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Morphological study of the formative pattern of the circle of Willis

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ABSTRACT

Brain is a highly vascular organ and receives about 15% of cardiac output. The Circle of Willis (CoW) or Circulus arteriosus is a ring-like arterial structure located at the base of the brain. The circle of Willis has its greatest significance in collateral circulations of the brain specially in old people who may have reduced brain blood supply due to senile arteriosclerosis. Materials and methods: The study was therefore conducted on 20 brains obtained during routine anatomical dissection in the department of Anatomy. The formative pattern of the circle of Willi's external diameters of internal carotid arteries were measured, length of the anterior communicating was also recorded. Results: Out of twenty specimens studied, 8 specimens showed variations in the formative pattern of circle of Willis. Like The basilar artery continued as Left posterior cerebral artery, Right posterior cerebral artery arising was from right internal carotid artery with Bilateral absence of Posterior communicating artery , right posterior cerebral artery was arising from Right internal carotid artery. Bilateral fetal type of Posterior cerebral arteries. A long anterior communicating artery of about one cm (10mm) was also observed in one of the cases. Though variations of the arteries at the base of the brain are common, it is necessary to be aware of all the variations as they may breed problems in the blood flow to the brain and may cause confusions in radiological procedures.

Introduction

Brain is a highly vascular organ and receives about 15% of cardiac output. The Circle of Willis (CoW) or Circulus arteriosus is a ring-like arterial structure located at the base of the brain. It is the major arterial anastomoses in the brain and is responsible for the distribution of oxygenated blood throughout the cerebral mass[1].

The Internal Carotid (ICA) and Basilar (BA) arteries bring blood into the CoW and are termed afferent arteries. The Anterior (ACA), Middle (MCA), and Posterior (PCA) cerebral arteries transport blood away from the CoW and are termed efferent arteries. The circle is completed by one anterior (ACoA) and two posterior (PCoA) communicating arteries which allow blood to be rerouted in order to maintain oxygen supply to the cerebral tissue in the event that blood supply through any of the afferent arteries be reduced. It is the major arterial anastomoses in the brain and is responsible for the distribution of oxygenated blood throughout the cerebral mass[2].

Functionally, the circle of Willis is rarely complete even though it is the only anastomosis in brain, and also ones these branches enter the brain substance no further anastomoses occur. They behave like end arteries[3]. Among the general population, only approximately 50% have a complete CoW[4].

However absent or hypoplastic vessels are common, among a multitude of possible anatomical variations, reducing the degree to which blood may be rerouted. While an individual with one of these variations may under normal circumstances suffer no ill effects, there are certain pathological conditions which can present a risk to the person's health and increase the possibility of suffering an ischaemic stroke when compounded with the effects of an anatomical variation[5].

The circle of Willis has its greatest significance in collateral circulations of the brain specially in old people who may have reduced brain blood supply due to senile arteriosclerosis[6].

The present study had therefore aimed at studying the formative patterns of circle of Willis. There is considerable individual variation in the pattern and calibre of the vessels that make up the circle of Willis. The study also includes the variations in the length of the anterior communicating artery and also external diameter of internal carotid arteries and ACoAs.

Materials and methods:

The study was therefore conducted on 20 brains obtained during routine anatomical dissection in the department of Anatomy, Kasturba Medical College, Manipal. The brains thus obtained were freed from the overlying meninges and the circle of Willis was revealed. The arterial pattern was then painted and allowed to dry. The formative pattern of the circle of Willis was observed. The external diameters of internal carotid arteries were measured using scale and thread. The length of the anterior communicating was also recorded using the vernier caliper. Data obtained were tabulated. The noted Variations were photographed.

Results:

The study showed the following results:-

1. Formative pattern:

Out of twenty specimens studied, 8 specimens showed variations in the formative pattern of circle of Willis.

Figure 1: The basilar artery continued as Left posterior cerebral artery. Right posterior cerebral artery arising was from right internal carotid artery. Bilateral absence of Posterior communicating artery was also observed.

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Figure 2: The right posterior cerebral artery was arising from Right internal carotid artery i.e., Fetal type of PCA was observed.

Figure 3: The left posterior communicating artery had a larger diameter compared to left posterior cerebral artery.

Figure 4: The right posterior cerebral artery(RPCA) was arising from the right internal carotid artery. A communicating branch was seen to connect the RPCA to basilar artery.

