International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Anatomical Variations in Circle of Willis in Patients Undergoing Magnetic Resonance Angiography

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Abstract: ***The circle of Willis (CoW) is an important circulatory anastomosis responsible for maintaining a stable and redundant blood supply to the brain, thereby reducing the risk of ischaemia in the event of diminished cerebral blood flow. The CoW is found at the base of the brain and surrounds the pituitary stalk and optic chiasm. The CoW is bounded anteriorly by the anterior communicating artery (ACoA) which connects both anterior cerebral arteries (ACAs). The ACAs course posterolaterally to reach the terminal segments of the internal carotid arteries (ICAs). At the point of connection between the ACA and the ICA, the lateral continuation of the ICA becomes the middle cerebral artery (MCA). The MCAs supply the lateral cerebral hemispheres excluding the superior parietal, inferior temporal, and occipital lobes, while the ACAs supply the frontal lobes in the midline and the superomedial parietal lobes. The posterior communicating arteries (PCoAs) then join the MCAs to the posterior cerebral arteries (PCAs), which form the posterior limit of the CoW. Both PCAs unite to form the basilar artery at the base of the pons, which continues caudally anterior to the pons. The PCAs supply the occipital and inferior temporal lobes.***

Keywords: circle of Willis, cerebral circulation, anterior cerebral artery, posterior cerebral artery, cerebral blood supply

1. Introduction

CoW anomalies described include aplasia, hypoplasia, and accessory vessels. CoW examination can be done by various non-invasive methods including computed tomography angiography (CTA), magnetic resonance angiography (MRA), and transcranial doppler. The gold standard examination, however, is digital subtraction angiography (DSA), which provides a resolution unmatched to CTA and MRA. DSA is nevertheless an invasive procedure with inherent risks, including on-table ischaemic events, thromboembolism, and adverse reactions to iodinated contrast.

CTA acquires images quickly and provides excellent anatomy delineation. Disadvantages of CTA include exposure to ionizing radiation and possible adverse reactions related to iodinated contrast use.

MRA obtains images without the use of ionizing radiation and contrast medium. In MRA, flow-related enhancement is done by either time of flight or phase contrast imaging. MRA is 100% specific and 81.3%-100% sensitive for evaluating CoW variations.

Structural abnormalities in the CoW may be linked to future incidence of cerebrovascular disease, intracranial aneurysms, and migraines.

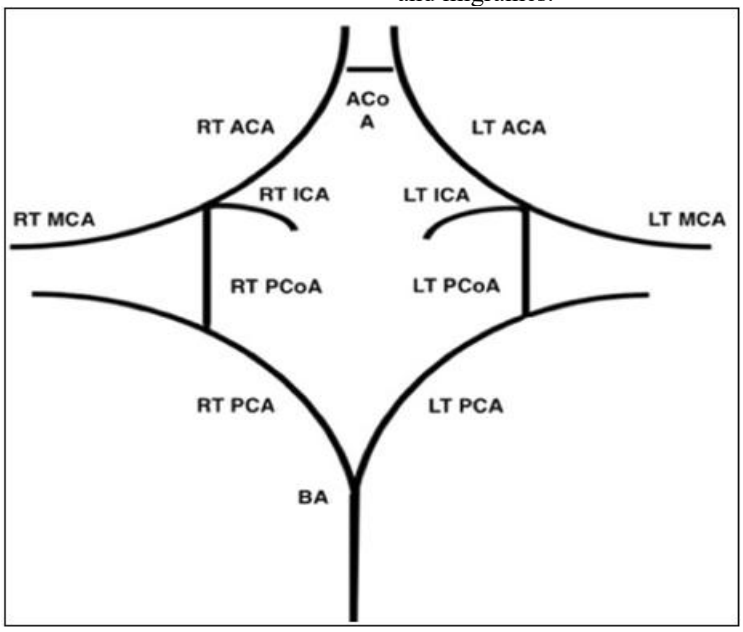


Figure 1

Schematic diagram demonstrating a complete circle of Willis. Abbreviations: RT = right; LT = left; ICA = internal carotid artery; MCA = middle cerebral artery; ACA = anterior cerebral artery; ACoA = anterior communicating artery; PCA = posterior cerebral artery; PCoA = posterior communicating artery; BA = basilar artery.

