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Original Research Article

A Study to Find the Anatomical Variation of Circle of Willis in Relation with Gender and Laterality

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Abstract

Aim: To provide some information regarding the anatomical variations circle of willis and its gender association.

Materials and Methods: The present observational study was conducted on 80 cadavers collected from voluntary body donation at the Department of Anatomy and Fresh corpses undergoing autopsy at the Department of Forensic Medicine, Hi-tech Medical College, Bhubaneswar, Odisha, India, from January 2017 to November 2018. The Circle of Willis of each brain was dissected carefully and a part of the base of the brain was cut and removed, if necessary, to expose the arterial circle clearly. The posterior communicating artery was observed carefully because it might be hidden by the thickened arachnoid mater. The length and circumference of different components of the Circle of Willis was measured. The circumference (perimeter) of artery was measured by a fine malleable copper wire. Photograph was taken and the detailed identity of the cadaver and its brain was marked. Whenever a circle revealed any gross deviations from what had been mentioned as normal in, it was represented by a free hand sketch or photograph.

Results: Out of 80 specimens, 62.5% were male and 37.5% were female. Mean age of the study specimens' was 54.19 years. Variations are seen in posterior communicating artery (10%), followed by anterior cerebral artery (6.25%) and anterior communicating artery (6.25%).

Conclusion: Total 22.5% variations have been found during the course of investigation. Most of the variations are seen in posterior communicating artery. No variations are noticed in Posterior cerebral artery in the present study.

Keywords: circle of willis, gender, shape, symmetry, completeness

Introduction

The branches of two vertebral arteries and two internal carotid arteries supply a significant portion of the brain. The circulous arteriosus is a major anastomosis between the vertebral and carotid artery systems. The presence of a circular artery anastomosis at the base of the brain was originally documented by Thomas Willis, an English anatomist and physician. As a result, the arterial circle is also known as the "Circle of Willis." Since then, this arterial circle has been known as the 'Circle of Willis,' and it was first published in 'Ceribri Anatome' in 1664.[1]

Much work was done in the twentieth century on many elements of the vascular circle of will, including its embryological and angiographical features, but its study on Indian subjects is inadequate. According to Schaeffer JP in "Morris' Human Anatomy," the shape of the arterial circle of Willis is circular or hexagonal in nature, and there are various anomalies in different components of Circle of Willis, likely the posterior communicating artery may arise from the middle cerebral artery; it is usually slender but may be of considerable size, and the portion of posterior cerebral artery.[2] Some of these, according to Martinez et al. are linked with vascular abnormalities such as aneurysms.[3] Cerebrovascular disorders, internal carotid artery blockage, unilateral flow-restrictive extra cranial carotid artery disease, and associated signs and symptoms are all influenced by changes in the Circle of Willis anatomical pattern.[4-8]

Nonetheless, there is no denying that many a riddle encountered during the course of investigation for the assessment of function and applied significance of an anatomical entity can frequently be dispelled by proper appreciation of some very simple gross anatomic features that had previously gone unnoticed. As a result, the significance of gross anatomic studies on the circle of willis cannot be overstated. Hence, the aim of this study was to provide some information regarding the anatomical variations circle of willis and its association with gender.

Materials and Methods

The present observational study was conducted on 80 cadavers collected from voluntary body donation at the Department of Anatomy and Fresh corpses undergoing autopsy at the Department of Forensic Medicine, Hi-tech Medical College, Bhubaneswar from January 2017 to November 2018

Inclusion Criteria

- Cadavers of 20 -60 yrs.
- Cadavers with known identity.
- Cadavers with origin from India.

Exclusion Criteria

- Cadavers with head injury are excluded.
- Cadavers with improper preservation (especially brain) are excluded.

Study Tools

- 10% Formalin solution.
- Glass wool & large sized glass container.
- Forceps, scissors, gloves, bone-saw and other dissection instruments.
- Magnifying glass.
- Scale, measuring tape, thread and fine malleable copper wire.
- 3X zoom, 8 megapixel Nikon Digital Camera.
- Record form.

Method

The study was carried out after the approval of the Institutional Ethics Committee according to the above stated selection criteria.

