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Anatomical Variation And Morphometry Of Anterior Communicating Artery Of Circle Of Willis In Human Brain: A Cadaveric Study In Districts Of South Bengal

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Abstract:
Ojectives: *the aim of the study is to analyse the morphometry regarding shape, symmetry, length and diameters of anterior communicating arteries along with anatomical variations like absence, duplication and abnormal origin, aplasia or hypoplasia etc.*
Introduction*: The Circle of Willis is an anastomotic vascular network at the base of the brain in the interpeduncular fossa. Its major role is to provide efficient collateral circulation to cerebral and cerebellar tissue to prevent ischemia, and subsequent transient ischemic attack or stroke. Its anterior part is formed by the anterior cerebral artery from either side. Anerior communicating artery connects the right and left anterior cerebral arteries. Posteriorly, the basilar artery divides into right and left posterior cerebral arteries and each join to ipsilateral internal carotid artery through a posterior communicating artery. Anterior and posterior communicating arteries are important components of Circle of Willis, acts as collateral channel to stabilise blood flow. In the present study, anatomical variations and morphometry of anterior communicating arteries were noted.*
Methods: *Total eighty two apparently normal brain specimens from donated embalmed cadavers were collected at the Department of Anatomy, College of Medicine & JNM hospital, Kalyani, W.B.U.H.S., Nadia. Careful observation & measurement, pattern and variations of anterior communicating arteries were noted after proper formalin fixation and necessary dissection. The variations were photographed, coloured, numbered and labelled accordingly.*
Results: *The Sample of the present study included 82 formalin preserved brains of human cadavers. Out of total 82 human brains, 59 (72%) brains has been found to Confirm the classic form of 'Circle of Willis', that was, complete, symmetrical, normal calibre and heptagonal in shape. These 59 specimens have, therefore, been considered as 'Normal'. The rest 23 specimens (28%) of human brain were found as 'variations'. 72 out of 82 specimens (88%) of human brain were found 'Heptagonal' in Shape and complete; rest 10 specimens (12%) were incomplete and not heptagonal in shape. 59 out of 82 specimens (72%) were found 'symmetric'; rest 23 specimens (28%) were found to be 'asymmetric'. Normal and Complete heptagonal form of circle of willis are found without any Gross Variation Was Found in 59 Cases (72%). Thirteen types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of ACoA, (15.85%).*
Keyword: *Circle of Willis, Arterial variation, Neuroanatomy, Clinical Anatomy, Anterior communicating Artery, Hypoplasia, Aplasia, Duplication, Triplication.*

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I. Introduction:

The circle of Willis (CoW) was originally defined by the English anatomist Thomas Willis who first described it completely and correctly in 1664, in his paper entitled Cerebrianatome cui accessitnervorum descriptioetusus, as an arterial anastomotic structure that exhibits complete symmetry in shape and its configuration. Much later, in the literature appeared more and more articles reporting various variations from the original definition. Many authors reported, especially in the last two decades, a percentage higher than 50% of all PAWs they have analyzed as having significant asymmetries and variations. Because CoW provides the best collateral source of blood flow in arterial occlusive disorders, identifying anatomical variants that could be present at this level is especially essential in planning surgery for cerebral aneurysms. Also, several studies have shown these anatomical variations of the CoW play an important role in the development of cerebrovascular diseases (ischemic and hemorrhagic strokes) and even in psychiatric disorders. (Health Science Journals 2001)

The Circle of Willis (CoW) is an anastomotic arterial network on the base of the brain. Its major role is to provide efficient collateral circulation to cerebral and cerebellar tissue to prevent ischemia, and subsequent transient ischemic attack or stroke (Karatas, Coban, Cinar, Oran, &Uz, 2015; Karatas, Yilmaz, Coban, Koker, &Uz, 2016; KlimekPiotrowska et al., 2016) (1-3). Stroke is a major cause of disability and the second leading cause of death worldwide [4]. Seventy five percent of all stroke deaths and 81% of the total disability adjusted life years lost due to stroke occur in developing countries [5, 6]. First described in Thomas Willis' landmark work “CerebriAnatome” (Willis, 1664), (7) the CoW is classically described as a symmetrical polygon, derived from anastomoses between Stroke risk factors include age, sex, race, hypertension, diabetes, hyperlipidemia, diet, smoking, and alcohol. Arteriogenesis is a complex embryologic process and can lead to numerous anatomical variations. In case of a major cerebral arterial occlusion, collateral vessels play an important role in maintaining essential blood flow. Circle of Willis is the most important collateral system in the brain with multiple potential anatomical variations. Some of the most common variations in the circle of Willis include hypoplasia or aplasia of one or both posterior communicating arteries (PCoA) (34 to 68%), hypoplasia or aplasia of the A1 segment of anterior cerebral artery (ACA) (4 to 10%), absence or fenestration of anterior communicating artery (ACoA) (12 to 21%), persistent fetal origin of posterior cerebral artery (fPCA) (4% to 26%), and infundibular dilatation or widening of PCoA (7% to 15%). Although there are numerous studies on anatomical variations of the circle of Willis, presence of any association between anatomical variations of circle of Willis and incidence of ischemic stroke is still unclear. The blood supply to the brain was achieved from two sources, internal carotid artery and vertebral artery. 9153

