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Original Research Article

A STUDY OF CIRCLE OF WILLIS BY MR ANGIOGRAPHY

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ABSTRACT

Introduction: The arterial Circle of Willis at the base of the brain serves as a potential collateral pathway, which will maintain adequate cerebral perfusion in the case of diminished afferent blood supply through internal carotid and basilar arteries.

Aim: 1.The present study aims to assess the normal mean diameter of the vessels forming Circle of Willis. 2. To compare the normal mean diameter of the vessels forming Circle of Willis in age and gender.

Material and Methods: Circle of Willis of 100 healthy persons were examined with the help of 3D-TOF MR Angiography of brain.74 individuals were aged 18-60 years and 26 individuals were aged above 60 years of either sex. All component vessels of the circle were assessed by measuring the diameter. Sections of the vessels that were visualized as continuous segment for at least 0.8mm in diameter were considered to be normal, those smaller than 0.8mm in diameter were considered hypoplastic.

Result: The normal mean diameter of the anterior and posterior cerebral arteries was more or less equal i.e.1.32mm. Internal carotid artery was found to be large i.e.2.70mm and communicating artery was 0.97mm. The diameters of the blood vessels forming circle of Willis were larger in males than in females.

The diameters of the centripetal arteries i.e. Internal carotid artery are larger in older age group while those of centrifugal arteries is smaller.

Conclusion: The present study is an observational study; the data of this study can be helpful to the neurosurgeon in the selection of patient as well as assessing the feasibility of shunt operation.

KEY WORDS: Circle of Willis, 3D TOF MR Angiography, Centripetal Arteries, Centrifugal Arteries, Shunt Operation.

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INTRODUCTION

Brain is highly metabolic organ; it requires constant supply of blood. The major arteries supplying the cerebrum are joined to one another at the base of the brain in the form of an arterial circle or circle of Willis. The arteries which form the circle of Willis are the branches of internal carotid artery and the basilar artery. The cerebral arterial circle is an arterial wreath encircling the optic chiasma, the tuber cinerium in the cistern interpeduncularis.The arterial circle is formed by Anteriorly anterior communicating artery, Anterolateraly right and left anterior cerebral arteries, Laterally

proximal segment of right and left internal carotid arteries, Posterolateraly - right and left posterior communicating arteries, Posteriorly proximal segment of right and left posterior cerebral arteries, which are derived from the bifurcating terminals of the basilar artery.

The cerebral arterial circle is set to equalize the blood flow to various parts of the brain, but normally there is little exchange of blood between right and left sides of arterial circles because of the equality of blood pressure [1,2].

Magnetic Resonance Angiography {MRA} has been evaluated into an attractive and non radiation dependant alternative for imaging of the intracranial vasculature [3,4]. Though many workers have reported abnormalities in the diameter of vessels of Circle of Willis, the normal diameter of these vessels have not been reported. The vessels have been described as narrow, thread like etc, but the actual diameters have rarely been measured. The knowledge of size of these vessels is helpful to the surgeon in selection of patients as well as assessing the feasibility of shunt operation. An attempt has been made to study the normal anatomy of Circle of Willis by MR Angiography.

MATERIALS AND METHODS

MR Angiography images of 74 adult individuals of age Group 18-60 years and 26 adult individuals aged above 60 years of either sex attending department of Radio-diagnosis for brain MRA were analyzed.

Brain MR Angiography images required for this study were obtained from the Radiodiagnosis department of General Municipal Hospital. The permission of the Head of Department of Radio-diagnosis as well as consent from the patients was taken. Approval from Ethical Committee was obtained.

Inclusion Criteria: Normal individuals in the age group of 18 to 90 years of either sex attending the department of Radio-diagnosis.

Exclusion Criteria: 1) Individuals younger than 18 years. 2) Any history of accidental head injury, cerebral infarction due to atherosclerosis or embolism, intracranial surgery. 3) Abnormal brain MR findings such as aneurysm or tumor.

Material used for the study is MR Angiography machine "PHILIPS MR ACHIEVA (1.5T)".

Analysis of image: As MR Angiography was being performed, all the images were transferred to a dedicated workstation.

All component vessels of the circle were assessed by measuring their diameter. The section of vessels that were visualized as continuous segment for at least 0.8mm in diameter were considered normal, those smaller than 0.8mm in diameter were considered hypoplastic and those segments, which were not visualized, were considered as absent [5].

