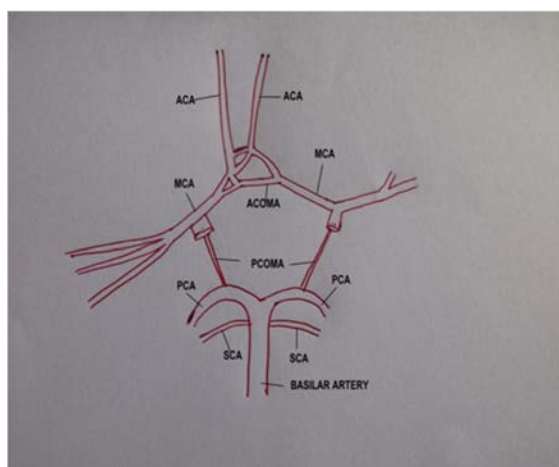


Figure 2: Plexiform AComA

(in 2% of the subjects) (Figure 1, Table 2), plexiform AComA (in 1% of the subjects) (Figure 2, Table 2). No fenestration or aneurysm was found in this study.

### Anterior Cerebral Artery

The most frequent variation found in ACA was triplicated A2 segment or Persistent Median Artery of Corpus callosum (in 2% of the subjects). Unilateral aplastic A1 segments were found in 1.5% of the subjects (both right and left sides) (Figure 3) whereas unilateral hypoplastic A1 segments were found in 1% of the cadavers in both sides (Figure 4). In 1% of the cases, A1 segment of one side supplied frontal lobes of both the hemispheres, a variation called bihemispheric ACA.