History of Circle of Willis:

On St Martin’s Day (November 11), volleys of gunpowder explosions disturb the quiet of Fenny Stratford, a small country town midway between Oxford and Cambridge close to Stony Stratford. The explosions are part of a curious celebration, which has taken place every year since 1734. The celebration consists of three events. The first is a sermon in the parish church for which the invited speaker receives the fee of one guinea. The next event is a turkey dinner at the Bull, the inn next door, where each attendee must pay his own alcoholic burden without compulsory aid from his companions. The third event is the firing by the town dignitaries of the “Fenny poppers,” six mugs like cannonades, forged from gunmetal, each weighing about 20 pounds and measuring 7 inches high with a 3⁄4-inch bore and 6 inches deep. The poppers are filled with a quarter pound of gunpowder, plugged with well rammed newspaper, lined up in a protective trench, and fired at 12 noon, 2 PM, and 4 PM using a metal rod made red-hot in the church furnace. So is remembered in inimitable English fashion the death on St Martin’s Day in 1675 of Thomas Willis, the famous anatomist-physician and professor of natural philosophy at Oxford. (This, probably unique among medical memorials, was conceived by Browne Willis, Thomas Willis’s grandson, a scholar and antiquarian of repute, as a monument to his grandfather [Stephen Huckle, personal communication, 1996]. The rent from houses left in the will of Browne Willis in 1760 pays for the strange custom.) Willis of course is famous for the arterial anastomosis at the base of the brain that bears his name. In medical and scientific research, originality of theme and content is of major importance. Fame is often derived from having a clinical sign, disease, or anatomic structure named after the originator. Thus, we have Lhermitte’s sign, the Babinski reflex, the Chiari malformation, the Dandy-Walker syndrome, the aqueduct of Sylvius, the veins of Trolard and Labbe´, and the circle of Willis. We believe the individuals whose names are attached to these signs, diseases, or structures to be the first to have described them. This is almost always true. Willis is thought by many to be the first to illustrate the arterial circle at the base of the brain that has his name. This attribution is in error. Thomas Willis’s fame is derived from multiple sources. Not only did his book CerebriAnatome describe and illustrate the circle, but it marked the transition between medieval and modern notions of brain function. Willis was also the first physician to use the term neurology and was among the first to present the notion of a circulating hormone from the pituitary and gonads. Willis illustrated the ‘circle ‘(which actually is nine sided, a nonagon) in his book published in 1664. Von Haller in the late 18th century was the first to refer to the arterial anastomosis as the circle of Willis. Before Willis, little was known about the physiology and function of the brain. Willis was the first to recognize the importance of the circle in maintaining collateral flow to the brain (“. . . if the Carotides of one side should be obstructed, then the vessels of the other side might provide for either Province . . .” [4]), and recorded the clinical histories of two patients in whom this anatomic arrangement had prevented apoplexy. Willis never claimed to be the first to describe the circle. Johan Jacob Wepfer of Schaffhausen in Switzerland in his book ObservationesAnatomicae ex CadaveribusEorom Quos SustulitApoplexia in 1658 clearly described in detail the anastomoses that make up the circle; however, he failed to illustrate the circle. Even before Wepfer, Vesling in 1647 and 1651 illustrated an almost complete circle in his book SyntagmaAnatomicum. (The circle AJNR

18:1033–1034, Jun 1997 0195-6108/97/1806–1033 © American Society of Neuroradiology HISTORY 1033 is almost complete because of a question as to whether the anterior communicating artery is shown in the illustration, or whether the apparent communication merely represents background shadowing (Samuel, 1997)

There is no mention of a communication in the explanatory text.) Delving further back into history we encounter GuilioCasserio (1545–1605), who in his elegant atlas published posthumously in 1627 illustrated an almost complete arterial circle in a book De HumaniCorporisFabrica published by AdrianusSpigelius. This illustration is probably the first documented illustration of the anastomoses, although 65 years earlier Gabriel Fallopius in 1561 and 1562 in his Anatomical Observations described an almost complete circle save for the posterior communicating artery, which he thought was only indirectly connected with the internal carotid artery through a network of small arteries. Casserio in his illustration corrected this mistake on one side but left it as Fallopius described it on the other side (the octagon of Casserio?). (It is quite possible that the posterior communicating artery was absent, a not infrequent anomaly, in the brain specimen that Casserio examined.) Thus, 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. Originality is a more basic value than priority. While Willis might not have been the first to recognize the presence of an arterial circle at the base of the brain, it is his independence of thought and creativity in understanding the significance of the circle that has produced the scientific work of the most value and has generated the most lasting recognition. This alone provides sufficient historical justification for calling the structure the circle of Willis.