Figure 5: Right anterior cerebral artery showed a very thin diameter/calibre and after continuing into the inter hemispheral region and on communicating with the ACoA, presented with the larger calibre comparable with LACA

Figure 6: Bilateral fetal type of Posterior cerebral arteries

The following variations were also observed:

Left posterior cerebral artery was very thin in calibre in comparison to right

Left posterior cerebral artery was arising from left internal carotid artery

2. Measurements recorded:

The external diameters of the right and left internal carotid arteries (ICAs) and the anterior communicating arteries (ACoA) were recorded. The length of the anterior ACoA was also tabulated. (Refer Table for contents)

Of the 20 specimens examined, one showed a larger calibre of the anterior communicating artery compared to the Right anterior cerebral artery. Difference in the diameters of the right and left internal carotid arteries were noted.

Discussion:

With this study, an attempt is made to observe the different patterns of the formation of circle of Willis and also the diameters of internal carotid and anterior communicating arteries.

Variations in the origin, termination and distribution of the arteries at the base of the brain are common. Some authors believe that in adults the anatomical configuration of the circle of Willis is closely related to blood flow in the brain-feeding arteries [7]. In embryos, the internal carotid arteries (ICAs) are formed between 28– 30 days, and the basilar artery (BA) is formed between 31–36 days, when the longitudinal neural arteries combine [8-10]. A completely formed circle of Willis appears in the 52-day embryo and all segments are slender and have an identical caliber [11, 12]. In the remaining fetal period, important changes occur in the basic anatomy of the cerebral vasculature. The most obvious is the change from a dominant fetal-type feeding of the posterior cerebral arteries (PCAs) from the ICA via the posterior communicating artery (PCoA) towards a normal adult configuration with feeding of the PCAs from the vertebrobasilar system. The PCoAs normally regress in caliber as the vertebrobasilar system develops. As pointed out by some authors, this process will be complete, resulting in a normal adult-type circle of Willis, or incomplete with a persisting fetal-type feeding of the PCA [13]. Also on the anterior aspect of the circle of Willis, the anatomical development will result in several variations [4].

However the disappearance of the vessels that normally persist or the persistence of the vessels that normally disappear or formation of new vessels can also be attributed to hemodynamic factors and is also the probable reason for the anomalies[14].

Most of the arterial variations may not affect the the brain function due to the collateral circulation and compensation from the arteries of the other side. But these variations gain importance when conditions like stroke, ischemia are considered.

Hollinshead WH had mentioned that the variations of the vertebrals, the basilar or their branches are a rule rather than the exception, and the variations in the sizes of the vessels participating in the arterial circle are very common. The most common defect in the circle is absence of one or both posterior communicating arteries. Another relatively common variation is a major or entire origin of the posterior cerebral artery from the internal carotid artery, by way of an enlarged posterior communicating artery[15].

In a study by Kapoor K et al, out of 1000 specimens examined, 452 cases (45.2%) confirmed to the typical pattern. Rest of the specimens (54.8%) showed variations in the Circulus Arteriosus. The main variations include absence, hypoplasticity, duplication, triplication or persistence of the embryonic pattern[16].

De Silva KRD et al had reported 90.7% of normal patterns of CoW. 9.33% showed variations out of which hypoplastic precommunicating part of the anterior cerebral artery was also reported[17].

In yet another study of 35 Circulus Arteriosus, variations were found in 3 cases (8.6%). In rest of the 32 cases (91.4%), the formation of Circle of Willis was normal. The pre communicating segment of the posterior cerebral artery was larger in calibre than that of posterior communicating artery and all these variant were found bilaterally[18].

Magnetic Resonance Angiographic studies of 143 Circle of Willis showed aplasia of posterior and anterior communicating, hypoplasia of the anterior and posterior cerebral arteries. The anomalies of anterior cerebral, posterior communicating and internal carotid arteries were found to be more common on the left side[19].

In the present study, 60% of the cases showed normal arterial pattern of CoW which is closely comparable to the previous studies. Out of the eight variations observed one presented a rare case. The basilar artery failed to bifurcate and continued as the left posterior cerebral artery. The right posterior cerebral artery was arising from right internal carotid artery (Fetal type of PCA).Bilateral absence of Posterior communicating artery was also observed. These multiple variations are not reported so far. Haemodynamic insults at arterial bifurcations are hypothesized to play a key role in intracranial aneurysm formation [20].

HypoplasticACoA (diameter< 1mm.)Vassil was observed in 20% of the cases. This is in close agreement with the studies done by De Silva et.al.[18] The latter reported hypoplasticACoA in 25.07% of the cases. Although these findings are normally asymptomatic, it could a causative factor for vascular insults in conditions like atherosclerosis.