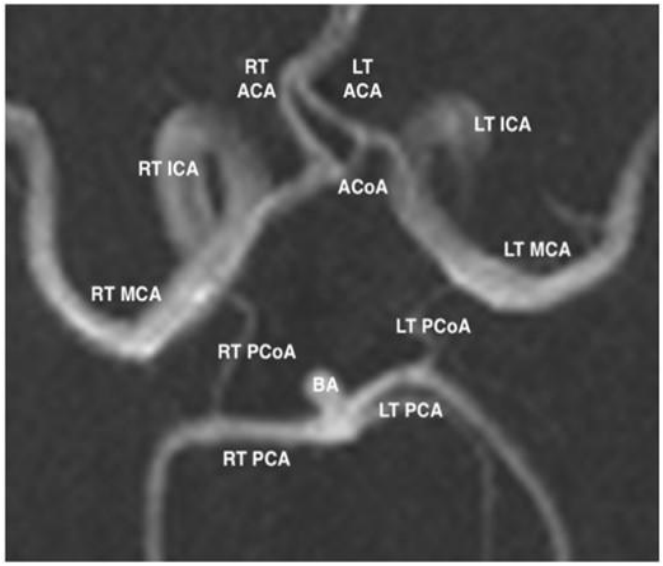


Figure 2: Axial maximum intensity projection magnetic resonance angiography image demonstrating a complete circle of Willis.