Anterior Communicating Artery:

The anterior communicating artery complex consists of two anterior cerebral arteries (ACA), the anterior communicating artery (ACoA) and the recurrent arteries of Heubner. ACA can be divided into the three following segments: A1 originating from the internal carotid artery, A2 extending from ACoA and A3 also known as the pericallosal artery. The ACoA complex has a strong clinical relevance due to the fact that it is the most common site of intracranial aneurysm location. Despite its considerable significance, little is known about the anatomical variations of the ACoA complex.

Many anomalies such as aplasia, hypoplasia, duplication or fenestration of ACA segments and ACoA have been described. Authors used various methods such as digital subtraction angiography, computed tomography angiography or intraoperative observations to study the anterior cerebral circulation. However those studies have a number of limitations. First of all they are focused on patients with intracranial aneurysms, and not healthy subjects. 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 ACoA aneurysms) regardless of ACoA and A2 segment anomalies.

Comparatively few studies describe the anatomy of the ACoA complex in subjects without intracranial aneurysms. These are mainly cadaveric studies and thus are hard to extrapolate to living patients. There is still a need to further explore the anatomy of the anterior cerebral circulation. The results of such studies would be useful when planning surgical approaches, and would allow avoiding any unexpected anatomical variations during treatment of ACoA aneurysms. Such anatomical problems may include double fenestrations of the A2 segment mimicking an aneurysm neck or mistaking a duplicated A1 segment for an ACoA aneurysm (Krzyz˙ewski, Tomaszewski, Kochana, Kopec, Klimek-Piotrowska , Walocha,2015) .

Review Of Literature:

The review of Literature is a specific area related to this study, entitled “Anatomical Variation and Morphometry of Anterior communicating Artery of Circle of Willis in Human Brain: A Cadaveric Study in Districts of South Bengal” have been reviewed.

Gunnal, Farooqui, and Wabale (2014) have studied the Circle of Willis (CW) is a polygonal anastigmatic channel at the base of the brain which unites the internal carotid and vertebrobasilar system. It maintains the steady and constant supply to the brain. The variations of CW are seen often. The Aim of the present work is to find out the percentage of normal pattern of CW, and the frequency of variations of the CW and to study the morphological and morphometric aspects of all components of CW. Methods. Circulusarteriosus of 150 formalin preserved brains were dissected. Dimensions of all the components forming circles were measured. Variations of all the segments were noted and well photographed. The variations such as aplasia, hypoplasia, duplication, fenestrations, and difference in dimensions with opposite segments were noted. The data collected in the study was analysed. Results. Twenty-one different types of CW were found in the present study. Normal and complete CW was found in 60%. CW with gross morphological variations was seen in 40%. Maximum variations were seen in the PCoA followed by the ACoA in 50% and 40%, respectively. Conclusion. As it confirms high percentage of variations, all surgical interventions should be preceded by angiography. Awareness of these anatomical variations is important in neurovascular procedures(Gannals, Faroque, & Wabale, 2014).

Dumitrescu, Cobzaru , Barbu , Costea Tanase and Hilițanu (2021) have studied the circle of Willis provides the best collateral source of blood flow in arterial occlusive disorders, identifying anatomical variants that could be present at this level is especially essential in planning surgery for cerebral aneurysms. Given the fact that the frequency of these anatomical variations of circle of Willis has not yet been sufficiently evaluated in the Romanian population until presently, we have conducted a research in a regional health unit, where there are admitted patients with neurological and neurosurgical diseases living in the North-Eastern region of Romania, in order to identify morphological features of the constituent vessels of fresh circles of Willis at the moment of the autopsy of the deceased patients in the Emergency Clinical Hospital „Prof. dr. N. Oblu" Iași. There has been noted the presence or absence, variations of shape, position or trajectory of each arterial segment. In the end, our results were compared with those from literature in order to identify some particular pattern of this anastomotic structure in the population of the North-Eastern region of Romania(Dumitrescu, Cobzaru, Babu, Cotea, Tanase, & Hlitanu, 2021)

Accourding to Yaseen, HussainRiyaz, Siddiqui (2016) study about the variations regarding shape, symmetry, length and diameters of the component arteries. The study also includes other variations like absence, duplication and abnormal origin of component arteries. Methods: In the present study 31 specimens of human brains are obtained from the Department of Anatomy IIMSR Warudi, Badnapur, Dist. Jalna. Careful observation & measurement of the component arteries are done after proper preservation and necessary dissection. The findings are then recorded and analysed. There were 21 out of 31 specimens (67.74%) found to be classic form of 'Circle of Willis', that was, complete, symmetrical, normal calibre and heptagonal in shape. These 21 specimens have, therefore, been considered as 'Normal'. The rest 10 specimens (33.5%) of human brain were shows variations. Out of 33.5% variations most of the variations are seen in posterior communicating artery 3.22%, followed by anterior cerebral artery (6.45%) and anterior communicating artery (6.45%). Most common type of variation is hyperplasia(Yaseen, Riyaz, & Siddique, 2016).

