

Configuration of Circle of Willis and Its Clinical Significance

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ABSTRACT:

In occlusive vascular brain diseases, the structure of the circle of Willis is of immense importance. A high percentage of variations have been reported in the arteries forming circle of Willis. These have profound clinical implications. With advances in interventional radiological procedures, the interventional radiologists and neurosurgeons need to have thorough knowledge of these variations. This article will help readers understand the significance of anatomical variations and their clinical effects.

Key words: Circle of Willis, Anatomical variations, cerebral arteries

INTRODUCTION:

Cerebrovascular diseases present one of the leading problems of the modern medicine. Besides having a high mortality rate, these cause a high level of disability in those who survive a cerebrovascular accident. Cerebral perfusion depends on the status of the cerebral vessels as well as on the variations shown by these vessels, thus making it important to emphasize on these variations. As these variations are common they may have intense clinical implications¹.

Accurate knowledge of intracranial vascular anatomy is increasingly gaining importance with advances in neurosurgeries and radiological neurointerventions². The pathologies of arteries at the base of brain can thus be tackled more effectively. In case of internal carotid artery occlusion, it is the arteries in the circle of Willis that serves as a major collateral channel but the size and patency of these arteries are variable³.

The circle of Willis (CoW) is considered as major anastomosing channel which maintains ample cerebral blood flow⁴. In case of cerebral occlusion, morphology, size and presence of the contributing vessels influence its ability to redistribute blood flow⁵.

Cerebral vascular structures show numerous variations. Radiological recognition of these variations are essential in diagnosis, treatment and for safe performance of neurosurgical and interventional radiological procedures⁶.

LITERATURE REVIEW:

Blood supply to brain is via paired internal carotid and vertebral arteries that anastomose at the base of the brain to form arterial ring called “the Circle of Willis”. It is named after Dr. Thomas Willis who first accurately described its anatomical and physiological significance. It is located in the subarachnoid space within the interpeduncular fossa⁷. The internal carotid artery branches to give off paired anterior cerebral arteries. The right and left anterior cerebral arteries (ACA) communicates to each other via anterior communicating artery (AComA) supplying the forebrain and constitutes the anterior circulation⁸.

The two vertebral arteries joins at the mid medullary level to form single large median artery called basilar artery runs in the basilar groove of Pons and ends by dividing into terminal branch the right and left posterior cerebral artery (PCA) thereby constituting the posterior circulation supplying the hindbrain.

The anterior and posterior circulations communicate with each other via the posterior communicating artery(PCoM)

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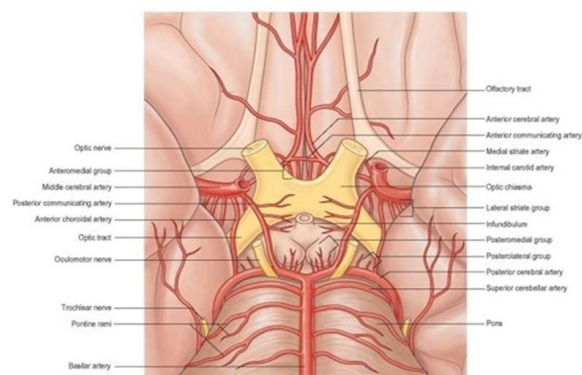


Figure 1: Circulus arteriosus showing formation of Circle of Willis and its different branches⁹

which is a branch of internal carotid artery thereby completing the arterial ring as shown in figure 1¹⁰.

Surgically the posterior cerebral artery is divided into two parts: Pre communicating part (P1) –proximal portion of PCA where it originates from the basilar artery till it joins the PComA. Post communicating part (P2) – course distal to the junction with the posterior communicating artery¹¹.

The cerebral arterial circle of Willis pattern is considered classical text book type if all the component vessels (anterior and posterior cerebral arteries and anterior and posterior communicating arteries) are present; they are not duplicated or absent, contributing vessels arise from their typical source and their diameter is not less than 1 mm¹².

Development of Circle of Willis:

During intrauterine life developmental variations in the circle of Willis may be encountered¹³. The first stage at which variations can occur during embryogenesis is angiogenesis. As these cerebral arteries continue to develop anatomical variations occur that may affect arterial diseases in later life. The first artery to develop is the internal carotid artery at day 24 of embryonic life; providing blood to the primitive brain. As brain growth progresses, the brainstem and cerebellum enlarge; blood supply from the internal carotid artery becomes scanty, bringing about the development of the posterior circulation¹⁴. Internal carotid artery divides into anterior, middle and posterior cerebral artery. The posterior cerebral artery joins the basilar artery.

Posterior circulation begins to start consisting of primitive arterial branches originating mainly from proximal carotid-vertebrobasilar anastomosis and from distal carotid artery. The proximal portion of the posterior cerebral artery decreases in luminal caliber because of the hemodynamic stress and it is now called as posterior communicating artery (PComA) the distal portion of the PCA connects with the basilar artery hence the PComA becomes branch of ICA whereas the PCA becomes the branch of basilar artery. When the vertebral and basilar arteries fully develop and become independent from the internal carotid artery the carotid-vertebrobasilar anastomosis regresses forming two separate systems. The carotid system supplying forebrain and the vertebral system supplying the hind brain¹⁵. During these embryological stages multiple events occur that lead to the formation of anatomical variants.