The measurements were done with help of Dicomworks software installed in the computer. The diameters of the vessels were measured where they formed part of the circle of Willis, internal carotid arteries were measured 1mm before origin of posterior communicating arteries. Anterior cerebral and posterior cerebral arteries were measured 2mm away from their origin. Posterior communicating arteries were measured 3mm away from their origin and anterior communicating artery measured midway between the two anterior cerebral arteries[5].

Fig. 1: Complete Circle of Willis.

Fig. 2: Complete Circle of Willis with Diameters of Anterior Communicating Artery (Acom), Left Anterior Cerebral Artery (LAC), Right Internal Carotid Artery (RIC), And Right Posterior Cerebral Artery (RPC).

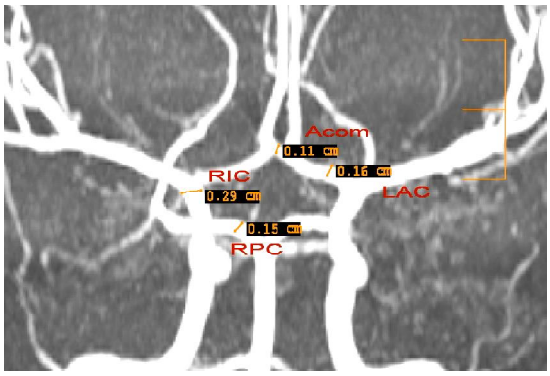
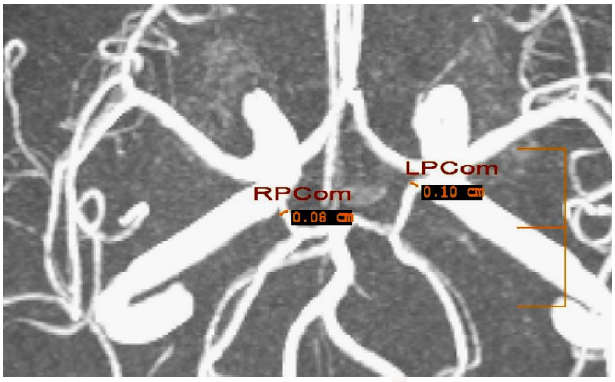


Fig. 3: Complete Circle Of Willis With Diameters Of Right Posterior Communicating Artery (RPCom) And Left Posterior Communicating Artery (LPCom).



RESULTS

Table 1: Mean diameter of vessels which form the Circle of Willis: (In all age groups).

Vessel	No.	Mean diameter (mm)	Std. Dev	S E of Mean
RAC	95	1.36	0.2	0.026
LAC	92	1.27	0.3	0.027
RPC	88	1.33	0.3	0.031
LPC	90	1.32	0.3	0.027
RIC	99	2.72	0.5	0.05
LIC	100	2.67	0.5	0.046
RPCom.	28	0.96	0.2	0.037
LPCom.	33	0.97	0.2	0.031
Acom.	64	0.98	0.01	1

Mean diameter of the vessels calculated by excluding the hypoplastic and absent vessels. In the present study, anterior cerebral artery, posterior cerebral artery and internal carotid artery (of both sides) were considered as major vessels.

The average mean diameter of the anterior cerebral artery is 1.31mm (SD 0.2) and posterior cerebral artery is 1.32mm (SD 0.3), average mean diameter of the internal carotid artery is 2.70mm (SD 0.5), average mean diameter of the posterior communicating artery is 0.96mm (SD 0.2) and anterior communicating artery is 0.98 (SD 0.01).

Table 2: Comparison of mean diameter of blood vessels which form Circle of Willis in males and females.

Vessel	Sex	No.	Mean diameter (mm)	Std. Dev	S E of Mean	Unpaired t test	p value
ACA	Male	56	1.33	0.3	0.035	0.722	0.533
	Female	38	1.3	0.2	0.04	Difference is not significant	
PCA	Male	50	1.35	0.3	0.039	1.022	0.321
	Female	40	1.29	0.2	0.044	Difference is not significant	
ICA	Male	58	2.72	0.4	0.059	0.547	0.593
	Female	42	2.66	0.5	0.048	Difference is not significant	
PCom	Male	18	0.95	0.1	0.044	-0.812	0.424
	Female	13	1	0.1	0.05	Difference is not significant	
Acom	Male	35	0.98	0.02	1	0.481	0.632
	Female	29	0.97	0.02	1	Difference is not significant	

The diameters of the blood vessels forming circle of Willis is larger in males than in females except posterior communicating arteries.

