https://doi.org/10.22502/jlmc.v9i1.448

Original Research Article

Morphological Variation of Circle of Willis in Nepalese Population: A 3D Time-of-Flight Magnetic Resonance Angiography Based Study

Rupesh Sharma,[a,d] Sona Pokharel,[b,d] Phanindra Neupane,[b,d] Ritu Raj Subedi,[c,d]

ABSTRACT:

Introduction: The Circle of Willis (COW) is an anatomic ring of vessels located at the base of brain connecting the anterior and posterior circulation by uniting the internal carotid and vertebrobasilar systems to maintain an adequate cerebral perfusion. The importance of a detailed information of the COW morphology and integrity in any patient cannot be overemphasized, especially for neuro-physicians, neurosurgeons and interventional neuroradiologists who are considering intervention to the intracranial arteries. This study was conducted to study the variation of COW among Nepalese population and compare the results with those of other nationalities. **Methods:** It was a prospective cross-sectional study performed using a 1.5 Tesla MRI machine. Complete anatomical assessment of the COW was done. The anterior and posterior components of COW were defined as per the standard literature and evaluated in detail. **Results:** A total of 118 patients were studied during the period out of which 75 (63.6%) were males and 43 (36.4%) were females. A morphologically normal COW configuration was found only in 55 (46.6%) cases whereas a variant configuration was present in 63 (53.4%) cases. The most common variation was noted in the PCOM which was present in 42 (67%) cases. The most common single variation in abnormal COW configuration was absent right PCOM. **Conclusion:** The morphologic variation of the COW is more common than the normal textbook configuration in Nepalese population, PCOM being the most commonly involved vessel.

Keywords: Circle of Willis, Magnetic Resonance Angiography, Time of flight, Nepalese

INTRODUCTION:

The Circle of Willis (COW) is an anatomic ring of vessels located at the base of brain connecting the anterior and posterior circulation by uniting the internal carotid and vertebrobasilar systems to maintain an adequate cerebral perfusion. [1,2] It has two distinct components namely the anterior and posterior components. It provides collateral flow to the brain especially in situations of arterial incompetency such as cerebrovascular disease. Moreover, its ability to redistribute blood flow depends upon its morphology. Various studies have found considerable variation in the morphology of COW in healthy individuals and individuals of different ethnicity. The importance of a detailed information of the COW morphology and integrity in any patient cannot be overemphasized, especially for neurophysicians, neurosurgeons and interventional neuroradiologists who are considering intervention to the intracranial arteries. Most of the previous studies were based on cadaver studies. In fact it was Sir Thomas Willis, an English physician who provided a complete description and illustration of cerebral vascular anatomy and its physiological significance as early as 1664.[3]

Submitted: 20 May, 2021
Accepted: 21 June, 2021
Published: 30 June, 2021

a- Assistant Professor, Department of Radiology
b- Lecturer, Department of Radiology
c- Resident, Department of Radiology
d- Lumbini Medical College and Teaching Hospital, Palpa, Nepal.

Corresponding Author:
Rupesh Sharma
e-mail: roopskarma@gmail.com
ORCID: https://orcid.org/0000-0002-3422-6150

How to cite this article:
Sharma R, Pokharel S, Neupane P, Subedi RR. Morphological Variation of Circle of Willis in Nepalese Population: A 3D Time-of-Flight Magnetic Resonance Angiography Based Study. Journal of Lumbini Medical College. 2021;9(1):5 pages. DOI: https://doi.org/10.22502/jlmc.v9i1.448. Epub: June 30, 2021.

With the advent of modern imaging technologies like computed tomographic angiography (CTA) and magnetic resonance angiography (MRA), significant progress has been made in the imaging of COW with unparalleled details. Though Digital Subtraction Angiography (DSA) is the gold standard of angiographic evaluation, studies have found that Time of Flight (TOF) MRA gives comparable results to DSA for evaluation of COW.[4] Although CTA is an excellent imaging modality, MRA has certain advantages over CTA in that besides being a non-invasive method, there is no radiological hazard and no intravenous contrast agent is required when using the TOF sequence. Unfortunately very few studies, if at all any, have been done on the morphologic variation of COW based on Nepalese population. So this study was conducted to study the variation of COW among Nepalese population and compare the results with those of other nationalities.