The sex and age of the cadavers from which the specimens of the brain had been obtained, were noted. Using a scalpel, a circumferential incision was made around the scalp. After pulling the whole thing, it was cut as high as possible. Then by a bone –saw the bone of the calvarium and a wedge of the occipital bone were removed. After reflecting the dura mater the spinal cord, vertebral arteries, and superior spinal nerves were transected for careful removal of the brain. The brain was then kept in 10% Formalin for fixation. Each brain was placed over glass wool in separate container to avoid distortion. Arachnoid mater was probed and peeled away to reveal the arteries at the base of the brain. The Circle of Willis of each brain was dissected carefully and a part of the base of the brain was cut and removed, if necessary, to expose the arterial circle clearly. The posterior communicating artery was observed carefully because it might be hidden by the thickened arachnoid mater.The length and circumference of different components of the Circle of Willis was measured. The circumference (perimeter) of artery was measured by a fine malleable copper wire. Photograph was taken and the detailed identity of the cadaver and its brain was marked. Whenever a circle revealed any gross deviations from what had been mentioned as normal in, it was represented by a free hand sketch or photograph.

Needless to mention that the arterial circle of willis was considered to be normal, complete, symmetrical only when it conformed to the aforesaid "Standard anatomic description". It is to be realized, however that the term 'Normal' means not a fixed point but a range. Hence, the circle of willis in question would be considered 'normal' only when their existed no gross or markedly conspicuous deviation from the "Standard description" in respect of shape and configuration of the said circle, or in other words, when no grossly apparent dissimilarities were revealed in the pattern and architecture of the different arteries and their branches taking part In the formation of this circle. Rest o of the specimen that were not following the aforesaid description were stamped as 'variant or abnormal'. 'Aplasia' of component artery was defined as absence of artery by naked eye with magnifying glass after repeated meticulous examination. 'Hypoplasia' of component artery was defined as diameter less than 1mm. All such definitions are as per convention as well as previous and current literature support. In case of measuring the diameter and length of duplication or double Acom, after taking the length and diameter of individual Acom, average were finally taken. During measurement of the length of Pca, the segment from the bifurcation of basilar artery to the meeting point with the Pcom was taken. In some cases, where Pcom is absent, the measurement of length of that particular segment was not possible. For those cases length of the Pca was not measured. During statistical analysis, valid number of specimens was taken as per statistical principle.

Statistical Analysis

Software used for calculation were Statistica version 6 (Tulsa, Oklahoma: Statsoft Inc., 2001) and Medcalc version 11.6 (Mariakerke, Belgium: Med calc Software 11.6).

Results

Table 1: Distribution of the study specimens according age and gender

Variables	Male	Female
Gender (N=80)	50 (62.5%)	30 (37.5%)
Age (Mean, Median)	54.19 years, 56.0 years	

Table 2: Nature, Number and %percentage of variation with variants and total specimens

Name of artery	Nature	Number	%of total variants	% of total specimen
ACA	Hypoplastic, Right	1	5.56%	1.25%
ACA	Fused	4	22.22%	5%
PCOM	Aplastic, Left	2	11.11%	2.5%
PCOM	Aplastic, Right	1	5.56%	1.25%
PCOM	Hypoplastic, Left	2	11.11%	2.5%
PCOM	Hypoplastic, Right	3	16.67%	3.75%
ACOM	Double	4	22.22%	5%
ACOM	Hypoplastic	1	5.56%	1.25%

