Study of variations of the anterior cerebral artery in human brain

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Abstract

Background and aims: Stroke, the most frequent expression of cerebrovascular disease is one of the leading causes of death and disability throughout the world. The manifestations are largely accounted by the anatomical distribution of the stems and branches of the circle of Willis supplying the brain. Considerable individual variation exists in the pattern and caliber of the individual vessels forming the circle of Willis, which may possibly impair the collateral blood flow. The knowledge of these variations thus, becomes essential for medical as well as surgical interventions. There may possibly be some regional variations in the cerebral arteries not mentioned in standard available texts. Thus, the regional based study of variations present becomes essential. The present study aims to focus on the variation of one of such branches, the anterior cerebral artery (ACA) in the population of Assam, India.

Material and Methods: The ACAs of 70 human cadaveric brains were examined by gross dissection in the department of Anatomy and Forensic medicine in Gauhati Medical College. Results: Hypoplastic A-1 segment were found in 7% cases, Hypoplastic A-2 segment in 2.85% cases, Buttonhole formation in 8.57% cases and aneurysmal dilatation in 1.42% cases. The results were compared with that of other authors and variations noted. Conclusion: The present study of ACA using gross dissection is an initial step in providing a reference to the healthcare professionals in the region of Assam. Based on this further studies using newer imaging methods should be carried out to correlate the manifestations clinically.

Keywords: stroke, circle of willis, cerebrovascular accidents, aneurysmal dilatation.

Introduction

Cerebrovascular disease is regarded as a worldwide health problem. It includes some of the most common and devastating disorders: Ischemic stroke, hemorrhagic stroke and cerebrovascular anomalies such as intracranial aneurysms and arteriovenous malformations. They cause more than 200,000 deaths each year in the United States. In India, they are one of the major causes of hospital admissions, with a prevalence rate of 1.54 per thousand and death rate of about 0.6 per 1000 of total cases. With rising disease burden, a detailed study on the cerebral vessels and their individual variations has become a necessity for better understanding of the pathophysiology of the disease process and the medical and surgical interventions needed.

The brain needs a continuous supply of oxygenated blood due to its continuous neuronal activity with no metabolic reserve and is extremely susceptible to hypoxia. The circle of Willis present at the base of the brain, derived from the internal carotid and the vertebralbasilar system, serves as a potential pathway through which adequate distribution of the cerebral blood flow is maintained. Though there is a complete circle in almost all the cases, in most of them one or other of the vessels is sufficiently narrowed to impair its role as a collateral route. These variations thus may play a major role in the development of cerebrovascular accidents (stroke). The anterior cerebral arteries (ACA) are derived from the internal carotid arteries, supplying most of the medial surface of the brain. Like most of the branches of circle of Willis supplying the brain the ACA also show a substantial amount of variations in pattern and caliber.
There may also be some regional variations of the ACA, which have not been dealt with sufficiently in standard books. Some variations may remain asymptomatic and it is possible that in the presence of major malformations, homeostasis is maintained only under advantageous conditions. The present study is focused on the population of Assam, India, which is ethnically unique from the rest of India. It is an effort to provide an important reference to the healthcare professionals serving in this region.

Materials and methods

A total number of 70 brain specimens without obvious pathological changes and decomposition were collected from cadavers, for a period from October 2009-September 2010 in the department of Anatomy and unclaimed dead bodies in the department of Forensic Medicine, Gauhati Medical College, Assam, India.

Collection of specimen

Specimens of the Brain were collected from two sources:

a) Unclaimed and donated bodies were officially received in the Department of Anatomy. The bodies were first embalmed in the Department for the purpose of dissection. Later at a convenient time, the brains were dissected out.

b) The specimens of Brain were collected from autopsies done in the Department of Forensic Medicine, Gauhati Medical College, Guwahati, India.

Dissection and processing

The brains from the cadavers with their arteries intact were gently taken out by detaching the falx cerebri. After taking out the brains gently, the ventral surfaces were cleared. The cerebral arterial circle and its branches (ACA) were cleared off from the overlying meningeal coverings and any adhesions wherever present, to expose them distinctly. The specimens were preserved in 10% formalin and dissected further at a convenient time later. Wherever needed red fabric colour was used to enhance contrast and photographs were taken. Relevant data were recorded and compared with data by other authors.

