

Cerebral Angiographic Study of Anatomical Variations of Anterior Cerebral Artery Complex in Bangladeshi Population

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Abstract:

Background: Anterior cerebral artery is an important terminal branch of internal carotid artery. It forms the anterior component of circle of Willis along with the anterior communicating artery. It is known for the frequent variations. The knowledge of anatomical variations in anterior cerebral artery is of considerable help to clinicians and interventionists. Method: Morphology and variations of the anterior cerebral arteries and the anterior communicating artery were studied in 90 patients undergone digital subtraction angiography (DSA). **Results:** Variations were found in 33% (n=30). Variations of the segments in relation with size, course, communications and terminations of the anterior cerebral artery (ACA) were noted. These were divided into different groups like hypoplasia, aplasia, duplication and fenestrations. Hypoplasia/Aplasia of proximal anterior cerebral artery (A1) was 24.5% in right side and 9% in left side. Anterior communicating artery (AComA) was found absent in 9% and fenestration in 9%. Callosomarginal artery was found absent in 2.2% in right side and 4.5% in left side. In right callosomarginal artery 6% had abnormal origin and 3.5% abnormal in left side. Pericallosal artery was present 100% on both sides. Conclusion: Variations of anterior cerebral artery complex anatomy is found common in Bangladeshi population.

Key words: Anterior cerebral artery complex, variations, hypoplasia, aplasia, fenestration.

Introduction:

The anterior cerebral artery complex consists of two anterior cerebral arteries (ACA), one anterior communicating artery (AComA) and two recurrent arteries of Heubner. The anatomy of the anterior cerebral artery (ACA) is variable and the description of the ACA and its branches is complicated¹. Segmentation and branching of the ACA is mostly described similarly by different authors, although the relationship of the pericallosal (PrcA) and callosomarginal arteries (CmA) is not agreed upon². Different branches of ACA are also variable in origin³. Different authors have described these segments of the ACA differently. It can be divided into proximal or pre-communicating and distal or

post-communicating segments. The pericallosal artery is distal to the A1 segment and consists of several segments that can be divided according to its relationship with the corpus callosum⁴. The A2 segment (infracallosal section) runs vertically from the AComA to the genu of the corpus callosum. The A3 segment (precallosal part) curves around the genu, and the A4 segment (supracallosal section) usually runs in the callosal sulcus and almost reaches the splenium⁵. The A5 segment (cortical branches) varies considerably; for this reason it is difficult to describe a standard arterial pattern. The two basic configurations of the ACA are determined by the presence or absence of the CmA⁶. The different segments of the ACA are

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illustrated in Figure 1. Few authors only described three separate segments, namely the A1 segment (also referred to as the horizontal proximal segment or pre-communicating part), the A2 segment (vertical proximal segment or post-communicating part) and the A3 segment (the distal segments and cortical branches). The A2 and A3 segments have collectively been referred to as the ascending (or vertical) segment and the A4 and the A5 segments as the horizontal segment. The ACA have also been divided into a basal (from the origin to the rostrum of the corpus callosum) and a distal part (runs around genu and above corpus callosum)⁷. Some authors refer to the A1 segment as the ACA and the artery distal to the AComA as the pericallosal artery. A few authors have also referred to the A1 and A2 segments as the ACA, and the artery distal to the origin of the callosomarginal artery, the pericallosal artery⁸. Since the origin of the callosomarginal artery can vary, this terminology can be problematic. The CmA is also not always present and therefore it is preferable to classify the pericallosal artery as the segment distal to the AComA. Presence of the CmA artery has been observed in 40.0% to 93.4% of specimens.⁹ The CmA can be due to the different definitions used for this artery. The variability of the absence or presence of the CmA can be due to the different definitions used for this artery. The ACA complex has a strong clinical importance. It is the most common site of intracranial aneurysm¹⁰. Despite its considerable significance, little is known about the anatomical variations of the ACA complex^{11, 13, 14}. Many anomalies such as aplasia, hypoplasia, duplication or fenestration of ACA segments and AComA have been described^{15, 16}. Authors used various methods such as digital subtraction angiography (DSA), computed tomography angiography (CTA), Magnetic resonance angiography (MRA), cadaveric dissection or intraoperative observations to study the anterior cerebral circulation of brain. However those studies have a number of limitations. Firstly, they are focused on patients with intracranial aneurysms, and not healthy subjects^{17, 18, 19}. Secondly, the authors base their conclusions on a relatively small study group, rarely exceeding 100