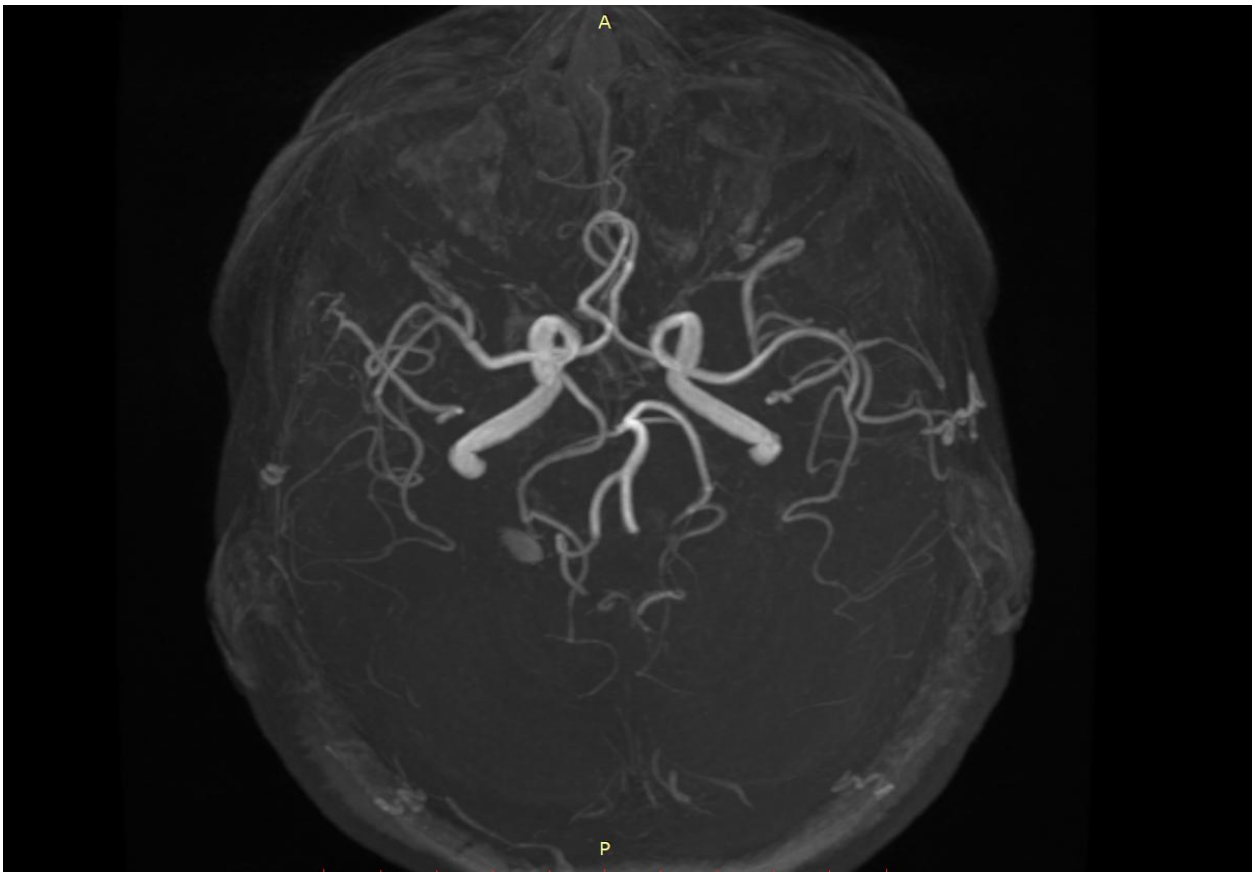
Magnetic resonance protocol

The patients were supine with the neck and head in the neutral position. MRA examination consisted of 3D-TOF-MRA and fast spin-echo T2-weighted axial imaging (repetition time [TR]/effective echo time, 4000/101 ms; matrix, 256 × 256; field of view [FOV], 200 mm; section thickness, 5 mm). Variations in the CW were also classified using 3D-TOF-MRA (TR/echo time, 35/4.7 ms; flip angle, 20°; matrix, 256 × 256; FOV, 200 mm; slab thickness, 52.8 mm; section thickness, 0.8 mm). 3D-TOF-MRA of the CW was obtained with the sequence of spoiled gradient-recalled acquisition. T2-weighted imaging was done to rule out abnormalities or lesions in the brain.

Case 1:

A 56-year-old female patient was referred to our department with history of headache for 2 weeks.

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.



Fetal origin of right posterior cerebral artery is noted.

A fetal (origin of the) posterior cerebral artery (fetal PCA), sometimes also referred to less accurately as fetal (origin of the) posterior communicating artery (fetal PCom), is a common variant in the posterior cerebral circulation.