Observations and results

In the current study 70 specimens of brain were examined for the anatomical pattern and the variation of the anterior cerebral artery (ACA) as shown in Table1. The arteries were examined under two segments A-1 (from its origin at the internal carotid till the junction with the anterior communicating artery) and A-2 (the course distal to junction with the anterior communicating artery). The ACA were found to be arising from the internal carotid artery (ICA) of either side. No anomalous origin (both ACA arising from ICA of one side) of the anterior cerebrials were found in the present study. It was found that in 16 (22.85%) cases the ACA of both sides were unequal in size. Out of which in 11 (15.71%) cases the right anterior cerebral (RACA) and in five (7.14%) cases the left anterior cerebral artery (LACA) were narrow when compared with the opposite side. Out of these 16 specimens, hypoplastic A-1 segments were noted in four (5.71%) cases in RACA and one (1.42%) case in the LACA. Along with the narrowing, all of these five cases also presented with a tortuous course. Hypoplastic A-2 segments were found in two (2.85%) cases on the right side. In these cases the left A-2 segment of the anterior cerebral artery irrigated both sides, compensating for the deficit. Absence of the anterior cerebral artery was not observed in any of the cases. In many of the previous works, it was observed that the ACA of both sides occasionally fuse to form a single arterial trunk and re-divides into right and left branches. In the present study, one such case was observed (Fig. 1). In many of the previous studies, the presence of an additional median artery was mentioned, which was found to be arising from anterior communicating artery and coursed with its fellow of right and left side. No such arterial branch was observed in the present study. A cleft-like, fenestrated, slit like or buttonhole
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Fig. 1: Photograph showing complete fetal Posterior cerebral artery (left side) with absence of Anterior communicating artery and fusion of Anterior cerebral artery (Red arrow)

Fig. 2: Photograph showing single aneurysm of Anterior cerebral artery (right side)

Fig. 3: Photograph showing partial bifurcation of anterior cerebral artery (left side).

Fig. 4: Bar diagram showing Right sided and left sided variations of Anterior Cerebral artery

formation of about 1cm length was observed in one (1.42%) case on the right side and five (7.14%) cases on the left side (Fig. 3). All the variations observed in the A-1 segment of anterior cerebral artery bilaterally. Very minute buttonhole formations were observed in three (4.28%) cases on left side. Aneurysmal dilatation of the ACA was found in one (1.42%) case on the right side (Fig 2).

Discussion

Variations, regarding formation of cerebral arterial circle, are common than exception. The variation of anterior cerebral artery (ACA), like hypoplasia results in abnormal physiology of the circle and was compensated by hypertrophy of the anterior communicating artery. It was reported by Babladi that, because of the variations, the clinical manifestations of occlusion of vertebral or carotid arteries may differ considerably from one individual to another, and the effectiveness of collateral circulation may be greatly influenced. In case of single or multiple hypoplastic stems, homeostasis of circulation could not be maintained under adverse conditions. The resistance offered by hypoplastic ACA and alterations of carotid field of supply, associated with certain malformed components of the circle, suggest that anomalous formation offers greater mechanical impediment to the
Table 1: Variations of Anterior Cerebral Artery

<table>
<thead>
<tr>
<th>VARIATIONS</th>
<th>RIGHT</th>
<th>LEFT</th>
<th>TOTAL</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal in caliber</td>
<td>-</td>
<td>-</td>
<td>54</td>
<td>77.14%</td>
</tr>
<tr>
<td>Unequal in caliber</td>
<td>11</td>
<td>5</td>
<td>16</td>
<td>22.86%</td>
</tr>
<tr>
<td>Hypoplastic: A1 segment</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>7.14%</td>
</tr>
<tr>
<td>Hypoplastic: A2 segment</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2.85%</td>
</tr>
<tr>
<td>Buttonhole formation</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>8.57%</td>
</tr>
<tr>
<td>Aneurysmal dilatation</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1.42%</td>
</tr>
</tbody>
</table>

Table 2: Comparison of variations of Anterior Cerebral Artery with other studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Brains No.</th>
<th>Absence</th>
<th>Hypoplastic</th>
<th>Median artery</th>
<th>Slit like</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuchades et al.</td>
<td>42</td>
<td>1</td>
<td>8</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Shubh Bahadur</td>
<td>50</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>P.N. Jain (1990)</td>
<td>144</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Krabbe-Marhamp (1998)</td>
<td>150</td>
<td>10</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Present study</td>
<td>70</td>
<td>Nil</td>
<td>7</td>
<td>Nil</td>
<td>4</td>
</tr>
</tbody>
</table>

free flow of blood than the configuration designated as typical.