Length also determines the flow of blood and its haemodynamic effect on the vessel wall. The mean value of the length of the anterior communicating artery in the present study is 3.125mm which correlates with the 3D morphometric study by Zurada et al who reported the mean length of ACoA to be 3.99mm [22]. However in one of the specimens studied, the ACoA was about one cm (10mm). Average length of anterior communicating artery is 4mm with a range 2mm-8mm. [1]. Detailed data regarding the arterial topography may be useful in detecting early changes in this vessel due to pathology and may assist in the treatment of vascular lesions and planning of neurosurgical or radiological interventions in the region including ACoA aneurysms.

There were two out of 20(10%) showing differences in the sizes of ICA of both sides. However no studies have been reported so far comparing the diameters of the same. But this may carry clinical significance in reference to blood supply to brain in patients of Cerebro vascular accidents, aneurysms etc.

Conclusion:

Our study was focussed on the formative pattern of the circle of willis. We also observed changes in length of ACoA and the external diameters of the ACoA and ICA. Though variations of the arteries at the base of the brain are common, it is necessary to be aware of all the variations as they may breed problems in the blood flow to the brain and may cause confusions in radiological procedures. Therefore in order to be able to plan, and design confident surgical, and endovascular interventions and yield successful results, probability of combined anatomical variations in the region should be kept in mind by the professionals.

Conflict of Interest: Nil

Funding Source: None

Table 1. The external diameters of the right and left internal carotid arteries (ICAs), anterior communicating arteries(ACoA) and the length of the anterior ACoA. (Significant findings are boldfaced)

Specimen Number	Diameter of Right ICA mm	Diameter of Left ICA mm	Diameter of ACoA mm	Length of ACoA mm.
1	3	3	1.5	2
2	5	5	1	3.5
3	5	5	2	3
4	4	5	2	2.5
5	4	5	4	2.5
6	3	3.5	1.5	2
7	5	3	3	1
8	4	4.5	0.5	5
9	4	5	3	4
10	4	4	2	2
11	3.5	4.5	3	1
12	4.5	4.5	1	1
13	4.5	4.5	1.5	4
14	4.5	4.5	0.5	10
15	4	4.5	2	4
16	4	3.5	2.5	4
17	3	3.5	0.5	3.5
18	2	4	1	2
19	5	4.5	0.5	4
20	4	3.5	3	1

Figure 1: Photograph showing the basilar artery (BA) failing to bifurcate and continues as the left posterior cerebral artery(PCA). The right posterior cerebral artery (PCA) was arising from the right internal carotid artery(ICA). Posterior communicating artery was absent bilaterally.

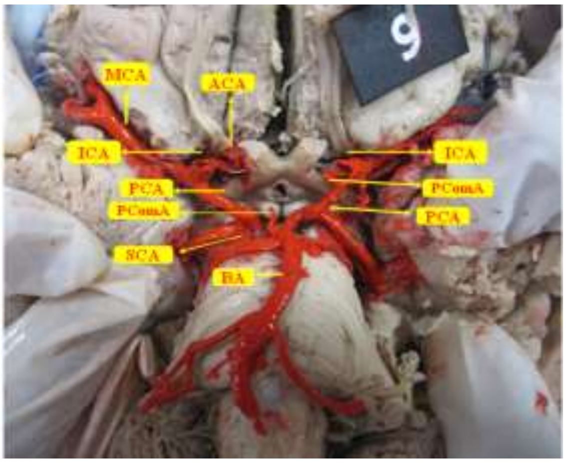

Figure 2: Fetal type of posterior cerebral artery(PCA) on the right side. ICA- Internal carotid artery, ACA- Anterior cerebral artery, PComA- Posterior communicating artery, MCA- Middle cerebral artery, SCA- Superior cerebellar artery, BA- Basilar artery

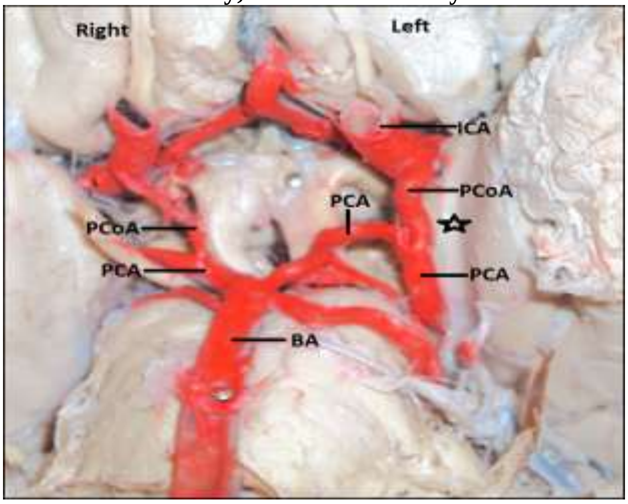

Figure 3: *Left posterior communicating artery(PCoA) had a larger diameter compared to left posterior cerebral artery(PCA). ICA- Internal carotid artery, BA- Basilar artery