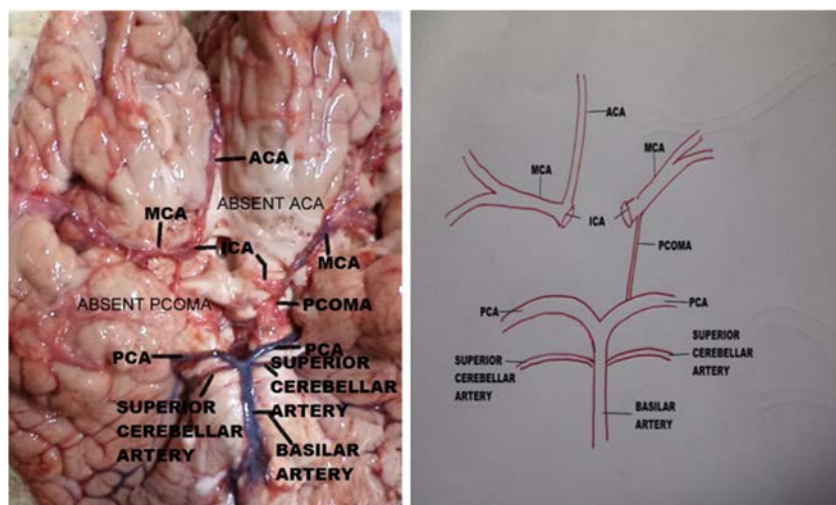


Figure 3: Unilateral Aplastic AI Segment and Aplastic AComA on Left Side

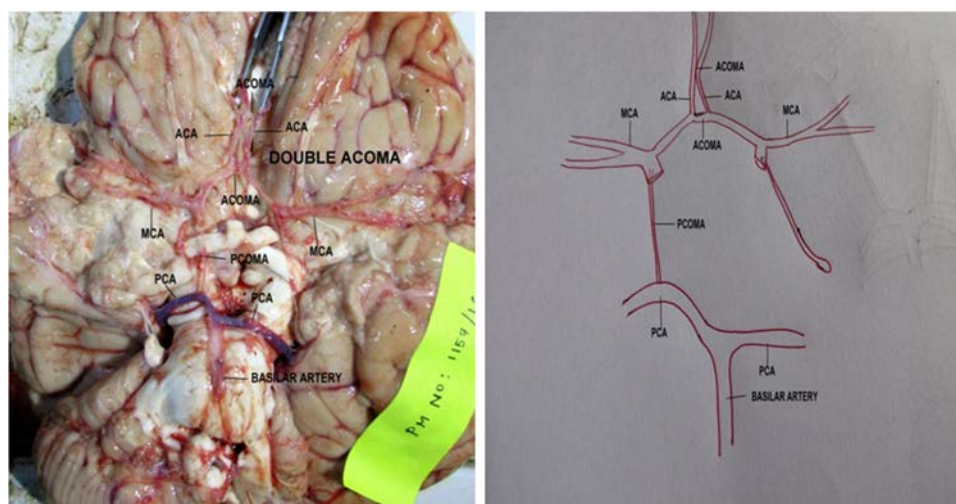


Figure 4: Unilateral Hypoplastic AI Segment on Left and Duplicated AComA

## DISCUSSION

### Anterior Communicating Artery

The most common variation in the anterior circulation of Polygon of Willis accessible from the basal aspect of brain, as revealed in present study was aplastic AComA with the prevalence of 3%. Significant difference in findings were found when compared to a few other cadaveric studies conducted on the same racial population by medicolegal autopsy procedures, in which the variation was reported to be 1.8% [9], and 0.6% [10]. The contradictory findings from these two studies might be influenced by the sample size. Among imaging studies, In Computed Tomography (CT) angiography studies, the percentage of aplastic AComA was found to be higher than cadaveric studies and counted for 19.71 % [5] and 9.38 % [11]. In a Magnetic Resonance Angiography (MRA) study, the percentage of the same variation appeared to be 18.34% [12]. Imaging studies show greater prevalence of AComA aplasia than cadaveric studies [13]. The possible explanation of this disparity might be that the non-functional vascular structures are considered as non-existent in imaging studies whereas in cadaveric dissection studies, the anatomical presence or absence of the vessels is considered rather than its functionality [14]. So, the non-functional AComA is shown as aplastic AComA in image studies.

Considering hypoplasia of AComA, the prevalence found in this study was 2% which is strongly supported by the findings of two other studies conducted in Poland and India which found prevalence for this variation to be 2% [15] and 2.1 % [9], and 2.8% [16]. Wide range in prevalence of hypoplastic AComA can be seen in autopsy studies ranging from 9% [17], 11% [18] to 14% [19] suggesting that racial variation, differences in sampling techniques and methods of data

collection could have had a significant impact on the wide range of differences in various studies. CT imaging or MR angiographic studies tend to undervalue hypoplastic arteries because a hypoplastic artery is misdiagnosed as an aplastic artery in these techniques.

A duplication is defined as two distinct arteries with separate origins and no distal arterial convergence [20]. Fenestration, On the other hand, is defined as a division of the arterial lumen into distinctly separate channels, each with its own endothelial and muscular layers, while the adventitia may be shared [21]. Duplicated AComA, had been found to be 2% in the present study. The result was not in alignment with some other studies conducted on the same ethnic group which reported this variation to be 10% [9] and 6% [8]. whereas autopsy studies conducted in USA [16] and Morocco [18] did not report this variation. A few cadaveric autopsy studies carried on different ethnic groups revealed a range of percentages for this variation like 10% [15], 7.28% [22], 6.4% [23]. A Multidetector CT angiographic studies reported the prevalence of duplicated AComA as 18% [24]. An MRA study showed a percentage of 8.28% [12].

Fenestrated AComA could be considered preferably as a CT image finding with a prevalence of 5.3% [25]. The present study did not find fenestration of arteries in its study group. As it is evident from different autopsy studies, plexiform patterns of AComA is a rare finding which accounted for 1% of cases in the current study and aligned with other autopsy studies which reported the prevalence of this variation to be 1% [15] and 0.4% [9]. In an MRA study, the prevalence of plexiform AComA was reported to be 0.13 [12]. The wide disparity in prevalence of these anatomical variations might be attributed to differences in health status of the sample group, ethnicity, method of study and sample size.