Furuichi, Ishikawa, Uwabe, Makishima, Yamada (2018) have studied the Variations of the circle of Willis (CW) influence blood supply to the brain and adjacent structures in adults. We examined the formation of the CW in 20 human embryo samples at the end of the embryonic period using 3-D reconstructions of serial histological sections. The CW was closed in all samples, and did not form in a single plane, but was composed of multiple stair-like planes. The artery acutely curved at the caudal part of the CW, namely, at the inlet of the basilar artery and bifurcation of the P1 segment of the posterior cerebral artery (PCA), reflecting flexure of the mesencephalon and diencephalon at this stage. Variations were observed in 17 of 20 samples—only anterior parts (anterior communicating artery [Acom] and anterior cerebral artery [ACA]) in 10 samples, only posterior parts (posterior communicating artery [Pcom]) in one sample, and both anterior and posterior parts in six samples. Variations included the Acom formed as partially duplicated in three samples, duplicated in four, plexiform in three, and no channel as a result of a single azygos ACA in one. The ACA formed as duplicated in two, median ACA in two, and right hyperplasia in one. The Pcom formed in hyperplasia of either side in six samples. Variations observed in this study are similar to those observed in foetuses, neonates, and adults. The P1segment of PCA was very large in all samples(Furuchi, Ishikawa, Uwabe, Makishima, & Yama, 2018).

Singh, Kannabathula, Sunam and Deka have discussed the circle of Willis (CW) is a vascular network formed at the base of skull in the inter peduncle fossa. Its anterior part is formed by the anterior cerebral artery, from either side. Anterior communicating artery connects the right and left anterior cerebral arteries. Posterior, the basilar artery divides into right and left posterior cerebral arteries and each join to ipsilateral internal carotid artery through a posterior communicating artery. Anterior communicating artery and posterior communicating arteries are important component of circle of Willis, acts as collateral channel to stabilize blood flow. In the present study, anatomical variations in the circle of Willis were noted.

82 apparently normal formalin fixed brain specimens were collected from human cadavers. 59 Normal anatomical pattern and 23 variations of circle of Willis were studied. The Circles of Willis arteries were then coloured, photographed, numbered and the abnormalities, if any, were noted. Also discussed the twenty variations were noted. The most common variation observed is in the anterior communicating artery followed by some other variations like the Posterior communicating arteries, anterior cerebral artery and posterior cerebral artery (PCA) was found in 20 specimens.

Knowledge on of variations in the formation of Circle of Willis, all surgical interventions should be preceded by angiography. Awareness of these anatomical variations is important in the neurovascular procedures.(Singh, Kannabathula, Sunam, & Deka, 2017)

Aims and Objectives:
Aim:

To study the anterior communicating artery in Circle of Willis for morphometry along with variation in the branching pattern and to correlate them clinically.

Objectives:

a) To study the branching patterns of anterior communicating artery under the following parameters in morphological specimens:
   i. Normal or abnormal calibre of anatomizing vessels.
   ii. Symmetrical or asymmetrical formation.
   iii. The morphometry and variations of anterior communicating arteries.

b) To study the variations in the formation under the following parameters in morphological specimens:
   i. Accessory vessels
   ii. Hypoplasia
   iii. Aplasia
   iv. Duplication
   v. Triplication
   vi. Absent vessels, and
   vii. Anomalous origin in morphology

c) To study the clinical correlation of the anterior communicating artery in Circle of Willis and to state its importance in cerebrovascular diseases such as transient ischemic attack, CVA etc.
d) To compare the results of this study with the previous studies and eventually arriving in a conclusion.

II. Materials And Methods:

This Study was done in the Department of Anatomy, College of Medicine & JNM Hospital, Kalyani,Nadia, W.B.U.H.S. The study was started by undertaking the institutional Scientific Review Committee and Ethics committee clearance. Circle of Willis was studied on 82 formalin preserved brains of human cadavers. The cadaveric bodies from which brains removed were of unknown age and unknown cause of death. The approximate age was 60-80 years. Arachnoid mater in the interpeduncular fossa was removed carefully to expose the circulus arteriosus. All components of the CoW were observed emphasizing anterior communicating arteries. Gross morphological variations of anterior communicating arteries in CoW were noted and photographed. Detailed study of these regarding morphometric aspects of the ACoA was done. Length and diameter of all the ACoA forming CoW were measured. Morphological variations were well photographed. Specimens were sorted out according to classification of the anatomical variation of ACoA of circulus arteriosus (CW). Variations of all the segments were noted and were photographed. The variations such as hypoplasia, aplasia, duplication, fenestrations, and difference in dimensions with opposite segments were noted.

III. Results And Analysis:

The Sample of the present study included 82 formalin preserved brains of human cadavers.