patients. Thirdly, their observations are often limited to the anomalies of the A1 segment (most commonly associated with AComA aneurysms) regardless of AComA and A2 and other segment anomalies¹. Complete study of anterior cerebral artery complex is lacking in the population of our country. Digital subtraction angiography is now-a-days becoming popular minimally invasive angiographic study method for cerebral vessels^{20, 21}. Most of the pathologies of cerebral vasculature can be explored and treated by Neurointervention methods. The development of Neurointervention is progressively increasing in the field of management of vascular pathologies in brain. So complete understanding by the help of digital subtraction angiography of ACA complex is very important for this population of Bangladesh.

Comparatively few studies describe the anatomy of the ACA complex in subjects without intracranial aneurysms. These are mainly cadaveric studies^{26, 27}. There is still a need for further study to explore the anatomy of the anterior cerebral circulation. The results of such studies would be useful when planning neurointerventional procedures and surgical approaches²⁵, and would allow avoiding any unexpected anatomical variations during treatment of AComA aneurysms. Such anatomical problems may include double fenestrations of the A2 segment mimicking an aneurysm neck¹² or mistaking a duplicated A1 segment for an AComA aneurysm¹⁹. The aim of this study was to see the common variations of ACA complex configurations by using digital subtraction angiography (DSA).

Materials and Methods:

This retrospective observational study was conducted in the department of Neurointervention of National Institute of Neurosciences Hospital, Dhaka, Bangladesh during January 2015 to December 2015. All collected data were collected from digital database, checked, edited and analyzed by using computer based SPSS software version 16.0. Data were presented by frequency distribution and percentage.

A total of 90 patients referred in the Neurointervention department for digital subtraction

angiography (DSA) were included in this study. Sampling technique was purposive. The angiogram machine was SIEMENS Artis Zee system and framing rate was 4f/sec. Angiograms with gross pathology like arteriovenous malformations (AVM) in anterior circulation were excluded from this study. Anterior part of the circle of Willis was studied. Morphological variations, branching pattern and course of the ACA and AComA were observed. Variations of the size, course, segments, communications and terminations of the anterior cerebral artery complex were noted. These variations were divided into different groups like hypoplasia, aplasia, and duplication of pre-communicating segment of ACA (A1), double AComA, fenestrations, azygos ACA and variation in the A2 segment of ACA in its terminal branches. Origin of callosomarginal artery and the course of pericallosal artery were noted and pictures were drawn in data collection sheet.

Results:

Out of the 90 patients, majority 63(70%) were belonged to over the age 40 years. And 40 or less than 40 years were 27 (30%) (Table I). It was observed 50(55.5%) were male and 40(44.5%) were female. Male to female ratio was 5:4 (Table I). Morphologic variation seg. Aplasia/hypoplasia/fenestration in A1 or AcomA or absent/abnormal origin of callosomarginal artery were present in 30(33%) of cases. Variations related with the A1 segment of ACA are agenesis, hypoplasia and duplication. Hypo- plastic/ under-developed A1/ Aplastic segment were present in 30 cases. It was seen in 22 (24.5%) on the right and 8 (9%) on the left A1 segment. (Table II).

Table-I
Socio-demographic characteristics of the study patients (n=90)

| Characteristics | No. of respondents | Percentage |
|-----------------|--------------------|------------|
| Sex | | |
| Male | 50 | 55.5 |
| Female | 40 | 44.5 |
| Age | | |
| ≤40 | 27 | 30 |
| >40 | 63 | 70 |

Table-II
Morphologic variation of A1 segment of ACA on both sides (n=90)

| Right A1 | Number of patients | Percentage |
|--------------------|--------------------|------------|
| Normal | 68 | 75.5 |
| Hypoplasia/Aplasia | 22 | 24.5 |
| Left A1 | | |
| Normal | 82 | 91 |
| Hypoplasia/Aplasia | 8 | 9 |

All possible forms of abnormalities of AComA were present in 22 (24.5%) of cases and normal in 68 (75.5%) cases. Fenestration of AcomA was seen in 8 (9%) cases, Hypoplastic/ Absent AComA was seen in 8 (9%) cases. Other abnormalities like duplication were present 6 (6.5%) cases. (Table III)

