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Study on Variations of Circle of Willis in Cadaveric and Radiological Study-in South Costal Population of Andhra Pradesh, India

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ABSTRACT
The circle of Willis is a large anastomotic ring present at base of brain. Variations in circle of Willis are frequent, it is important to have knowledge of variations in the diagnosis and treatment of different cerebrovascular diseases. Main objective of present study is to know the formative pattern of circle of Willis, note the variations in circle of Willis. Present Study was conducted on 50 cadaveric specimens obtained from voluntary body donation at the department of anatomy and 100 radiological films who referred for neuroimaging magnetic resonance angiography of human brain of both sexes, for a period of 3 years. Based on present study out of 50 cadavers 40% of circles, out of 100 radiological films 46% of circles variations were identified. Attenuated vessels (hypoplasia) were frequent of all anomalies, in 9 circles (18%) of cadaveric study, 26 circles (26%) of MRA films, accessory vessels (duplication) – in 7 circles (14%) of cadaveric study, 6 circles (6%) of MRA study, absence of vessels (aplasia)-in 4 circles (8%) of cadaveric study, 9 circles (9%) of MRA study, anomalous origin – in 5 circles (5%) of MRA study. Variations encountered in present study are attenuated vessels, accessory vessels and absence of vessels, anomalous origin. The most common anomaly of the circle of Willis in normal brains was hypoplasia of one or other components of the circle. Most frequent anomaly that encountered in this study was hypoplastic vertebral artery, followed by the circular part of the anterior communicating artery (A-1 segment), in both MRA and cadavers. Anomalies of the circle of Willis play an important role in the occurrence, manifestation of symptoms, treatment options and recovery process of certain cerebrovascular disorders.

INTRODUCTION

The correct recognition of the arterial ramifications at the base of the brain had a long and gradual evolution and it appears that many anatomists had a hand in describing and illustrating the circle, in the year 1664, sir Thomas Willis was the first describe the importance of circle of Willis in maintaining collateral flow[1].

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[2,3]; A completely formed circle of Willis appears in the 52-day embryo and all segments are slender and have an identical calibre[4,5]; In the remaining foetal period, important changes occur in the basic anatomy of the cerebral vasculature. The most obvious is the change from a dominant foetal-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 calibre 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[6]. Variations of circle of willis play important role in the development of cerebrovascular disease[7]; The state of the circle becomes important in determining the adequacy of brain circulation for cerebral aneurysms and also in ligation of internal carotid artery. There a several studies which described the possible link between anomalies of circle of Willis and mentally ill patient[8,9].

Arterial Circle (Circle of Willis): The major arteries that supply the cerebrum are joined to one another at the base of the brain in the circle of Willis (Fig. 1, 2). Starting from the midline in front, the circle consists of the anterior communicating, anterior cerebral, internal carotid (a short segment), posterior communicating and posterior cerebral arteries; then it continues to the starting point in reverse order. Normally, little exchange of blood takes place between the main arteries through the slender communicating vessels. The arterial circle provides alternative routes, however, when one of the major arteries leading into it is occluded. Frequently, these anastomoses are inadequate, especially in elderly people in whom the large vessels and communicating arteries may be narrowed by atheroma. Numerous central arteries arise from the region of the arterial circle as four groups. The abnormal arteries and the absent arteries are considered in this study as anomalies as they rise to incomplete circle of Willis. Other morphological differences which do not result in an incomplete circle