Out of total 82 human brains, 59 (72%) brains has been found to Confirm the classic form of 'Circle of Willis', that was, complete, symmetrical, normal calibre and heptago- nal in shape. These 59 specimens have, therefore, been considered as 'Normal'. The rest 23 specimens (28%) of human brain were found as 'variations'. 72 out of 82 specimens (88%) of human brain were found 'Heptagonal' in Shape and complete; rest 10 specimens (12%) were incomplete and not heptagonal in shape. 59 out of 82 specimens (72%) were found 'symmetric'; rest 23 specimens (28%) were found to be 'asymmetric'. Normal and Complete heptagonal form of circle of willis are found without any Gross Variation Was Found in 59 Cases (72%).

Twenty different types of incomplete and complete heptagonal form of circle of willis are found in this present study.

(1) Classical type of Circle of Willis was seen in 59 specimens.
(2) Eight types of complete heptagonal and in- complete form of Circle of Willis associated with the variations of A1 segment of ACA (9.75%).
(3) Thirteen types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of ACoA, (15.85%).

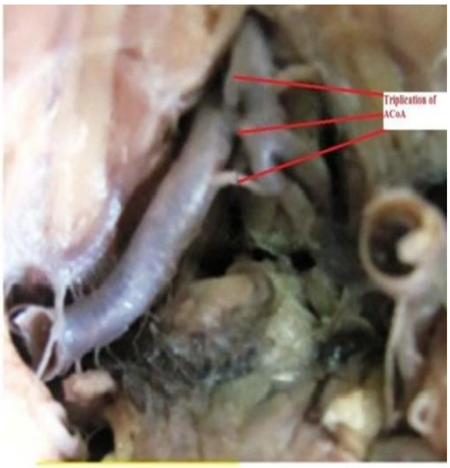

Fig.1: Triplication of ACoA

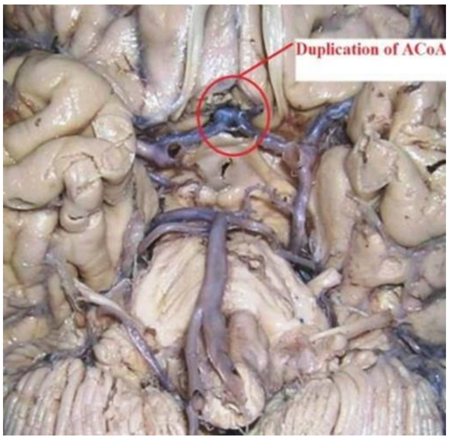

Fig.2: Duplication of ACoA

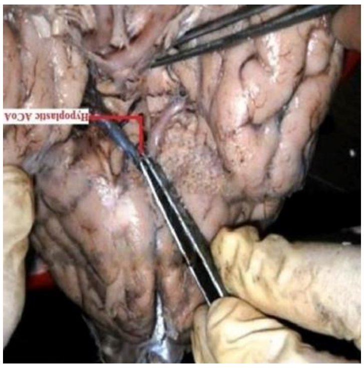

Fig.3: Hypoplastic ACoA

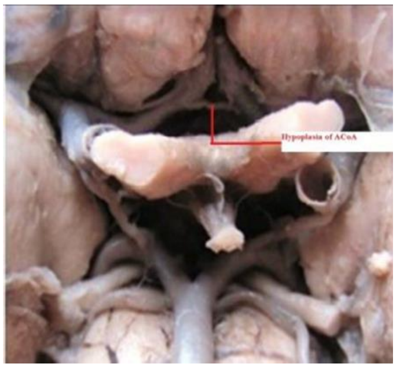

Fig.4: Hypoplasia of AcoA

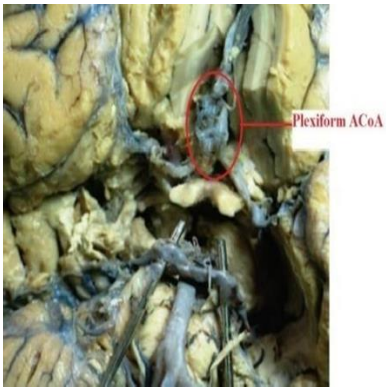

Fig.5: plexiform ACoA

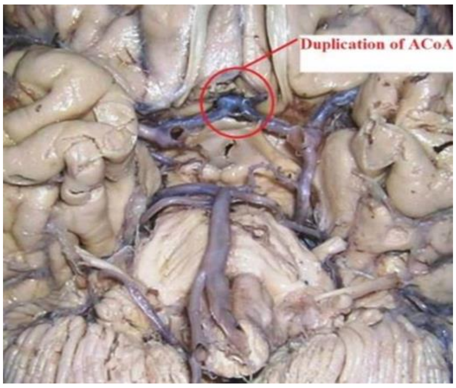

Fig.6: Duplication of ACoA

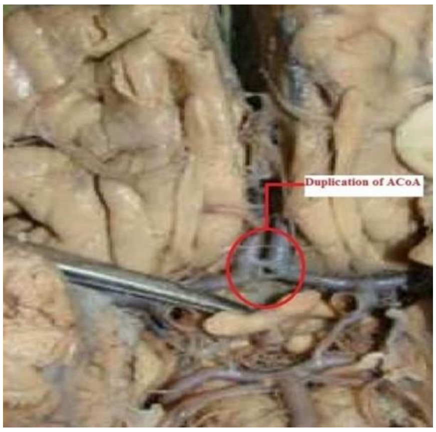

Fig.7: Duplication of ACoA

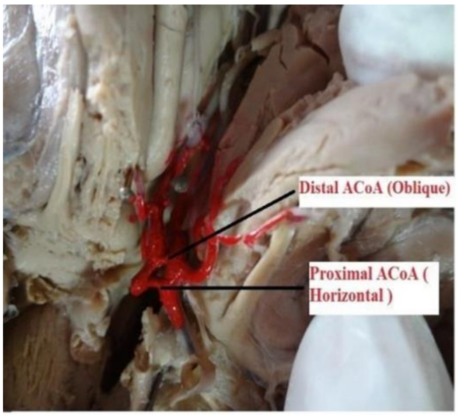

Fig.8: Multiple ACoA (Horizontal & Oblique)

Table 1: Anatomical Variations