Table-III
Morphologic variation of AComA of ACA complexes (n=90)

| AComA | Number of patients | Percentage |
|--------------------|--------------------|------------|
| Normal | 68 | 75.5 |
| Fenestration | 8 | 9 |
| Hypoplasia/Aplasia | 8 | 9 |
| Others | 6 | 6.5 |

Azygos anterior cerebral artery was found in 2 (2.2%) cases. Triple A2 segment was found in 1 (1.1%) case. Callosomarginal artery was absent in 2 (2.2%) in right side and 4 (4.5%) in left side. Out of them 5 (6%) in right side and 3 (3.5%) in left side were abnormal in origin. (Table IVA, IVB)

Pericallosal artery was found in all cases on both sides in this study.

Table IVA
Morphologic variation of origin of Right Callosomarginal artery (n=90)

| Right Callosomarginal Artery | Number of patients | Percentage |
|------------------------------|--------------------|------------|
| Present | 88 | 97.8 |
| Absent | 2 | 2.2 |
| Origin | | |
| Normal | 83 | 94 |
| Abnormal | 5 | 6 |

Table-IVB
Morphologic variation of origin of Left Callosomarginal artery (n=90)

| Left Callosomarginal Artery | Number of patients | Percentage |
|-----------------------------|--------------------|------------|
| Present | 86 | 95.5 |
| Absent | 4 | 4.5 |
| Origin | | |
| Normal | 83 | 96.5 |
| Abnormal | 3 | 3.5 |

Discussion:

Multiple variations in anatomy of anterior cerebral artery complex like agenesis, hypoplasia, fenestrations etc resulting in defective circulation has been reported in the different publications^{1,8}. If the artery on one side is narrowed, the vascular insufficiency is compensated by crossing over by opposite side artery, or by giving branches that cross over to the other side. It indicates that the circle of Willis offers a potential shunt in abnormal conditions such as occlusions and spasms. In normal circumstances it is not an equalizer and distributor of blood from different sources. Majority (70%) of the study subject was over 40 years of age, and less than 40 years is 30%. Among them male were 55.5% and female were 44.5%, and male to female ratio were 5:4. Morphological variations eg. Aplasia/hypoplasia/fenestration in A1 or AcomA or absent/abnormal origin of callosomarginal artery was present in 30 (33%) of cases. In Text book of Practical Neuroangiography by Pearse Morris, third edition showed the range of variation between 11% to 43%². In a cadaveric study Gunnal et al found total variation up to 31.3%³⁰. Variations related with the A1 segment of ACA are agenesis, hypoplasia and duplication. Hypo- plastic/ under-developed A1/Aplastic segment were present in 30 cases. It was seen in 22 (24.5%) on the right and 8 (9%) on the left A1 segment. In previous cadaveric study by Riggs and Rupshowered 7% A1 hypoplasia⁴. Pai et al found no hypoplasia or aplasia.⁵ But Piganiol et al found 2.1% and Macchi et al found it 0.7%^{6,7}. In a 3DCTA study Niederberger et al showed 10% hypoplasia/aplasia in a series. In general, our study shows a higher percentage of variations. Hypoplasia/Aplasia are

more common in right side than the left side (24.5% vs 8%).

All possible forms of abnormalities of AComA were present in 22 (24.5%) of cases and normal in 68 (75.5%) cases. Fenestration of AcomA was seen in 8 (9%) cases, Hypoplastic/ Absent AComA was seen in 8 (9%) cases. Other abnormalities like duplication were present 6 (6.5%) cases. Autopsy studies described the frequency of fenestrations in the anterior circulation in up to 64.4 %²⁵. Investigations that used three-dimensional digital subtraction angiography (DSA) found a greater incidence of fenestrations in the anterior cerebral circulation, which was 27 % for aneurysm patients and 22 % for patients without aneurysm¹⁸. On the other hand, Sanders et al. studying 5,190 cerebral angiograms found only 3 fenestrations in the AComA complex.²³ A study by Bozýek et al. using CTA described the incidence of AComA complex fenestrations to be 1.75 %³. Zhao et al, Uchino et al and Saidi et al in cadaveric study found fenestration 0,8%, 1.2% and 26% respectively^{13, 15, 28}. These findings emphasize the fact that two-dimensional imaging is not a suitable tool for detecting intracranial arterial fenestrations. The most common anomaly of the anterior cerebral circulation was fenestrated AComA. Again Cadaveric studies show a vast range of AComA hypoplasia frequency from 9.15 to 30 %^{1, 4, 7}. In addition, aplastic AComA is a rare autopsy finding, found only in 1.8 % of studied subjects⁹. This phenomenon can be explained by the fact that hypoplastic arteries may not be hemodynamically efficient, therefore are not visible in angiographic studies and thus are considered to be aplastic. On the other hand, autopsy findings always visualize the artery trunk, even when contrast flow would not be possible. Li et al. using CTA found aplastic AComA's in 9.38 % of study subjects⁸. AComA 3D imaging provides the excellent quality data, but unfortunately it is rarely available in everyday clinical practice²⁰. Pai et al showed 20% aplastic/hypoplastic AComA⁵.