Variants of arteries of circle of willis

Data from previous anatomical and radiological studies have shown that more than 50% of healthy subjects have anatomical variations and prevalence of an entire complete circle is 21 to 42%¹⁶. Typical configuration of CoW may show variations. Caliber of the vessels may vary often they are fenestrated, duplicated, triplicated, hypoplastic or even aplastic as shown in figure 2. Vessels having luminal diameter less than 1mm are considered to be hypoplastic¹⁷.

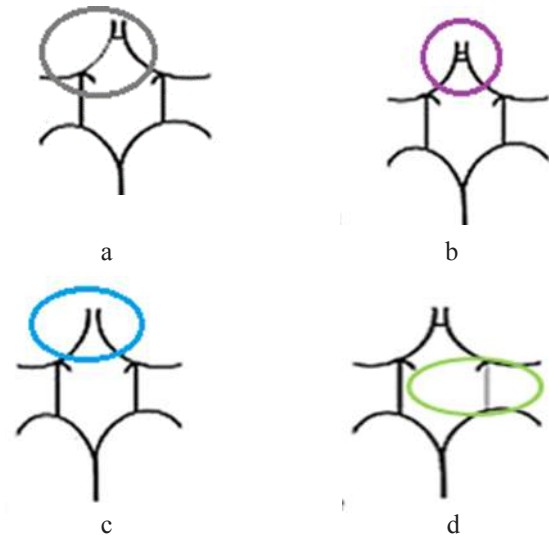


Figure 2: Schematic diagram showing the variations in the circle of Willis, (a) Hypoplastic ACA. (b) Double ACoA. (c) Absent AcomA. (d) Hypoplastic PComA

Padgett in 1984 divided the Circle of Willis into three configurations according to diameters of posterior cerebral artery (PCA) and posterior communicating artery (PComA): fetal, Adult and transitional. In fetal configuration, the diameter of PComA is greater than the diameter of P1 segment of PCA. Hence, the occipital lobes are supplied largely through the internal carotid arteries. In the adult configuration, PComA has smaller luminal diameter than the P1 that's why the blood supply to the occipital lobes is mainly via the vertebrobasilar system. In transitional configuration, PComA is equal in diameter to the P1 segment of the PCA. Such type of anatomical variations are important clinically as in atherosclerotic lesion of internal carotid arteries thrombus arising from atheromatous plaque may dislocate into posterior cerebral artery via the larger diameter of posterior communicating artery¹⁹.

Clinical significance of variants of cow

For establishment of better collateral circulation through CoW, acquaintance between the two sides of the circle of Willis as well as link between the internal carotid and vertebrobasilar systems are equally important^{20,21}.

PComA and AComA play an important role if one of these arteries is thin/thread like. In such cases, collateral circulation through the circle may be impaired. Absence or hypoplasia of PComA is a known risk factor for cerebrovascular conditions such as ICA occlusion, minor strokes, border zone infarcts, transient ischemic attacks due to restricted collateral flow²². In absence of ICA occlusion, one of the contributing risk factor for ischemic stroke is PCA hypoplasia²³. In case of ICA occlusion, hypoplastic PComA may be a risk factor for developing neurological deficit²⁴.

In case of thromboembolic disease hypoplasia of anterior

cerebral arteries results in decreased collateral supply resulting in increased risk of infarction²⁵. Miyazawa et al in 2011 suggested that incomplete anterior part of CoW (absent AComA, Hypoplastic or aplastic ACA) results in lacunae in basal ganglia leading to lacunar stroke²⁶.

Many studies have documented association between cerebral aneurysm and variations in the arterial circle²⁷. In diagnosis and management of cerebrovascular accidents, TIA and hemorrhagic stroke awareness about these variations like duplications, triplication, fenestrations and fetal arteries plays a critical role and may help in surgical planning^{28,29}.

A classical text book type of circulus arteriosus is bilaterally symmetrical arterial polygonal ring providing important collateral pathway to maintain blood flow to the brain tissues in case of vessel occlusion³⁰. Anatomical variations are possibly determined genetically, develop during intrauterine life and persist even after birth³¹. There is a large variety of configurations of the CoW among both normal and diseased populations in different ethnic groups³².

Previous data reported that the anterior circulation was complete in 68% and the posterior circulation was complete in 38% of cases³³. Different studies put the occurrence of normal circle of Willis in the range between 28 to 52% in different populations^{34,35}. A study conducted by Sande et al suggested that variations are common in posterior part of CoW (43 %) than in anterior part (16 %) ³⁶.

Variations in the morphology of the circulus arteriosus alter the severity of symptoms of cerebrovascular diseases like stroke, aneurysms, infarcts and other vascular malformations. Clinically important association have been noticed between intracranial aneurysm and fenestration³⁷. The framework of the circle of Willis becomes important in ascertaining the effectiveness of the circulation of brain in surgeries like aneurysm coiling AVM embolisation, and also internal carotid artery ligation³⁸. The absence of some CoW elements may be fatal for patients with internal carotid artery stenosis³⁹. Anatomical arrangement of the arteries in CoW plays a major role in the development of and its corrective surgery⁴⁰. Persons with efficient collateral circulation have a lower risk of transient ischemic attack and stroke⁴¹.

CONCLUSION:

Knowledge of variations in cerebral arterial circle is useful for various interventional radiological and surgical procedures. In patients undergoing cerebral surgery, a pre-operative examination of the structure and variations of the Circle of Willis through easily accessible and non-invasive techniques will decrease the potentially significant neurological complications and associated secondary risks of morbidity and mortality.

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