Variation type	Number of variations	Percentage
Complete and normal CW	59	72
CW gross variations	23	28
Incomplete CW	10	12
ACA - A1 Segment	8	9.75
ACoA	13	15.85
PCA - P1 Segment	4	4.87
PCoA	12	14.63

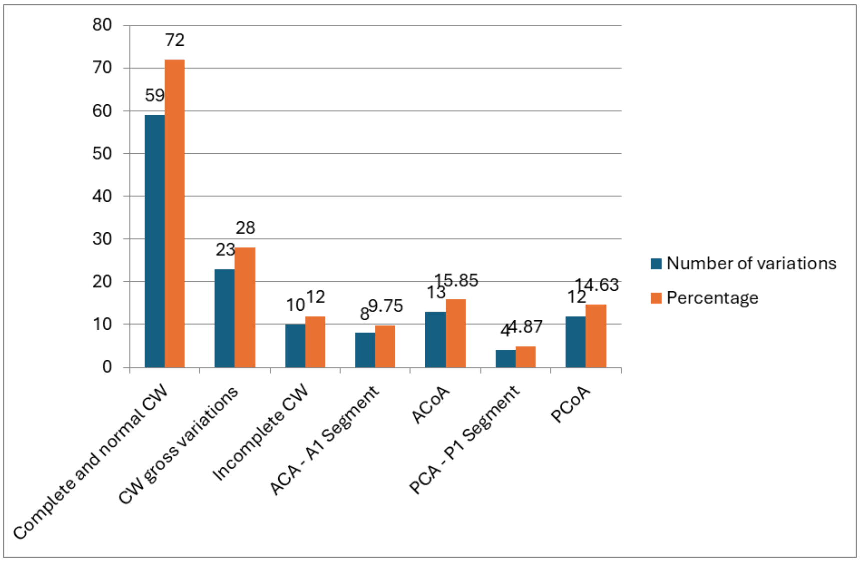

Fig.9: Variation Chart

Table 2: Symmetry of different components of circle of Willis

Segment of CW	Symmetrical	Asymmetrical
ACoA	69 (84.15%)	13(15.85%)
ACA-A1	74(90.25%)	8(9.75%)
PCoA	70(85.37%)	12(14.63%)
PCA- P1	78(95.13%)	4(4.87%)

Table 3: Percentages of different variations of circle of Willis

Components	Variations	Right	Left	Number of Specimens	Total	Total %
ACA – A1 Segment	Hypoplasia	5	--	5		
	Aplasia	--	1	1	8	9.75%
	Plexiform1	--	1	1		
	Accessory	1	--	1		
ACoA	Duplication	--	--	4		
	Triplication	--	--	1		
	Hypoplasia	--	--	5	13	15.85%
	Fused	--	--	2		
	Plexiform	--	--	1		
PCoA	Hypoplasia	3	5	8	12	14.63%
	hyperplasia	--	1	1		
	Aplasia	1	2	3		
PCoA- P1 Segment	Hypoplasia	1	1	2		
	Hyperplasia	--	0	0	4	4.87%
	Aplasia	1	1	2		

IV. Discussion:

Blood supply to the brain is mainly from the circulus arteriosus and Thomas Willis was pioneer in describing Circle of Willis in 1962]. Since then, many authors have reported number of anatomical variations in the formation of Circle of Willis. Variations of the origin and distribution of the arteries at the base of the brain are common. All these variations are either due to the disappearance of the vessels that normally persist or the persistence of the vessels that normally should disappear or formation of new vessels due to hemodynamic factors. In most of the arterial variations, the brain function may not be affected due to the collateral circulation and compensation from the arteries of the other side