Table 3: Comparison of Length and diameter between Males and Females

Group	Mean Male	Mean Female	t-value	df	p	Valid N Male	Valid N Female	Std. Dev Male	Std. Dev Female
Age	54.52	53.63	0.611	78	0.543	50	30	6.18	6.45
AcaR_L	14.19	14.45	-0.872	78	0.386	50	30	1.463	0.932
AcaR_D	2.30	2.21	0.942	77	0.349	49	30	0.415	0.474
AcaL_L	14.22	14.52	-1.013	78	0.314	50	30	1.450	0.876
AcaL_D	2.26	2.26	0.036	78	0.971	50	30	0.403	0.340
AcomL	3.13	3.44	-1.662	74	0.101	47	29	0.741	0.929
AcomD	1.85	1.99	-1.609	73	0.112	46	29	0.372	0.379
PcaR_L	6.91	6.96	-0.223	77	0.824	50	29	1.003	1.172
PcaR_D	2.17	2.17	0.039	78	0.968	50	30	0.456	0.464
PcaL_L	10.67	7	1.073	76	0.720	48	30	18.655	1.189
PcaL_D	2.18	2.16	0.177	78	0.860	50	30	0.468	0.466
PcomR_L	14.19	14.33	-0.827	77	0.410	50	29	0.713	0.710
PcomR_D	1.50	1.49	0.246	74	0.806	48	28	0.177	0.180
PcomL_L	14.22	14.47	-1.378	76	0.172	48	30	0.699	0.880
PcomL_D	1.52	1.47	0.975	74	0.333	47	29	0.178	0.175

Discussion

The prevalence of the 'typical or classic circle', the "normal" textbook polygon ranges from 4.6% to 72.2%.[9] 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 the vessel 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, out of 80 specimens, 62.5% were male and 37.5% were female. The 'normal' circles 62.9% are male and 37.1% female; whereas, in 'variant' circles 61.1% are male and 38.9% female. There is no statistically significant sex variation between the two groups.

In the present study, the anterior cerebral artery, one of the components of circle of willis has been found to exhibit abnormalities by the way of fusion between the artery of the one side with that of the contralateral side, forming fused ACA. 5% of such specimens have been found. Fusion of the anterior cerebral arterties may cause absence of Acom artery. Absence of Acom is also possible without fusion of anterior cerebral arteries. The present observations largely corroborate with those of who recorded such variations, that is, absence of the Acom due to fusion of the two anterior cerebral arteries in 3% and 2% cases respectively.[10,11] The present observations fail to demonstrate the complete absence of Acom without fusion of anterior cerebral arteries and so unable to compare the finding with those of Fawcett et al (1906), Saltzman (1959) and Prosad J et al (1970), who found complete absence of anterior communicating artery in 0.14%,10% and 2.2% cases respectively.[12-14]

Another form of variation has been found in the anterior cerebral artery, that is, right sided hypoplastic anterior cerebral artery (1.25%). The diameter below which the A1 segment could be called hypoplastic has not been well defined, but Perl mutter and Rhoton used 1.5 mm as the cut off figure.[15] They found 10% of the brains to have an A1 segment less than 1.5 mm in diameter. Alpers et al.[10] observed string like components of one of the vessels of the circle of Willis in 28%, with the A1 being the predominant site. Riggs and Rupp found A1 hypoplasia in 7% of one of the largest series studied. No other form of abnormalities has been recorded in ACA.[16]

During the course of the study, we did not find third anterior cerebral artery (artery of the corpus callosum). Mean length of right and left sided ACA were found as 14.29 mm and14.33 mm, with standard deviation as 1.290 and 1.268. There is statistically significant difference in length of ACA of either side ($p=0.019$, <0.05). Mean diameter of right and left sided ACA were observed as 2.26 mm and 2.27 mm, with standard deviation as 0.399 and 0.364. Similarly, there is no statistically significant difference in diameter between them ($p=0.7197$,>0.05). When compared between both sexes, it shows no statistically significant difference in length of right ($p=0.386$,>0.05) and left side ($p=0.314$,>0.05). Again, no statistically significant difference in diameter of right ($p=0.349$,>0.05) and left side ($p=0.971$,>0.05) is observed between male and female.

The minimum threshold diameter for supplying collateral flow through CW, as assessed by transcranial color-coded duplex ultrasonography (TCCD) and carotid compression tests, was compared with their unfixed postmortem anatomy lies between 0.4 and 0.6 mm. The Posterior communicating artery (Pcom) threshold diameter for collateral function was slightly higher than the Acom threshold diameter, possibly due to greater length of Pcom.[17] In the absence of studies showing how far the postmortem arterial diameters of fresh or fixed brains are equal to in vivo diameters and the effect of absence of perfusion pressure and possible postmortem shrinking of the arterial wall, in the present study we defined vessels less than 1 mm in diameter as "hypoplastic" or "string-like". In the present study, the usual posterior communicating artery has been found absent or aplastic in 3.75% cases on either right or left side; 2.5% on left side, 1.25% on right side. Reported incidence of absent arteries in the CW in normal brains leading to an incomplete circle range from 0.6% 43 to