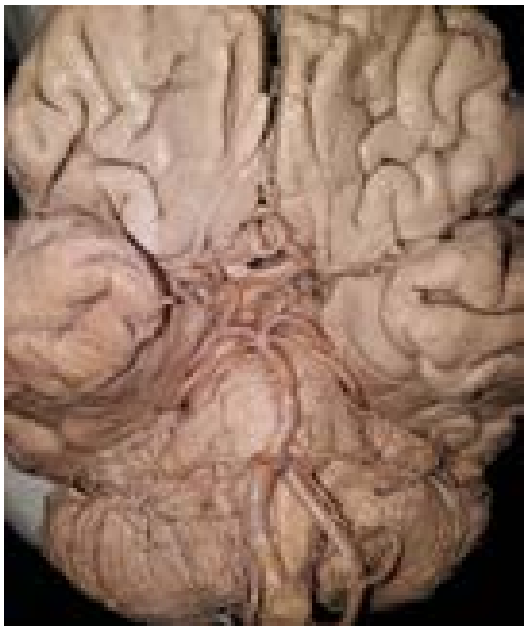

Fig. 1: Normal Circle of Willis (Cadaveric)

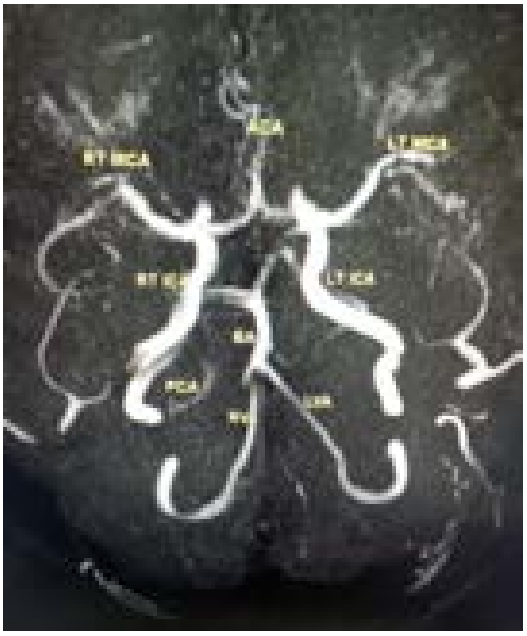

Fig. 2: Normal Circle of Willis (MRI)

of Willis are considered as anatomic variations. The basic criterion for considering the circle as anomalous was being unable to maintain an adequate blood flow. Alpers et al in their study defined that blood can circulate from any entrance point and return the same point[10].

MATERIAL AND METHODS

Study was conducted on 50 cadaveric specimens and 100 radiological films based on magnetic resonance angiography.

Specimens were collected from human cadavers (males and females) donated to Andhra medical college, Visakhapatnam for dissection and research purpose over last 10 years. Only cadavers with known identity were selected and all were originated from Andhra Pradesh region, aged between 25 to 75 years. Brains were removed carefully from the cranial cavity and immersed in 10% formalin for fixation. Each brain was placed over glass-wool in separate container to avoid damage. The circle of Willis of each brain was dissected carefully. The arterial circle was Studied, photographed and numbered. The pattern of the arterial circle and related variations were noted simultaneously. However, the calibre of each artery was not noted, though the variations were apparent, even on naked-eye.

Radiological study conducted on 100 films, the study includes subjects of adult age groups and of both sexes. The study was conducted in the department of radiology, Andhra medical college, Visakhapatnam, all patients went under 3D TOF-MR angiography using 1.5T machine. Arteries forming the circle of Willis were studied. For the purpose of identification, the circle of Willis is divided into anterior and posterior configurations. The anterior configuration consists of the anterior cerebral artery, anterior communicating artery and internal carotid artery. The posterior configuration consists of posterior cerebral artery, posterior communicating artery and basilar artery.

RESULTS

In the present study, the circle of Willis was studied by naked eye in 50 cadavers and magnetic resonance angiography (MRA) in 100 patients who have been advised for neuroimaging. We found variations in 40% of cadaveric study and 46% of MRA study

Anomalous circles: The following are the anomalies that encountered during study:

Anomaly	Cadavers (%) n= 50	MRA films (%) n=100
Attenuated vessels (hypoplasia)	18	26
Accessory vessels	14	6
Aplastic vessels	8	9
Anomalous origin	Nil	5

DISCUSSION

The observations made during the present study on the circle of Willis in both cadavers and MRA were compared with those recorded in earlier studies on the same topic. The prevalence of the typical circle i.e., the "normal text-book" polygon ranges from 4.6%[1] to 72.2%[11] In the present study 60 % of the circles in cadavers and 54% MRA exhibited the normal configuration. This was compared with the other studies with in the Indian and other than Indian population (Table 1 and 2).