Table 3: Comparison of mean diameter of vessels which form Circle of Willis in less than 60yrs and more than 60yrs age group.

Vessel	Age group	No.	Mean diameter (mm)	Std. Dev	S E of Mean	Unpaired t test	p value
ACA	Less than 60	70	1.33	0.2	0.03	1.45	0.229
	More than 60	24	1.25	0.2	0.05	Difference is significant	
PCA	Less than 60	67	1.32	0.3	0.034	0.471	0.642
	More than 60	23	1.33	0.3	0.059	Difference is not significant	
ICA	Less than 60	74	2.66	0.4	0.059	1.431	0.194
	More than 60	26	2.81	0.5	0.11	Difference is not significant	
PCom	Less than 60	26	0.98	0.2	0.037	0.296	0.772
	More than 60	8	0.95	0.1	0.072	Difference is not significant	
Acom	Less than 60	48	0.99	0.02	1	1.429	0.158
	More than 60	16	0.93	0.03	0.95	Difference is not significant	

The diameters of the centripetal arteries i.e. Internal carotid artery is larger in older age group while those of centrifugal arteries (i.e. anterior cerebral artery, posterior cerebral artery and communicating artery) is smaller except posterior cerebral artery which is larger in older age group.

DISCUSSION

Table 4: Comparison of diameter of blood vessels forming circle of Willis with previous studies. (Diameter in mm).

Author and year	ACA	PCA	ICA	Acom.	PCom.
Kamath S (1981) [6] By dissection method	2.3	2.1	4.2	1.9	1.4
Krabbe-HartKamp MJ et al (1998) [5] By MR Angiography method	1.9	1.9	3.7	1.4	1.2
HartKamp MJ et al (2000) [3] By MR Angiography method	-	-	-	1.1	1.3
Present study By MR Angiography method	1.31	1.32	2.69	0.98	0.96

The diameter of the anterior cerebral artery studied by Kamath S [6] by dissection method is greater by 0.99mm and by Krabbe-Hartkamp MJ et al[5] by MRA study is greater by 0.59mm than the present study. The diameter of the posterior cerebral artery studied by Kamath S[6] by dissection method is greater by 0.68mm and by Krabbe-Hartkamp MJ et al [5] by MRA study is

greater by 0.58mm than the present study.

The diameter of the internal carotid artery studied by Kamath S [6] by dissection method is greater by 1.51mm and by Krabbe-Hartkamp MJ et al[5] by MRA study is greater by 1.01mm than the present study.

The diameter of the anterior communicating artery studied by Kamath S [6] by dissection method is greater by 0.92mm, by Krabbe-HartKamp MJ et al[5] by MRA study is greater by 0.42mm and by HartKamp MJ et al [3] by MRA study is greater by 0.12mm than the present study. The diameter of the posterior communicating artery studied by Kamath S [6] by dissection method is greater by 0.44mm, by Krabbe-Hartkamp MJ et al[5] by MRA study is greater by 0.24mm and by HartKamp MJ et al [3] by MRA study is greater by 0.34mm than the present study.

Table 5: Comparison of sex related differences in the mean diameter of blood vessels forming circle of Willis with previous studies.

Author and year	ACA		PCA		ICA		Acom.		PCom.	
	M	F	M	F	M	F	M	F	M	F
Krabbe-HartKamp MJ et al (1998) [5] By MR Angiography method	1.95	1.95	1.9*	1.75*	3.8	3.65	1.2	1.1	1.1	1.15
HSIN-WEN CHEN et al (2004) [4] By 3D-TOF-MRA	1.95	1.95	1.8	1.85	3.2	3.15	.....	.....	.....	.....
Present study By MR Angiography method	1.32	1.3	1.35	1.29	2.72	2.66	0.98	0.97	0.95	1

The diameter of the anterior cerebral artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as by HSIN-WEN CHEN et al [4] (3D-TOF-MRA) method were equal in males and females and in the present study it is more in males than females. The diameter of the posterior cerebral artery studied by Krabbe-Hartkamp MJ et al [5] (1998) by MRA method was more in males than in females and the difference between them was statistically significant, by HSIN-WEN CHEN et al [4] (3D-TOF-MRA) method was more in females than in males and in the present study it is more in males than in females.