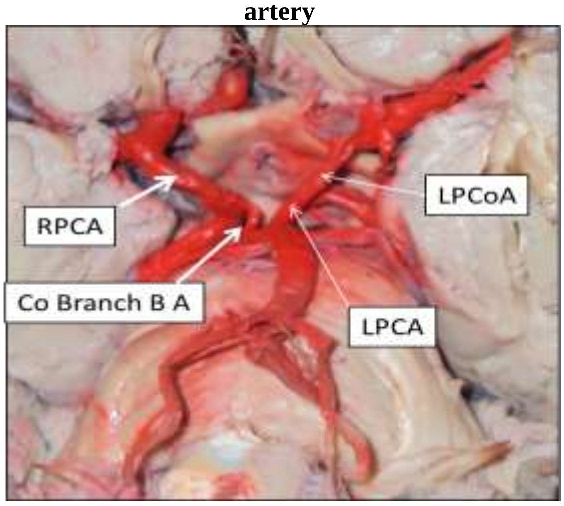

Figure 4: Right posterior cerebral artery(RPCA) arising from right internal carotid artery. A communicating branch(Co Branch BA) connecting RPCA to basilar artery. LPCA- Left posterior cerebral artery, LPCoA- Left posterior communicating artery

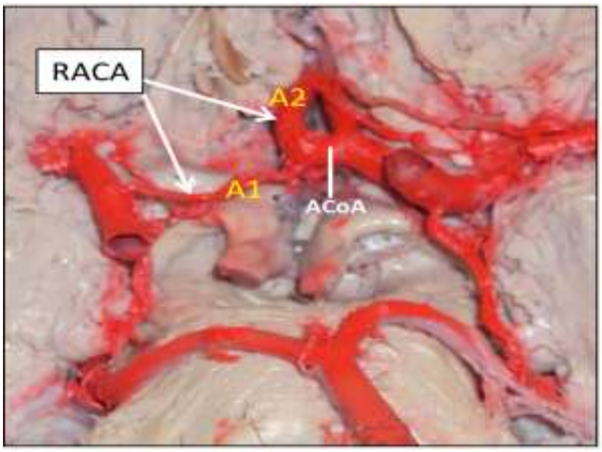

Figure 5: Right anterior cerebral artery showed a very thin diameter/calibre and after continuing into the inter hemispheral region and on communicating with the ACoA, presented with the larger calibre comparable with LACA, The precommunicating part of RACA (A1) is very thin (thread-like) than LACA. A2 segment of RACA seems to be a branch from Left anterior cerebral artery.

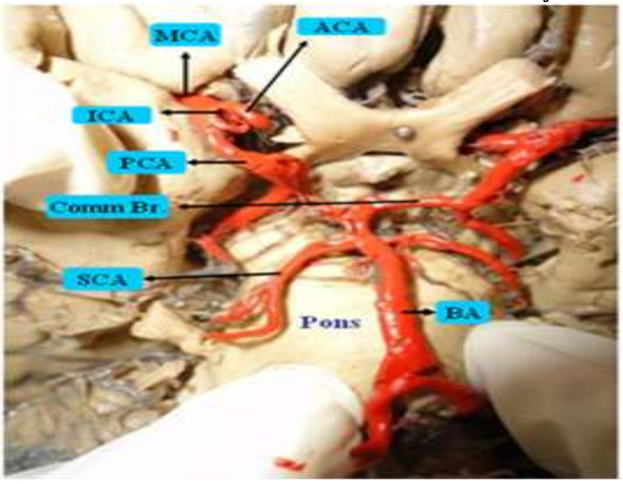

Figure 6: Bilateral fetal type of Posterior cerebral arteries(PCAs). A communicating branch(Comm Br.) from the Basilar artery(BA) to the PCA on the left side. ICA- Internal carotid artery, ACA- Anterior cerebral artery, MCA- Middle cerebral artery, SCA- Superior cerebellar artery,

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