Circle of Willis (COW)

The Circle of Willis (also called Willis' Circle, Loop of Willis, cerebral arterial circle, and Willis Polygon) is the main collateral system between the bilateral carotid systems and the vertebrobasilar system.

Named after Sir Thomas Willis who described the arterial circle (circulus arteriosus cerebri).

The circle of Willis encircles the stalk of the pituitary gland and provides important communications between the blood supply of the forebrain and hindbrain (ie, between the internal carotid and vertebrobasilar systems following obliteration of primitive embryonic connections). A complete circle of Willis is present in most individuals, although a well-developed communication between each of its parts is identified in less than half of the population.

The circle of Willis links the two main cerebral artery systems, namely the internal carotid artery system and the vertebrobasilar system, and it is also the primary collateral pathway locating in the base of brain. When the blood flow of an unilateral artery declines caused by stenosis, it can be compensated from the contralateral side by the CoW. The collateral capacity of the CoW improves cerebral perfusion in ischemic areas and may diminish the effect of ischemic events.

This structure provides important collateral circulation paths to maintain the sufficient blood supply, especially when stenosis or surgical clamping of the cerebral arteries happens. These collaterals consist of cross-flow through the anterior communicating artery toward the ipsilateral sphere of the ICA lesion, posterior to anterior flow through the ipsilateral posterior communicating artery, or both these systems.
**Composition**

**Anterior cerebral artery** (left and right)

**Anterior communicating artery**

**Internal carotid artery** (left and right)

**Posterior cerebral artery** (left and right)

**Posterior communicating artery** (left and right)

Because the carotid and vertebrobasilar arteries form a circle, if one of the main arteries is occluded, the distal smaller arteries that it supplies can receive blood from the other arteries (collateral circulation).

The pterional approach to aneurysms of the circle of Willis is one of the most common approaches in vascular neurosurgery.

**Variations**

COW normal variants are encountered in up to 62% of subjects.

The morphological variation of the CoW may affect aneurysm formation resulting from increased wall shear stress.

**A1 segment hypoplasia** is an uncommon fetal variant of the circle of Willis.

Hypoplasia or completely absent blood vessels, which may occur in the anterior circulation or the posterior circulation, may influence the collateral capacity of the CoW and the risk of ischaemic stroke. Therefore, evaluating the collateral capacity of different configurable CoWs in patients is very important.

There have been some studies performed on haemodynamics of CoW with different anatomical variations in recent years. Some researchers have treated the cerebral vasculature as 1D structure, however, basing on Poiseuille flow, it cannot capture the effects of the complex arterial geometry, especially the effects of blood vessel junctions.

**Function**

The arrangement of the brain's arteries into the Circle of Willis creates redundancies or collaterals in the cerebral circulation. If one part of the circle becomes blocked or narrowed (stenosed) or one of the arteries supplying the circle is blocked or narrowed, blood flow from the other blood vessels can often preserve the cerebral perfusion well enough to avoid the symptoms of ischemia.

**Subclavian steal syndrome**

The redundancies that the Circle of Willis introduce can also lead to reduced cerebral perfusion. In subclavian steal syndrome, blood is “stolen” from the Circle of Willis to preserve blood flow to the upper limb. Subclavian steal syndrome results from a proximal stenosis (narrowing) of the subclavian artery, an artery supplied by the aorta which is also the same blood vessel that eventually feeds the Circle of Willis via the vertebral artery.
Leukoaraiosis

The presence and the number of COW variants are associated with a higher leukoaraiosis volume in patients with significant internal carotid artery stenosis \(^{15}\).

**MRA**

Previous studies were mainly based on the study of autopsies, with limitations in reflecting the relationship between COW’s morphology and physiological changes of hemodynamic system. Moreover, the number of samples was limited in previous studies and hence their results were not able to represent the population of COW. With the development of modern technology, some new techniques, such as transcranial Doppler (TCD), DSA, and CTA, allow researchers to access the cerebral module on physiological or pathological status. Different from TCD and CTA, MRA (magnetic resonance angiography) is a noninvasive and no-radioactive damage inspection technique, which can be used to undertake a massive study on healthy people on evaluation of COW variation \(^{16}\) \(^{17}\) \(^{18}\).

MRA could enable reflecting the physiological morphology of COW in a comprehensive manner \(^{19}\).

Assessment of Circle of Willis (CoW) configuration on MRA may be helpful to understand the appearance of unilateral thalamic stroke independent from stroke etiology. A smaller diameter of the relevant CoW segment might be a risk factor for ipsilateral thalamic stroke in the corresponding thalamic vascular territory \(^{20}\).

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**Sphenoid wing meningiomas** (SWMs) can encase arteries of the circle of Willis, increasing their susceptibility to intraoperative vascular injury and severe ischemic complications.

**References**