Table 1: Incidence of abnormal circle of Willis in cadavers as reported in the Literature

		Incidence of abnormal circle of Willis in cadavers	
Researcher	Population	No of specimens	Percentage
Iqbal[4]	Indian	50	52
Singh *et al*.[6]	Indian	75	26
Siddiqi *et al*.[12]	Pakistan	51	29.4
Present study	Indian	50	40

Table 2: Incidence of abnormal circle of Willis in MRA as reported in the Literature

		Incidence of abnormal circle of Willis radiological	
Researcher	Population	No of specimens	Percentage
Krbbe *et al*.[1]	USA	150	42
Peyush pattayil	Pakistan	503	57.1
Arsany *et al*.	Switzerland	100	45
Present study	India	100	46

Hypolplasia of Vertebral Artery: The most common anomaly of the circle of Willis in normal brains was hypoplasia of one or other components of the circle. Arteries of less than 1 mm in external diameter were considered hypoplastic, except for the communicating arteries, where less than 0.5 mm was considered hypoplastic. Such hypoplastic vessels were encountered either alone or in combination with other anomalies.

Most frequent anomaly that encountered in this study was hypoplastic vertebral artery in cadaver (left side) in MRA film (right side) (Fig. 3, 4) followed by the circular part of the anterior communicating artery (A-1 segment). The present study by using cadavers and MRA stated hypoplastic vertebral artery by considering vessels diameter, we didn't find any other associated vascular anomalies of the vertebral artery. A hypoplastic basillar artery is frequently accompanied by vertebral artery hypoplasia and can predispose to posterior circulation ischemia[13] Hypoplastic Posterior

Fig. 3:Hypoplastic left vertebral artery (Cadaveric)

Fig. 4: Hypoplastic left vertebral artery (MRI)

Fig. 5: Duplication left superior cerebellar artery (Cadaveric)

Table 3: Incidence of hypoplastic vessels

	Incidence (%)	
Name of vessel	Cadavers (no-50)	MRA (no-100)
Vertebral artery	4	12
Anterior cerebral artery (circular part of A segment)	3	6
Posterior cerebral artery	1	4
Posterior communicating artery	1	4
Total	9%	26%

Table 4: Incidence of accessory vessels

	Incidence (%)			
	Cadavers (no-50)		MRA (no-100)	
Name of vessel	Duplication	Triplication	Duplication	Triplication
Superior cerebellar artery	2	2	1	1
Posterior cerebral artery	2	1	2	2
Total	4	3	3	3

Table 5: Incidence of aplasia of vessels

	Incidence (%)	
Name of vessel	Cadavers (no-50)	MRA (no-100)
A segment of Anterior communicating artery	2	4
Vertebral artery	1	3
Posterior cerebellar artery	1	2
Total	4%	9%

communicating artery with reticular fiber deficiency are the most probable source of unexplained haemorrhage[14]. Due to significant differences between cadaveric and radiological studies, it is necessary to analyse their results regarding arterial hypoplasia and aplasia separately. A diameter of less than 1 mm has been suggested as a criterion for arterial hypoplasia[15] A hypoplastic vertebro basillar system may be accompanied by foetal type posterior circle of willis and it predispose to ischemic events in posterior circulation[16] (Table 3).