### **Anterior Cerebral Artery**

The Median Artery of Corpus Callosum which is also called as triplicated A2 segment was found in 2% of cadavers in the current study and was supported by a Shri Lankan study which reported the finding to be 2% [26] though another autopsy study from same ethnic population exerted lower prevalence which was 0.9% [9]. Another cadaveric study revealed a result close to the present study regarding this variant where the value was 1.7% [16]. The reported prevalence of this variation in imaging studies were 0.4% [21] and 0.97% [5]. Most of the authors describe the third A2 segment as the persistent median artery of corpus callosum which is an embryological remnant [27]. As it is described, during fetal life, one to three ACA vessels exist: one artery involutes during development. Persistence of all of the three arteries in adult life due to failure of involution gives rise to triplicated ACA [28].

The second most common finding in the present study was unilateral aplastic A1 segment of ACA which accounted for 1.5%; out of which 1% cases were noted to have this variation on the right side and 0.5% showed it on the left side. The finding was in tandem with a previous autopsy study exerting value for the same as 1% on right side and no such variation on the left side [15]. The findings clearly indicate the fact that frequency of absence of A1 segment of ACA is more in the right side of brain. Angiographic imaging studies tend to exaggerate the value for aplasia of arteries because the technique concentrates on functionality of the vessel rather than its anatomical presence. As it occurred in imaging studies, the prevalence for the same variation had been 1.86% [29], 4.59% [5] and 8% [30].

Unilateral hypoplastic A1 segment was observed in 1% of subjects irrespective of sides in the present study. In 0.5% cases, the hypoplastic artery was present in right side and for the rest of the 0.5%, it was on the left side. Other autopsy studies from different ethnic groups showed a varied result in this regard with wide range of values like 2% [16], 2% [31] irrespective of side, 1% hypoplastic A1 on right side and 1% hypoplastic A1 on left side [15]. CT imaging might be considered as an effective and better methodological tool to diagnose hemodynamic variations rather than anatomical variations, as proven by the findings of the same variation being so high as 4.76% [30] and 7.25 % [5]. This disparity can be explained by the fact that an anatomically normal though functionally compromised artery appears to possess constricted lumen or no lumen in imaging studies.

The association of aneurysm at hemodynamically vulnerable pressure points had been documented frequently by using 3D CT imaging method [32], differently than what was observed in the autopsy study, in which aneurysm is a rare finding because cadaveric studies do not possess the precision to diagnose the subtle difference in vascular luminal diameter. Though some cadaveric studies reported this variation to be 0.4% [19] and 1% [9], the current study found no aneurysm to be associated with the aforesaid anatomical variations.

The percentage of bihemispheric ACA in the present study was 1% which was consistent with most of the authors who found the same variation to be 1% [15] in autopsy studies or 0.97% in imaging studies [5]. In certain group of subjects selected for cerebral microsurgery, finding of higher prevalence of this variation as 2% indicates the impact of health status of sample population on the ultimate result [24].

There are wide racial variations for each anatomical variant which was evident while comparing the present study with previous studies. This aspect could further be explored by cross-sectional studies on a specific racial population. It might render a fair scope to explore if neurovascular variations in a certain ethnicity could be directly linked to neurovascular diseases. In comparison an imaging study is an expensive tool and cannot always be recommended for general population but in the subset of people seeking medical help, selection bias might arise when imaging study is

chosen as the diagnostic procedure. This is why a cadaveric study might be considered to be a superior method to investigate the neurovascular variants in general population even though imaging studies are considered more accurate by some authors.

## CONCLUSION

The findings of the present study can be compared to the incidence of neuromuscular accidents occurring in the sample population. The knowledge of the study can be utilised for treatment and prognosis purpose.

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## Conflict of Interest

The authors confirm that this study had no conflict of interest

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