Azygos anterior cerebral artery was found in 2 (2.2%) cases. In text book Practical Neuroangiography by Pearse Morris showed that incidence of azygos ACA is only 0.3%². Schik et al,

Dietrich et al, Baptista et al and Kakau et al found 1.1%, 0.5-5%, 0-5% and 0.1-5% respectively^{17, 18, 22}. But some study like Osborn et al showed this value very high (10%).²⁴ In this study we found one (1.3%) case of a triple A2 segment. Most authors identify the triple A2 segment as a persistent median artery of corpus callosum, a remnant of embryological cerebral circulation¹¹. MRA studies show that the frequency of a triple A2 segment ranges between 0.4 and 3.03 %^{14, 28}. Usually a triple A2 is an incidental finding. Sun et al. reported a very interesting case of a triple A2 segment associated with the presence of an aneurysm¹⁶. We have not found such pathology in our study.

Callosomarginal artery was absent in 2 (2.2%) in right side and 4 (4.5%) in left side. Out of them 5 (6%) from right side and 3 (3.5%) from left side were abnormal in origin. Callosomarginal artery usually originates at the top of the knee of corpus callosum. But very early origin or late origin are also seen. Abnormal origin may be associated with aneurysm formation. The CmA is also not always present and therefore it is preferable to classify the pericallosal artery as the segment distal to the AComA^{17, 25}. The CmA has been observed in 40.0% to 93.4% of specimens^{6, 11, 17, 21, 25, 27, 26, 29}. The variability of the absence or presence of the CmA is due to the different definitions used for this artery by different authors. The CmA is the largest branch of the pericallosal artery that has been defined as the artery that runs near the cingulate sulcus and gives off two or more cortical branches². But this is problematic since there can occasionally be more than one artery that arises from the pericallosal artery, run in the cingulate sulcus and give rise to a number of cortical branches. Ugur et al. proposed a new classification system²⁹. The CmA was either defined as typical, atypical or absent. An atypical CmA was observed when there was only a very short artery coursing in the cingulate sulcus. Two symmetrical callosomarginal arteries can also be present in the same hemisphere. A typical CmA has a longer course compared to the two symmetrical atypical callosomarginal arteries and usually originates from the A3 segment. Ugur et al. observed typical, atypical or absent CmA's in 49%, 34% and 17% respectively²⁹.

Conclusion

Anterior cerebral artery complex is a common place for anatomical variations and this has a relation with aneurysm formations. The knowledge of these variations will help the clinicians to understand pathophysiology, angioarchitecture and hemodynamics of the lesions in anterior circulation. Morphology and variations of the anterior cerebral artery complex were studied in 90 patients undergone digital subtraction angiography (DSA). Among them 33.3% (n=30) had different forms of variations. Variations of the segments in relation with size, course, communications, origin of callosomarginal arteries, course of pericallosal arteries were noted. These were divided into different groups like hypoplasia, aplasia, duplication and fenestrations. Hypoplasia/Aplasia of proximal anterior cerebral artery (A1) was 24.5% in right side and 9% in left side. Anterior communicating artery (AComA) was found absent in 9% and fenestration in 9%. Callosomarginal artery was absent in 2.2% in right side and 4.5% in left side. Whereas, in right callosomarginal artery 6% had abnormal origin and 3.5% in left side. Pericallosal arteries were present 100% on both sides. This study was performed in a small number of subjects. Multicenter studies are necessary to reach a satisfactory conclusion about the complete understanding of anatomy of anterior cerebral artery complex in this population.

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