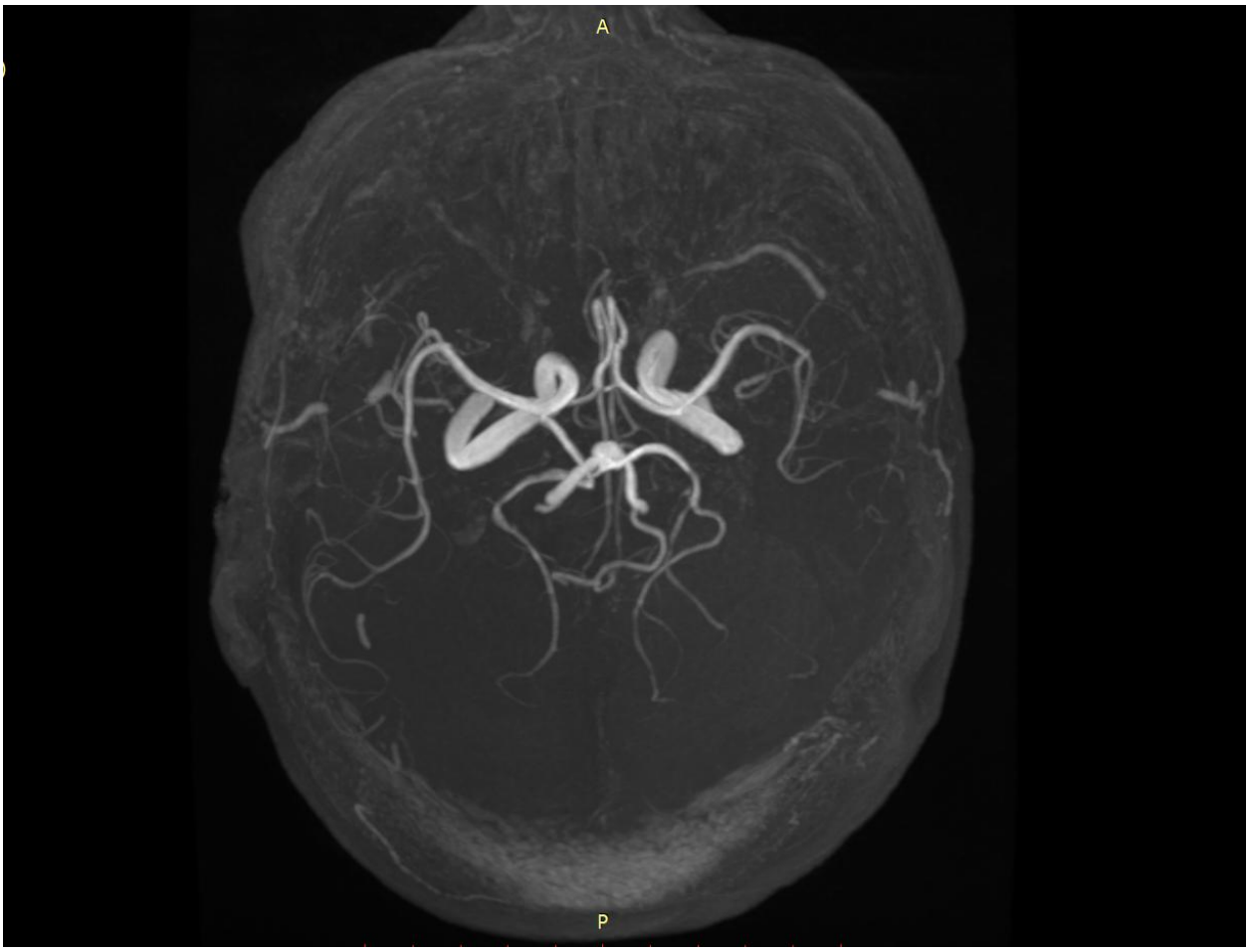
A fetal PCA describes a situation whereby the posterior communicating artery (PCom) is larger than the P1 segment of the posterior cerebral artery (PCA) and, thus, supplies the bulk of the blood to the PCA 4,5. The P1 can be small (hypoplastic) or absent in this setting. When bilateral fetal PCAs are present, the basilar artery will be significantly smaller in caliber than normal.

The significance of fetal PCA is in relation to the pattern of ischemic stroke, given that if a fetal PCA is present, the PCA is essentially part of the anterior circulation ref. This becomes relevant, for example, if there is ipsilateral internal carotid artery stenosis. Additionally, a larger PCom with an existing P1 allows for collateral circulation.

Case 2:

A 83-year-old female patient was referred to our department with history of giddiness, slurring of speech, heaviness of tongue and weakness.

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.



The left posterior communicating artery appears hypoplastic.