METHODS:

Study population:

It was a prospective cross-sectional study based on convenience sampling, comprising of the patients coming to the Magnetic Resonance Imaging (MRI) unit of department of Radiodiagnosis and Imaging, Lumbini Medical College and Teaching Hospital (LMC-TH) for MRI brain and MRA. The study after being approved by review committee of LMC (IRC-LMC 012-C/019), was done over a period of 12 months from May 2019 to April 2020. Patients with history of brain surgery or trauma, previously known or newly diagnosed brain tumors, cerebrovascular disease, vascular malformation or any other significant cerebral pathology were excluded from the study.

Imaging and evaluation:

The MRI examinations were performed using a 1.5 Tesla MRI MAGNETOM Sempra with Tim+Dot System (Siemens company, Germany) by a qualified technician. Data acquisition using TOF was done with the following parameters: TR 27 milliseconds (ms), TE 7 ms, Slice thickness 0.6 mm, Flip angle 25 degrees, Matrix size 256x228. The post processing of the images was done by maximum intensity projection (MIP). Complete anatomical assessment of the COW was done on Osirix® workstation. The anterior and posterior components of COW were defined as per the standard literature and evaluated in detail. Vessel with a minimum transverse diameter of 0.8 mm and seen as a continuous segment was classified as normal whereas any vessel less than 0.8 mm was considered to be hypoplastic.[5,6] Non-visualization or discontinuous vessel was considered absent. The anterior component of COW includes bilateral internal carotid artery (ICA), A1 segment of bilateral anterior cerebral artery (ACA) and anterior communicating artery (ACOM). Similarly the posterior component includes posterior communicating artery (PCOM), P1 segment of bilateral posterior cerebral artery (PCA) and the single basilar artery tip. When both the anterior and posterior components formed a complete ring, it was considered a complete circle. However, when either the anterior or the posterior component formed a complete circle, it was referred to as a partially incomplete circle. It includes both the hypoplastic and absent vessels. When none of the components formed a complete circle it was termed as an incomplete COW. The data were entered and analyzed using Statistical Package for Social Sciences (SPSS™) version 20. The descriptive results were presented in terms of mean, standard deviation, frequency and percentage.

RESULTS:

A total of 118 patients were studied during the period out of which 75 (63.6%) were males and 43 (36.4%) were females. The age of the patients ranged from 7 to 75 years with a mean age of 41.9 (+/- 17.5) years. A morphologically normal COW configuration (Figure 1) was found only in 55 (46.6%) cases whereas a variant configuration was present in 63 (53.4%) cases (Figures 2-5).

A total of 43 (57%) males and 12 (27%) females had normal configuration. Complete COW was noted in 60 (50.8%) patients, partially incomplete COW in 55 (46.6%) and incomplete COW in three (2.5%) patients. The most common variation was noted in the PCOM including unilateral or bilateral hypoplastic and absent vessel, which was present in staggering 42 (67%) cases out of total 63 cases with abnormal COW configuration. The most common single variation in abnormal COW configuration was absent right PCOM which was present in 16 (13.6%) cases as shown in the table below. The study also showed that females were more likely to have a variant configuration of COW as compared to males $\{X^2(df=1, N=118)=9.510, p=0.002\}$.

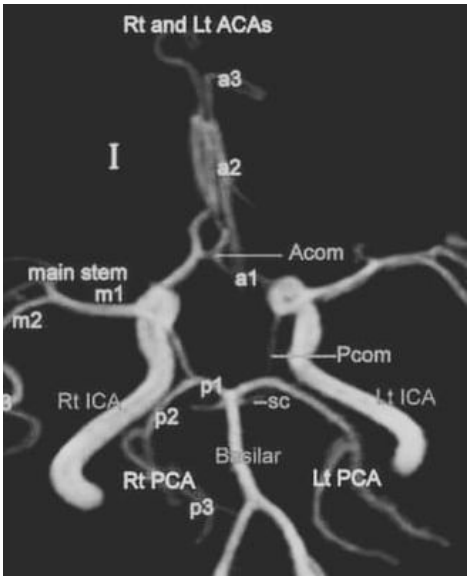

Figure 1. Normal COW.

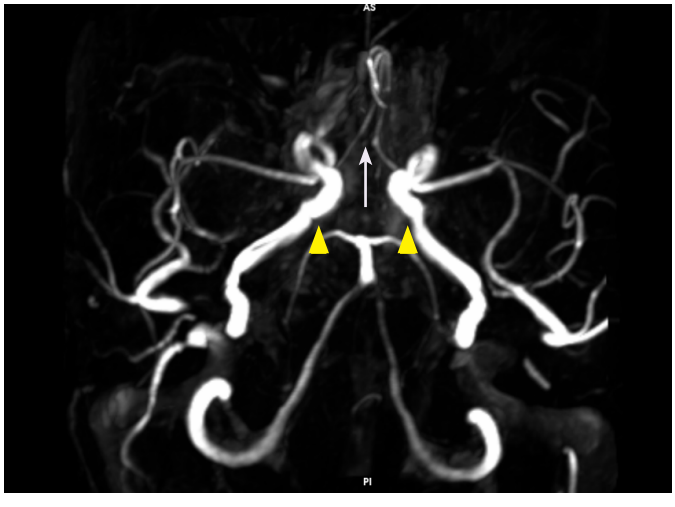

Figure 2. Absent ACOM (Arrow) and B/L PCOM (Arrowheads).