The diameter of the internal carotid artery studied by Krabbe-Hartkamp MJ et al[5] by MRA method, by HSIN-WEN CHEN et al [4] (3D-TOF-MRA) method and in the present study it is more in males than females.

The diameter of the anterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as in present study it is more in males than in females. The diameter of the posterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as in the present study is more in females than in males.

Table 6: Comparison of age related changes in the mean diameter of blood vessels forming circle of Willis with previous studies.

Author and year	ACA		PCA		ICA		Acom.		PCom.	
	<60 yrs	>60 yrs	<60 yrs	>60 yrs	<60 yrs	>60 yrs	<60 yrs	>60 yrs	<60 yrs	>60 yrs
Krabbe-HartKamp MJ et al (1998) [5]	2.25*	1.75*	1.9	1.8	3.7*	3.8*	1.2	1.1	1.2*	1.1*
Present study	1.33*	1.25*	1.32	1.33	2.65	2.81	0.99	0.93	0.98	0.95

The diameter of the anterior cerebral artery studied by Krabbe-Hartkamp MJ et al [5] (1998) by MRA method as well as in the present study is more in < 60yrs age group than in > 60yrs age group and the difference between them is statistically significant in both studies. The diameter of the posterior cerebral artery studied by Krabbe-Hartkamp MJ et al[5] by MRA method was more in < 60yrs age group than in > 60yrs age group but in the present study it is more in > 60yrs age group than in < 60yrs age group.

The diameter of the internal carotid artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as in the present study is more in > 60yrs age group than in < 60 yrs age group but the difference is statistically significant only in Krabbe-Hartkamp MJ et al [5] study.

The diameter of the anterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] (1998) by MRA method as well as by present study is more in < 60yrs age group than in > 60yrs age group. The diameter of the posterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as by the present study is more in < 60yrs age group than in > 60yrs age group but the difference between them is statistically significant only in Krabbe-Hartkamp MJ et al [5] study.

Justification: The diameter of centripetal vessels tends to be larger in older individuals, while that of centrifugal vessels tends to be smaller. This

might be explained in terms of compensatory enlargement of centripetal vessels in elderly persons in reaction to decreased cardiac output, decreased wall elasticity or atherosclerosis, of which prevalence is known to increase with age [5].

These factors may also account for the lower velocity of blood flow in the vessels of older individuals. Three dimensional time of flight MR Angiography depends on the blood flow velocity in the vessels. Blood flow rate in centrifugal vessels decrease with age. This is known to cause signal intensity loss at three dimensional time of flight MR Angiography and therefore smaller diameters of centrifugal vessels are measured[5].

CONCLUSION

The normal mean diameter of the anterior cerebral artery is 1.31mm (SD 0.2) and posterior cerebral artery is 1.32mm (SD 0.3), normal mean diameter of the internal carotid artery is 2.70mm (SD 0.5), normal mean diameter of the posterior communicating artery is 0.96mm (SD 0.2) and anterior communicating artery is 0.98 (SD 0.01). The diameters of the blood vessels forming circle of Willis is larger in males than in females except posterior communicating arteries. Diameters of the centripetal arteries i.e. Internal carotid artery is larger in older age group while those of centrifugal arteries (i.e. anterior cerebral artery, posterior cerebral artery and communicating artery) is smaller except posterior cerebral artery which is larger in older age group.

The present study was an observational study; the data of this study can be helpful to the neurosurgeons in the selection of patient as well as assessing the feasibility of shunt operation.

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ABBREVIATIONS

MRA – Magnetic Resonance Angiography
3D-TOF-MRA – 3 Dimensional Time of Flight Angiography
Std. Dev. – Standard deviation
S.E. of Mean – Standard error of mean
RAC – Right Anterior cerebral artery
LAC – Left Anterior cerebral artery
RPC – Right Posterior cerebral artery
LPC – Left Posterior cerebral artery
RIC – Right Internal carotid artery
LIC – Left Internal carotid artery
RPCom – Right Posterior communicating artery
LPCom – Left Posterior communicating artery
Acom – Anterior communicating artery
ACA - Anterior cerebral artery
PCA - Posterior cerebral artery
PCom – Posterior communicating artery
ICA - Internal carotid artery

Conflicts of Interests: None

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