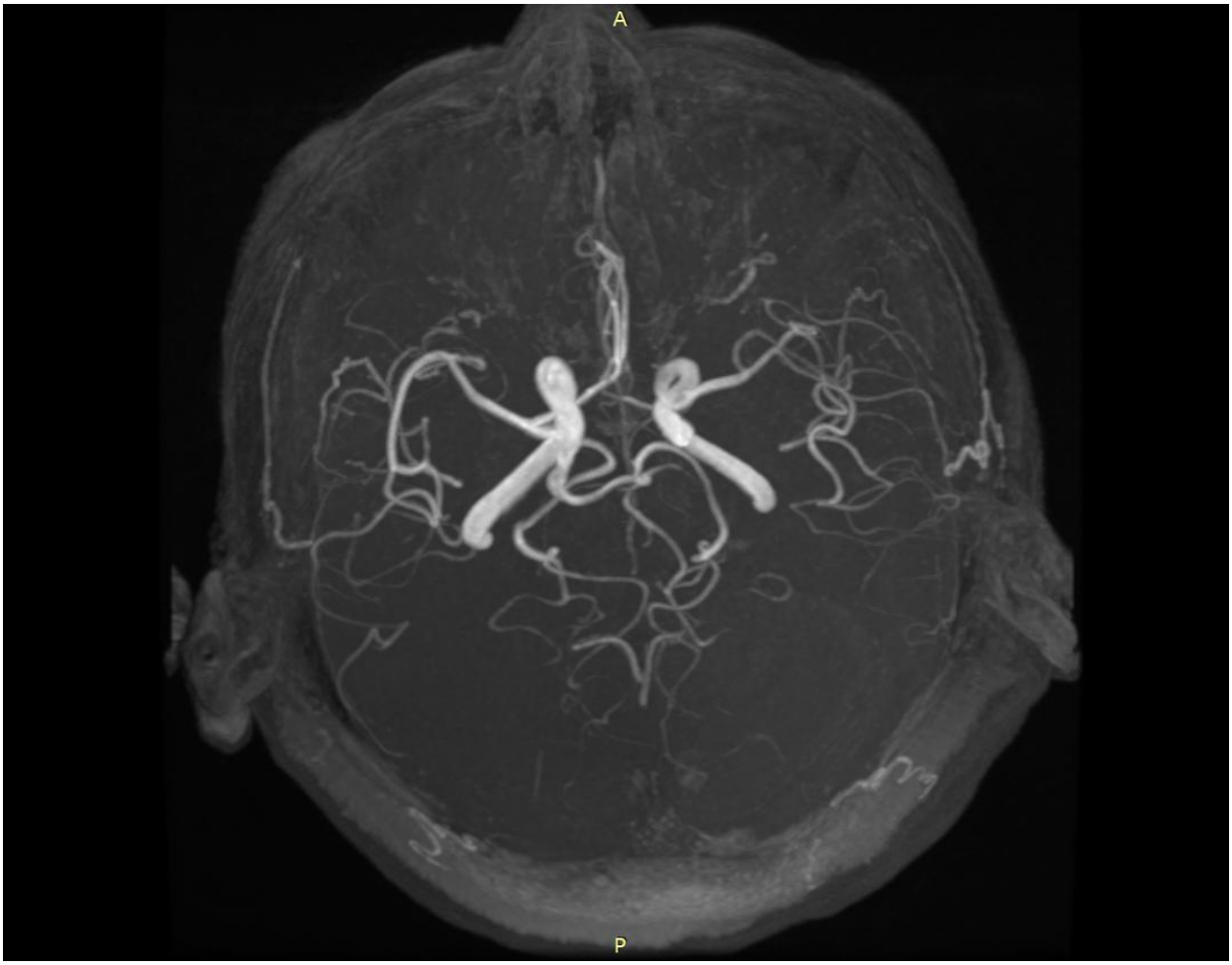
Posterior communicating artery hypoplasia refers to the absence of the posterior communicating artery, a blood vessel that connects the posterior cerebral artery with the internal carotid artery, thus acting as a connection between the anterior and posterior portions of the circle of Willis.

Posterior communicating artery hypoplasia is thought to increase the risk of ischemic stroke, presumably due to the absence of available collateral circulation.