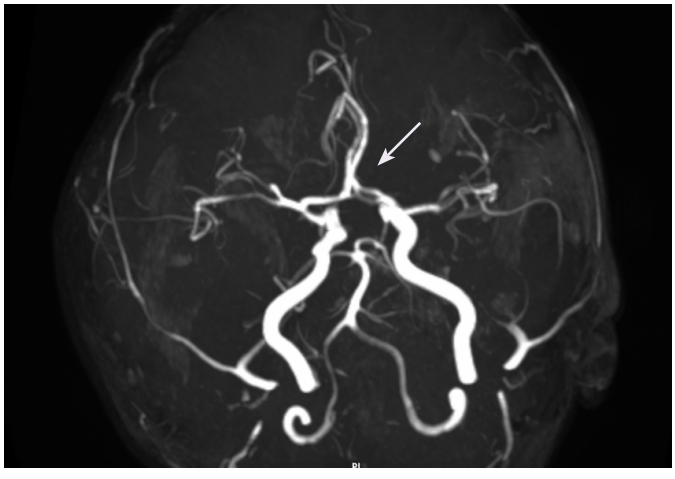

Figure 3: Duplicated Left A1 (Arrow).

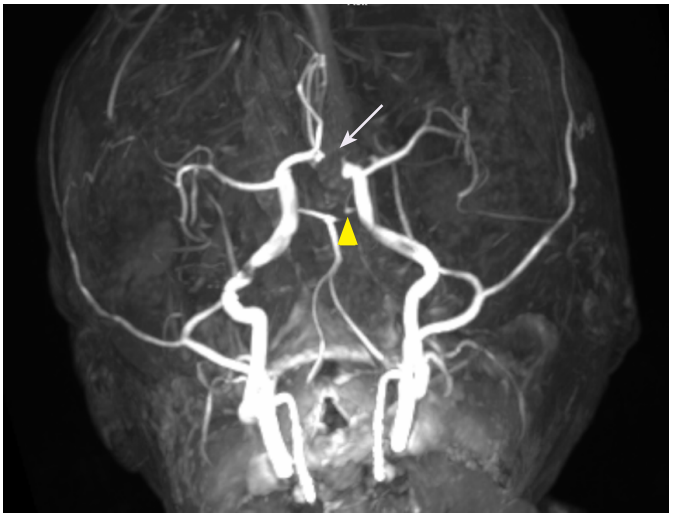

Figure 4. Absent Left A1 (Arrow) and Hypoplastic Left P1 (Arrow head).

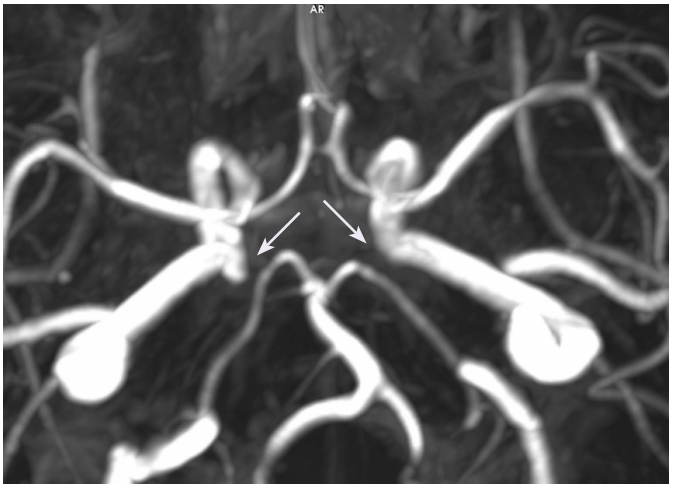

Figure 5. Absent B/L PCOM (Arrows).

Table 1. Frequency of COW configuration.