In the past it has been thought that most strokes or cerebral thrombosis were caused by local occlusion of the cerebral vessels supplying the areas of the brain so affected. This may occur, but usually the situation is much more complicated. The presence or absence of adequate collateral circulation is important. The anomalous segments of the circle are usually narrow or string like, but at times segments may actually be absent as a result of agenesis or involution during embryonic development. Complete fusion of both arteries somewhat distal to the commencement of median longitudinal fissure has been described earlier. In the present study complete fusion of the anterior cerebral arteries was not observed, but an incomplete fusion in which the anterior cerebral arteries of both sides fusing to form a single arterial trunk and re-dividing into right and left branches, was observed in one case. This type of incomplete fusion of the anterior cerebral artery was previously reported by Moffat. The buttonhole formation, or presence of slit is characteristics of rats. This observation has been described by Brown in his study of adult albino rats. Similarly, a united A-2 segment is the normal pattern in monkeys which was described by Kassel and Langfitt, in their study of circle of Willis in Macaca mulatta. Babladi observed five cases of buttonhole formation and one case of united A2 segment. In the present study, six cases (8.57%) of buttonhole formation were found (Fig. 4). This can be explained as an evolutionary throw back.

Aplasia of the ACA was observed once in an anatomical investigation by Curry and Culbrett, once in 360 cases by Mitterwallner, once in 62 cases by Puchades et al. and in none of the eighty three brains by Adachi and Hasebe. Angiographically, Tonnis and Schiefer noted an aplasia in 0.7% of 265 cases. Wendle however found the former vessel absent in nine out of 103 brains examined. Babladi reported aplasia in a single case out of the 50 brains, whereas Jain et al. observed five cases out of 144 brains. In the present study no such case of Aplasia of ACA was found.

A variant commonly reported is the agenesis or hypoplasia of A-1 segment of ACA. This anomaly was first described by Bullen, in his report of a patient whose ACA originated from one of the carotids. He stated that if both anterior cerebrals fill only from one side it is usually from the left one. This observation was already confirmed by the arteriographic studies by Fields et al. in which both anterior cerebrals originated from the left carotid eight times more frequently than from the right.

In the present study no such anomaly was found. Vare et al., Reddy et al. and Jayashree and Sadashivan recorded string like A-1 segment previously. Puchades et al. recorded eight cases out of 62 to be hypoplastic and Babladi found four hypoplastic anterior cerebrals out of 50 cases (Table 2.) Chuang et al. suggest that, in
the absence of ICA occlusion, A-1 hypoplasia could also be an independent contributor to risk of ischemic stroke. They further stated that the majority of A-1 segment hypoplasia-related strokes were associated with small vessel occlusion, especially within the striatum. One possible explanation is poor collateral capacity that would render arteries penetrating the striatum vulnerable to ischemic attack\textsuperscript{19}. On the basis of the grading system of Brucker\textsuperscript{24} et al., patients with A-1 segment hypoplasia have impaired collateral circulation. In this study string like A-1 segment was observed in five out of 70 cases (Table 2).

Presence of the median anterior cerebral artery was first reported by Windle\textsuperscript{19} in 4.5\% of his cases and in 10\% cases of Blackburn\textsuperscript{25} and Dunker\textsuperscript{26} et al. Later Jain et al\textsuperscript{27} observed five cases of median anterior cerebral artery out of 144 and Krabbe-Hartkamp\textsuperscript{28} found two cases out of 150 brains. In the present study no such anomaly was found. Padget\textsuperscript{29} explains that this artery appears to be formed from lower group arterial plexus, similar to the formation of ACA. Evidence supporting the concept that the circle of Willis is a potential source of collateral blood flow has come from numerous investigators. Kramer\textsuperscript{30} by injecting methylene blue into the carotid and vertebral arteries of experimental animals demonstrated that the dye does not pass from one arterial system into the other unless there is an obstruction and reduced pressure on the contra lateral side of the circle. Rogers\textsuperscript{31} further suggested that the value of circle of Willis was potential rather than actual because, like all anastomosis, it was capable of opening up and providing a by-pass, if one of the main channels which it joined, became occluded. Shenkin, Harmel and Kety\textsuperscript{32} have once again emphasized that the connections of the circle as potential rather than normally used one.

Wholley et al\textsuperscript{33} did a computed tomography angiograms (CTA) in 212 patients with suspected cervical carotid artery diseases to examine the distal internal carotid artery and the circle of Willis, and their correlation with stroke. Of the 212 patients, 38(18\%) had a complete circle of Willis. The only variants which proved to be precipitating the vascular insufficiency were the absent or hypoplastic A-1 & A-2 segments of the anterior cerebri, and posterior communicating artery (especially bilateral).

Conclusion

The circle of Willis is unquestionably important as a potential source of anastomotic blood flow. The present study done by gross dissection procedure is an initial attempt in observing and classifying the regional based variations in the anterior cerebral artery. Further studies using new imaging modalities based on quantitative measurements of the luminal diameters and flow of the segments should be carried out for a more specific detail on the clinical manifestation of these variations.

References