Case 3:

A 54-year-old female was referred to our department with history pain in bilateral lower limbs with tingling and numbness

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.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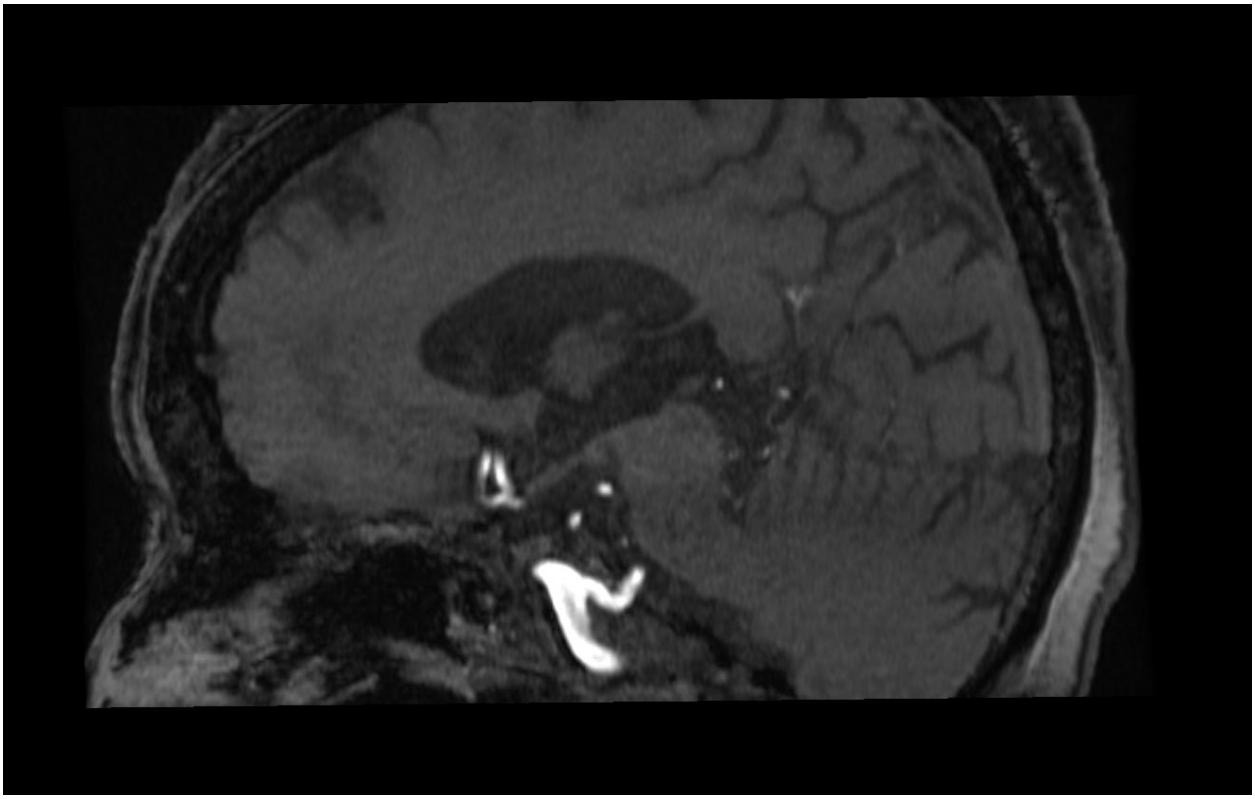


There is a communication between the C4/Cavernous segment of the right internal carotid artery and the basilar artery suggestive of Saltzman type I persistent primitive trigeminal artery.

Persistent primitive trigeminal artery (PPTA) is the most common type of the four persistent carotid-vertebrobasilar anastomoses. It is present in 0.1-0.6% of cerebral angiograms and is usually unilateral.