COW variation	Frequency (n=118*)
Normal COW configuration	55 (46.6%)
Absent ACOM	7 (5.9%)
Hypoplastic right A1	9 (7.6%)
Hypoplastic left A1	2 (1.7%)
Duplicated right A1	1 (0.8%)
Duplicated left A1	2 (1.7%)
Hypoplastic right PCOM	6 (5.1%)
Hypoplastic left PCOM	5 (4.2%)
Hypoplastic B/L PCOM	3 (2.5%)
Absent right PCOM	16 (13.6%)
Absent left PCOM	3 (2.5%)
Absent B/L PCOM	9 (7.6%)
Hypoplastic right P1	1 (0.8%)
Hypoplastic left P1	1 (0.8%)
Median artery of corpus callosum originating from ACOM	3 (2.5%)

*In 14 (11.9%) cases, more than one variation was noted.

DISCUSSION:

The Circle of Willis (COW) is an important arterial anastomotic structure for adequate cerebral perfusion, especially in times of arterial incompetency as evidenced by the fact that adequate collaterals have been found to be associated with a lower risk of hemispheric stroke and transient ischemic attack (TIA) in severe carotid artery stenosis.[7] Moreover a wide range of variations have been found in the morphology and integrity of this collateral system in different studies done in different parts of the world. These variations are known to be associated with occurrence, course, prognosis and outcome of certain cerebrovascular diseases such as stroke and aneurysms.

This study was conducted to see the anatomic variations in COW in Nepalese population based on TOF MRA. We noticed that a morphologically normal textbook COW configuration was present in less than half of the total cases, 46.6%. Of all the components of COW, PCOM was noted to be the most commonly involved vessel with absent right PCOM being the single most common variation. Quite similar to our findings, Naveen et al. in a TOF MRA study in India found that 50% cases had normal COW configuration with hypoplastic or absent PCOM being the most common variation.[8] Karatas et al. in a CTA based study in Turkey found that only 28% had normal COW morphology with PCOM hypoplasia and aplasia being the most common variations.[9] Though the rate of abnormal COW was significantly more than that in our study, the finding that PCOM variation was the most common was same as in our study. Gunnal et al. found normal COW anatomy in 60 % cases with PCOM variation being the most common.[10] This observation was comparable to what we found in our study. Zaninovich et al. found that a complete COW configuration was present in only 37.1% cases and PCOM was the most common artery to show variations.[11] They also observed that there was a statistically significant decrease in the completeness of COW with increasing age in both the sexes. In our study females were significantly more likely to have a variant configuration of COW as compared to males while no significant association of the variant morphology with age was noted. A study based on Egyptian population showed that a complete COW was present in only 28% cases and again PCOM variation was noted to be the most common.[12] They also found that posterior circulation variation was more common (62%) as compared to anterior circulation which was similar to our findings of 65% posterior circulation variation. Many other studies have found that PCOM is the most common component of COW to show variations albeit to a varying degree.[13,14,15,16,17] Incomplete COW configuration has been found to be associated with future anterior circulation stroke in patients with no prior cerebrovascular disease.[6] Our study found three (2.5%) patients with incomplete COW configuration. Timely advice regarding precautionary measures can be helpful in such cases. There are few innate limitations associated with MRA. When the flow within the vessel is turbulent as in stenosis or when it is slow, there can be signal loss because of spin dephasing. Some high signal structures such as subacute thrombus may be incorporated into MIP images which may alter the COW morphology.

CONCLUSION:

The morphologic variation of the COW is more common than the normal textbook configuration in Nepalese population, PCOM being the most commonly involved vessel. This finding is roughly similar to many studies done in other parts of the world. A larger population based and a multicentric study is necessary to better establish the normal pattern of COW morphology.

Acknowledgement:

Mr. Jitendra K. Shah, Mr. Rakesh Yadav, Mr. Pradeep Karki, Mr. Rupak Raj, Department of Radiology, LMC-TH.

Conflict of Interest: The authors declare that no competing interests exist.

Financial Disclosure: No funds were available.

REFERENCES:

1. Cui Y, Xu T, Chen J, Tian H, Cao H. Anatomic variations in the anterior circulation of the circle of Willis in cadaveric human brains. Int J Clin Exp Med. 2015;8(9):15005-10. PMID:26628984 PMCID: http://www.ncbi.nlm.nih.gov/pmc/articles/pmc4658873/
2. Wijesinghe P, Steinbusch HWM, Shankar SK, Yasha TC, De Silva KRD. Circle of Willis abnormalities and their clinical importance in ageing brains: A cadaveric anatomical and pathological study. Journal of Chemical Neuroanatomy. 2020;106(0):101772. DOI: https://doi.org/10.1016/j.jchemneu.2020.101772
3. Ustun C. NEUROwords Dr. Thomas Willis' Famous Eponym: The Circle of Willis. J Hist Neurosci. 2005;14(1):16-21. PMID: 15804755 DOI: https://doi.org/10.1080/096470490512553
4. Li J, Wang J, Wei X, Zhao YW, Wang F, Li Y. Examination of Structural Variations of the Circle of Willis by 3D Time-of-Flight Magnetic Resonance Angiography. Front Neurosci. 2020;14(0):71. PMID: 32116517 DOI: https://doi.org/10.3389/fnins.2020.00071
5. Krabbe-Hartkamp MJ, van der Grond J, de Leeuw FE, de Groot JC, Algra A, Hillen B, et al. Circle of Willis: morphologic variation on three-dimensional time-of-flight MR angiograms. Radiology. 1998;207(1):103-11. PMID: 9530305 DOI: https://doi.org/10.1148/radiology.207.1.9530305
6. van Seeters T, Hendrikse J, Biessels GJ, Velthuis BK, Mali WP, Kappelle LJ, et al. Completeness of the circle of Willis and risk of ischemic stroke in patients without cerebrovascular disease. Neuroradiology. 2015;57(12):1247-51. PMID: 26358126 DOI: https://doi.org/10.1007/s00234-015-1589-2
7. Henderson RD, Eliasziw M, Fox AJ, Rothwell PM, Barnett HJ. Angiographically defined collateral circulation and risk of stroke in patients with severe carotid artery stenosis. North American Symptomatic Carotid Endarterectomy Trial (NASCET) Group. Stroke. 2000;31(1):128-32. PMID: 10625727 DOI: https://doi.org/10.1161/01.str.31.1.128
8. Naveen SR, Bhat V, Karthik GA. Magnetic resonance angiographic evaluation of circle of Willis: A morphologic study in a tertiary hospital set up. Ann Indian Acad Neurol. 2015;18(4):391-7. PMID: 26713008 DOI: https://doi.org/10.4103/0972-2327.165453
9. Karatas A, Coban G, Cinar C, Oran I, Uz A. Assessment of the Circle of Willis with Cranial Tomography Angiography. Med Sci Monit. 2015;21:2647-52. PMID: 26343887 DOI: https://doi.org/10.12659/msm.894322
10. Gunnal SA, Farooqui MS, Wabale RN. Anatomical variations of the circulus arteriosus in cadaveric human brains. Neurol Res Int. 2014;2014(0):687281. PMID: 24891951 DOI: https://doi.org/10.1155/2014/687281
11. Zaninovich OA, Ramey WL, Walter CM, Dumont TM. Completion of the Circle of Willis Varies by Gender, Age, and Indication for Computed Tomography Angiography. World Neurosurg. 2017;106(0):953-63. PMID: 28736349 DOI: https://doi.org/10.1016/j.wneu.2017.07.084
12. Zaki SM, Shaaban MH, Abd Al Galeel WA, El Husseiny AAW. Configuration of the circle of Willis and its two parts among Egyptian: a magnetic resonance angiographic study. Folia Morphol (Warsz). 2019;78(4):703-9. PMID: 30761512 DOI: https://doi.org/10.5603/fm.a2019.0015
13. Jalali Kondori B, Azemati F, Dadseresht S. Magnetic Resonance Angiographic Study of Anatomic Variations of the Circle of Willis in a Population in Tehran. Arch Iran Med. 2017;20(4):235-9. PMID: 28412828
14. Shaikh R, Sohail S. MRA-based evaluation of anatomical variation of circle of Willis in adult Pakistanis. J Pak Med Assoc. 2018;68(2):187-91. PMID: 29479090
15. Ravikanth R, Philip B. Magnetic resonance angiography determined variations in the circle of Willis: Analysis of a large series from a single center. Tzu Chi Med J. 2019;31(1):52–9. PMID: 30692833 DOI: https://doi.org/10.4103/tcmj.tcmj_167_17
16. Varga A, Di Leo G, Banga PV, Csobay-Novák C, Kolossváry M, Maurovich-Horvat P, et al. Multidetector CT angiography of the Circle of Willis: association of its variants with carotid artery disease and brain ischemia. Eur Radiol. 2019;29(1):46-56. PMID: 29922933 DOI: https://doi.org/10.1007/s00330-018-5577-x
17. Yeniçeri IÖ, Çullu N, Deveer M, Yeniçeri EN. Circle of Willis variations and artery diameter measurements in the Turkish population. Folia Morphol (Warsz). 2017;76(3):420-5. PMID: 28150270 DOI: https://doi.org/10.5603/fm.a2017.0004