Accessory vessels: Accessory vessels in the form of duplications/triplications involving one or more arteries were frequently encountered in the anterior portion of the circle of Willis and were found in 7 circles in the cadavers 6 cases in MRA films. Among the accessory vessels, duplications/triplications of superior cerebellar arteries were commonly occurred. The superior cerebellar artery is the most consistent branch of the basilar artery and arises near the bifurcation of the basilar artery. Although SCA variations have no clinical significance, preoperative identification of SCA variations is important for avoiding complications during surgery and/or for interventional procedures of the distal basilar artery. Malicki *et al*.[17] in his study stated that majority of duplication of superior cerebellar artery were related to the basillar artery origin of the marginal branches variant origin of superior cerebellar artery is significant during diagnosis and interventional neuroradiology to avoid incorrect diagnosis, to explain unusual picture of posterior circulation shock[18]. Duplication of left superiorcerebellarartery in cadaver shown in Fig. 5 (Table 4).

Agenesis and aplasia: Agenesis and aplasia signify total absence of the vessel. In the presence of the aplasia of P1 segment of PCA, blood supply to the occipital lobe would be solely dependent on intact ICA while in the presence of the aplasia of PCoA blood supply to the occipital lobe would be solely dependent on intact vertebrobasilar artery. The clinical importance of 2.35% of aplasia cannot be stated at this stage. Absent Aplasia of A_1 segment of left anterior cerebral artery and right vertebral artery in MRA films shown in Fig. 6. A_1 agenesis or hypoplasia is a risk factor for contributing to ischemic stroke. Mainly in arteries penetrating the striatal area (Table 5)[19].

Table 6: Incidence of Anomalous origin of vessels

	Incidence (%)	
Name of vessel	Cadavers (no-50)	MRA (no-100)
Anomalous origin of vertebrobasillar system from aortic arch	-	2
Left foetal posterior communicating artery substituting for left posterior cerebral artery	-	3
Foetal origin of right posterior cerebral artery as a continuation of right posterior communicating artery	-	1
Embryonic derivation of the posterior cerebral artery from the internal carotid	5	-
Total	5%	5%

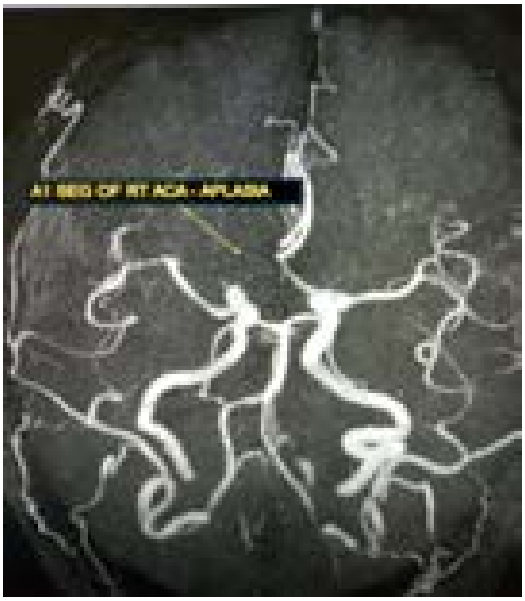

Fig. 6: Segment aplasia of Right anterior

Fig. 7: Absent right posterior cerebral artery cerebral artery

Abnormal origin: In this study we found anomalous origin of vertebrobasillar system from aortic arch in 2 MRA films (Fig. 6). Persistent left foetal posterior communicating artery substituting for left posterior cerebral artery in one film (Fig. 7). anomalous origin of the right vertebral artery may not be the sole reason for disease process. It can lead to misdiagnosis during diagnostic vascular studies (Table 6)[20].

CONCLUSION

Anatomical variations are probably genetically determined, develop in early embryonic stage and persist in postnatal life. Any change in normal morphology of the circle may lead to the appearance and severity of symptoms of cerebrovascular disorders, such as aneurysms and arterial variations are interconnected. A thorough knowledge of the variations of vessels is useful to surgeons in planning their shunt operations and the choice of the patients. Anomalies of the circle of willis play an important role in the occurrence, manifestation of symptoms, treatment options and recovery process of certain cerebrovascular disorders. It is very important to have knowledge on variation as they increase the incidence of aneurysm and thrombosis. This study will contribute the demography of this targeted population and to clinical medicine.

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