17%.[18] In our study aplasia leading to incomplete circle was 3.75%. A vessel was considered absent or aplastic only when it was not visualized despite careful examination under the dissecting microscope and there were no such instances observed. A meticulous examination is needed to demonstrate small twigs forming the CW. This is dependent upon proper collection of samples, careful removal of the brain and the CW and thorough examination under the dissecting microscope for torn arteries before a vessel is classified as absent. The presence even of small vessels may be important for potential collateral channels. In our study, we didn't use dissecting microscope, rather we used magnifying glasses to identify the presence or absence of artery within the circle. Hence the present observations regarding the absence or aplasia of the usual posterior communicating artery, agree with those of Jones (1946), Gardener et al (1963), and Romane (1964), who mention that this artery may be absent on one or both side.[19-21] The above investigation also appear to be fully in accord with those of Windle (1888) and Prosad et al (1970).[9,14] Furthermore, Alper's et al (1959) mention that this artery is never absent on both side.[10] In the present study we also did not find the absence of PCOM on both side. As we have small number of sample, it is difficult to interprete whether PCOM can be absent on both side or not.

Hypoplasia of posterior communicating artery has been found 6.25%; 2.5% on left side and 3.75% on right side in our present study. As a whole, we have found 10% variations in posterior communicating artery. No both sided hypoplasia and aplasia of PCOM were seen during the course of the study. No abnormal origin of the posterior communicating artery was seen. Mean length of right and left sided PCOM were found as 14.24 mm and 14.31 mm, with standard deviation as 0.711 and 0.777. There is no statistically significant difference in length between them ($p=0.0963,>0.05$). Similar observations were found by Fawcett et al.[12] Mean diameter of right and left sided PCOM were observed as 1.51mm and 1.50mm, with standard deviation as 0.173 and 0.175. Similarly, there is no statistically significant difference in diameter between either side ($p=0.1988,>0.05$). When compared between both sexes, it shows no statistically significant difference in length of right ($p=0.410,>0.05$) and left side ($p=0.172,>0.05$). When compared between either sex, no statistically significant difference in diameter of right ($p=0.806,>0.05$) and left side ($p=0.333,>0.05$) was noted.

In the present study, the anterior communicating artery, one of the component of circle of willis has been found to exhibit abnormalities by the way of doubling or duplication, that is, presence of two anterior communicating artery; one proximal, another distal to connect ACA of both side. 5% of such specimens have been found. This finding is largely in accord with the observations of Alpers et al43 (1959), Fawcett et al (1906) and Prosad et al (1970).[10,12,14] It is to be noted further that Gardener et al (1963) and Romanes (1964) also mention that the anterior communicating artery may exist as double.[20,21] Another form of variation has been found, that is, hypoplastic anterior communicating artery (1.25%) in our current study. No other form of abnormalities has been found in ACOM. Total variations found in our study in ACOM were 6.25 %. Mean length and diameter of ACOM were found as 3.25mm and 1.91mm with standard deviation as 0.827 and 0.379. When compared between either sex, it shows no statistically significant difference in length ($p=0.101,>0.05$). When compared between both sex, it shows no statistically significant difference in diameter ($p=0.112,>0.05$).

The Posterior cerebral artery, in our current study, we did not find any variations. No hypoplasia, aplasia or abnormal origin was found. Mean length of right and left sided PCA were found as 6.93mm and 6.94mm, with standard deviation as 1.061 and 1.114. No statistically significant difference in length is found between right and left sided PCA (p=0.567,>0.05). Mean diameter of right and left sided PCA were found as 2.17mm and 2.18mm, with standard deviation as 0.456 and 0.464. There is no statistically significant difference in diameter (p=0.320,>0.05) between right and left sided PCA (p=0.3203,>0.05). When compared between both sexes, it shows no statistically significant difference in length of right (p=0.824,>0.05) and left sided PCA (p=0.720,>0.05). Similarly, no statistically significant difference in diameter is observed between right (p=0.968,>0.05) and left side (p=0.860,>0.05) in either sex.