A thorough knowledge of the variations in cerebral arterial circle has grown in importance with the increasing number of procedures like aortic arch surgery, microsurgical clipping of anterior communicating artery aneurysms; its variations are common and the textbook picture of symmetrical, large, approximately equal sized vessels were present only in 30% subjects. . The prevalence of the 'typical or classic circle', the "normal" textbook polygon ranges from 4.6% to 72.2%. A possible reason for the wide range may be the diversity in nomenclature and the criteria used to define hypoplastic vessels. There is little unanimity in nomenclature and quantitative measurement of the diameters of all the component vessels of 'circle', which has not been measured in several studies and has relied upon rough estimations of t diameter in determining the anomalies of the CW rather than actual measurements. Vessels have been described as 'thread-like', 'string-like', 'minute', and 'very small' without regards to measured diameter. In the present study, typical or classic configuration was found only in 72% and variations found in the rest 28% of the brains. These observations appear to be more or less in according with those of Windle, Fawcett who observed normal pattern in 72.8% to 82.5% cases and variant pattern in 18% to 27.2%. But the present observations are at great variance with those of Alper's et al, Baptista, who recorded typical or classic pattern in 30% to 90% and variant in 10% to 70% cases. As mentioned earlier, in our present study most of the variations are seen in anterior communicating artery (15.85%), Followed by posterior communicating artery (14.63%, Table 2), followed by anterior cerebral artery (9.75%) and variations are found in Posterior cerebral artery (4.87 %) in this present study. In the present study, the anterior cerebral artery, one of the components of CW has been found to exhibit abnormalities where Hypoplasia on right side is 8%, Aplasia is 1.3% Plexiform pattern is 1.3% by the way of fusion between the arteries of one side with that of the contralateral side, forming fused ACA. 2.6% of such specimens were found. Fusion of the anterior cerebral artery may cause absence of ACOM artery. Absence of ACOM is also possible without fusion of anterior cerebral artery. The ACA has anastomoses between them in 2.6% with a short fused A2 trunk and one among the ACA is found to be predominant in the A2 segment. A fused short A2 trunk is more commonly found. In the A2 segment of the ACA, one ACA is found to be predominant and provides blood supply to both hemispheres in its distal aspect of the cerebral hemispheres.

The third ACA or an accessory ACA generation in A2 segment in the study is found in one brain specimens (1.3%) and is found to be originating from the ACoA. This represents our most common finding in the anterior circulation; with 3 cases of "extra ACA", they were all originated directly from the ACoA.

The present observations largely corroborate with those of Windle and Alpers et al who recorded 3% and 2% cases of absence of the ACOM due to fusion of the two anterior cerebral arteries respectively.

The present observations fail to demonstrate the complete absence of ACOM without fusion of anterior cerebral artery and so unable to compare the finding with those of Fawcett et al who found complete absence of anterior communicating artery in 0.14% cases.

Another form of variation was found, that is, right sided hypoplastic anterior cerebral artery 8%. The diameter below which the segment of ACA that is part of CW could be called hypoplastic has not been well defined, but Perlmutter and Rhoton used 1.5 mm as the cut off value.

They found 10% of the brains to have less than 1.5 mm in diameter in the aforesaid segment. Alpers et al found string like components of one of the vessels of the CW in 28% cases, with that part of ACA being the predominant site. Riggs and Rupp observed hypoplasia of that part of ACA in 7% cases.

Plexiform anterior cerebral artery is a very rare occurrence. The Plexiform nature of the anterior cerebral artery observed in the present study may be due to the incomplete fusion of the primitive plexiform anterior cerebral artery to form a single vessel. This specimen was unique, having a hypoplastic, plexiform initial segment of the right anterior cerebral artery. Since the distal part of the anterior cerebral artery was large and had a fusion with the left anterior cerebral artery, this variation might not cause any functional disturbances. But it might cause serious infarct of both hemispheres in case of thrombosis or rupture of the initial segment of the left anterior cerebral artery because of the poor collateral circulation provided by the artery of the right side. In present literature survey, we could not find a report on occurrence of such a variation. No other form of abnormalities has been found in ACA.

In the present study, the most common variation is seen in the (ACoA) anterior communicating artery (15.85%), most common type of variation is double or duplication of artery. Other variations were hypoplasia, fused artery, Triplication and Plexiform type. Duplication of anterior communicating artery was the most common variation, which was seen in 5.3% of subjects. Tripling of anterior cerebral artery was least common variation which was seen only in 1.3% of subjects. Same extent of a similar variation was also noted by Kanchan Kapoor, PN Jain and Vare and Bansal. The absence of anterior communicating artery was observed in 2.6% of subjects. Fawcett and Blachford, Blackburn, Von Mitter wallner, Kanchan Kapoor, PN Jain and Vare and Bansal found same variation, but less frequently, to range from 0.14% to 1.8%, as compared to that in the present study.