Conclusion

In the present study 22.5% variations have been found during the course of investigation. Our present study most of the variations are seen in posterior communicating artery (10%), followed by anterior cerebral artery (6.25%) and anterior communicating artery (6.25%). No variations are noticed in Posterior cerebral artery in the present study.

References

1. Willis Thomas (1621-1675)-Circle-arterial circle at the base of the brain, Cerebri anatome, cui accesit nervorum descriptio at vsus London 1664.
2. Schaeffer, J.P. (1942).Ed. Morris' Human Anatomy, 10th edn., The Blackiston Company,Philadelphia,Toronto.
3. Martinez F, Spagnuolo E, Calvo-Rubal A,Laza S, Sgarbi N, Soria-Vargas VR, Prinzo H.: Variants of the anterior circle of Willis. Anatomic and angiographic correlation and its implications in the surgery of intracranial aneurysms. Neurocirugia (Astur). 2004 Dec; 15(6):578-89.
4. Baumgartner RW, Baumgartner I, Mattle HP, Schroth G.: Transcranial color-coded duplex sonography in unilateral flow-restrictive extra cranial carotid artery disease; American Journal Neuroradiology.1996 Apr; 17(4):777-83.
5. Baumgartner RW,Baumgartner I,Mattle HP,Schroth G.Transcranial color-coded duplex sonography in the evaluation of collateral flow through the circle of Willis.American Journal Neuroradiology.1997;18:127-133.
6. Hartkamp MJ,van Der Grond J, van Everdingen KJ,Hillen B, Mali WP: Circle of Willis collateral flow investigated by magnetic resonance angiography; Stroke.1999 Dec;30(12): 2671-8.
7. Klutmans M,van der Grond J,van Everdingen KJ,Klijn CJ,Kappelle LJ,Viergever MAb:Cerebral hemodynamics in relation to patterns of collateral flow;Stroke.1999 Jul;30(7):1432-9.
8. Emsley HC, Young CA, White RP: Circle of Willis variation in a complex stroke presentation: a case report; BMC Neurol. 2006 Mar 15; 6(1):13.
9. Fisher CM. The circle of Willis: Anatomical variations. Vasc Dis. 1965; 2:99–105.
10. Windle BC. The Arteries Forming the Circle of Willis. J Anat Physiol. 1888 Jan;22(Pt 2):289-93.
11. Alpers BJ, Berry RG, Paddison RM. Anatomical studies of the circle of Willis in normal brain. AMA Arch Neurol Psychiatry. 1959 Apr;81(4):409-18.
12. Fawcett E; Blackford JV. The circle of Willis: An examination of 700

specimens. J.Anat.Physiol 1905; 40:63-69.
13. Saltzman GF. Circulation through anterior communicating artery studied by carotid angiography. Acta radiol. 1959; 52:194-208.
14. Prosad J, Lal RLP. Circle of willis . Patna journal of medicine. 1970; 44:475-479.
15. Perlmutter D, Rhoton AL. Microsurgical anatomy of the anterior cerebral artery- anterior communicating artery- recurrent artery complex. *J Neurosurg* 1976; 45: 259-72.
16. Riggs HE, Rupp C. Variations in form of circle of Willis. Arch Neurol. 1963; 8:8-14.
17. Hoksbergen AW, Fulesdi B, Legemate DA, Csiba L. Collateral configuration of the circle of Willis: Transcranial color-coded duplex ultrasonography and comparison with postmortem anatomy. Stroke 2000; 31:1346-51.
18. Ozaki T, Handa H, Tomomoto K, Hazama F. Anatomical variations of the arterial system of the base of the brain. Arch Jap Chir. 1977;46:3-17.
19. Jones FW. (1946) Ed.: Buchanon's Manual of Anatomy, 7th edn.; London Bail;liere, Tindall and Cox.
20. Gardener E., Grey DJ., O'Rahilly R. (1963): Anatomy, 2nd edn. W.B. Saunder's company, Philadelphia and London.
21. Romanes GJ (1964) Ed.: Cunningham's Textbook of Anatomy. 10th edn. London. Oxford university press.