Fusion of anterior communicating arteries were seen in 2 cases, the two anterior cerebral arteries were not joined by anterior communicating artery, but they came in close contact with each other, with a fistula formation in between them. This finding agreed with those of other workers. The incidence of this variation was similar to the observation made by Windle, Stopford. The old author using the term fistula is not convincing recent study done by Kanchan Kapoor included this variation of fused anterior communicating artery as the absence of artery.

Berk and Stopford had reported duplication of anterior communicating artery in 9% and 7.9% cases respectively. Vare and Bansal mentioned in their study, that in duplication or triplication of the vessel, the posterior most artery had a smaller size, which was similar to that which was seen in the present study. Various forms of duplications of anterior communicating artery and the incidence of this variation in present study were similar to the findings of study done by Kanchan Kapoor.

In the present study, 1.3% cases had persistence of plexiform pattern of anterior communicating artery, between the two anterior cerebral arteries. A similar variation with same frequency was observed by von Mitter wallner. Other studies found this variation to be less frequent. The anterior communicating artery appears in human embryo of size 18 mm, as a reticulated anastomosis between the two anterior cerebral arteries. The preservation of plexus or network of vessels between the two anterior cerebral arteries exists in few adult brains, as was observed in present study. Very few variations were seen during vessels. Two anterior communicating arteries seen in the present study had an oblique course. In two cases, the anterior communicating artery was seen in the median fissure. This variation during anterior communicating artery was associated with long and straight course of the anterior cerebral artery. Similar variations were mentioned by Vare and Bansal, Kapoor K in their study.

Abnormalities in the origin of posterior cerebral arteries are very rare. In this present study, the variations in posterior cerebral artery seen is 5.33%. An uncommon anomaly was found in this study in a brain specimen the right P1 segment (hypoplasia) of Rt posterior cerebral artery (PCA) is very thin compared to the contralateral side and is dividing into slender branches at distal end of P1 segment. One of its branches is joining the hyperplastic anterior choroidal artery.

The normal AChA has potential anastomoses with its neighboring arteries, especially with the PCoA and PCA. Hyperplasia of the AChA seems to represent a situation in which one of those anastomoses remains and enlarges as a main pathway of the artery, while a segment of the PCA just proximal to the anastomosis eventually attenuates. Although a study conducted by Macchi et al. reports that the possibility of origin of posterior cerebral artery from internal carotid artery is about 13%, there are hardly any other reports of origin of posterior cerebral artery from internal carotid artery. They have also observed about 2% of cases, where absence of a posterior communicating artery was associated with the origin of a posterior cerebral artery from the internal carotid artery as reported in the present study. There are some cases of hypo plasticity in posterior cerebral artery; however, this is reported to be less than that in the posterior communicating artery. According to Voljevica et al., among the variations that damage the posterior segment of circle of Willis, the unilateral posterior cerebral artery is the most common, followed by unilateral aplasia or hypoplasia of the posterior communicating artery. In a report by Kapoor et al, multiplication of posterior cerebral artery was observed in 2.4% cases while it was hypoplastic in 10.6% brains.

In this present study, the most common variation is seen in the posterior communicating artery (14.63%), is hypoplasia 8.66% followed by the Aplasia of PCoA (5.33%). These results were in accordance with the previous reports. Some reports state that the posterior communicating artery is the most common site of abnormalities in the posterior part of the circle. In most cases, it is either absent or hypoplastic.

A study conducted on cadavers revealed 51% cases of bilateral hypoplastic posterior communicating artery and 13% cases of unilateral hypoplastic posterior communicating artery. However, in the present study, there was complete absence of bilateral posterior communicating artery, and because of that, the posterior segment of circle of Willis was not formed. Such bilateral absence of posterior communicating artery is one of the rare variations and is reported to be about 3%.

Anomalies in the formation of circle of Willis are equally important for clinicians and surgeons as it is for anatomists. The neurosurgical importance of these variations lies in the exposure of this part of the brain for different purposes. Knowledge of vascular variations will increase the success rate of the surgical procedure. These variations should also be considered during the skull base and carotid surgeries, and cerebral angiography. In addition, it has been reported that the incomplete circle of Willis predisposes about one-sixth of individuals to cerebral ischemia during the transient closure of carotid artery, but the risk is more than three times in case of contralateral internal carotid artery occlusion.

According to Tanaka et al, variations in the circle of Willis correlate significantly with relative contributions by the flow rates of the bilateral internal carotid and basilar arteries, which might significantly contribute to the clinical importance of the variations. According to Alastruey et al, in normal subjects, the system does not require collateral pathways through communicating arteries to adequately perfuse the brain. The communicating arteries become important in cases of missing or occluded vessels.

It has been reported that the beginning, course, and result of the cerebral-vascular diseases depend hugely on the possibility of establishing collateral blood circulation, especially at the level of circle of Willis. The circle of Willis, through its communicating segments, provides an alternative route for the blood to reach parts of the brain which, due to insufficiency, do not receive enough quantity of blood. However, in cases such as the one reported here, due to the absence of communicating arteries, the alternative routes may not be available.

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