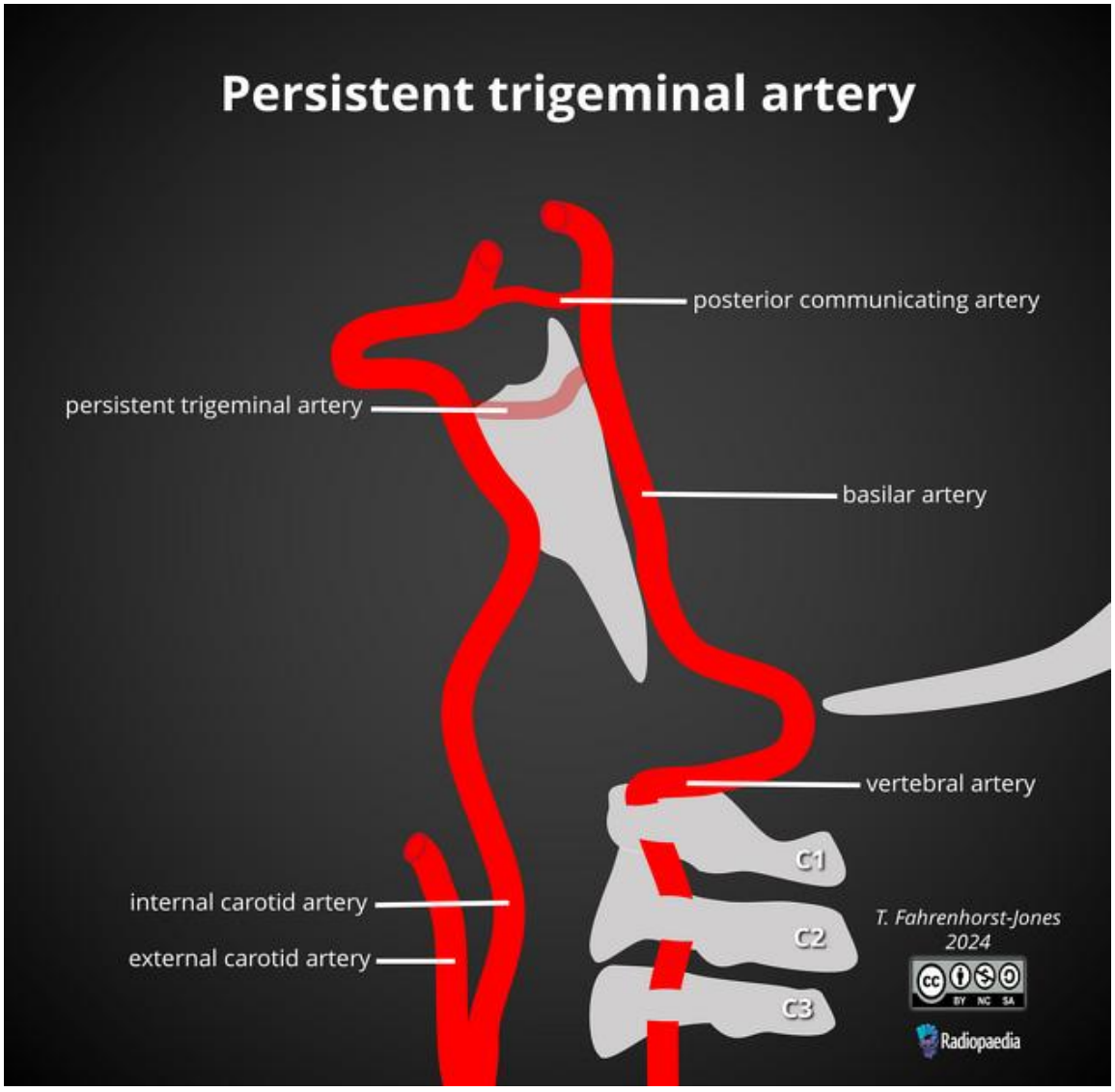
In utero, the trigeminal artery supplies the basilar artery before the development of the posterior communicating and vertebral arteries. The PPTA arises from the junction between petrous and cavernous segments of the internal carotid artery, and runs posterolaterally along the trigeminal nerve (41%), or crosses over or through the dorsum sellae (59%). Vertebral, posterior communicating and caudal basilar arteries are often hypoplastic.

Classification

There are 3 types of PPTA:

1) Saltzman type I: PPTA supplies the distal vertebrobasilar arteries. The posterior communicating artery is absent and the caudal basilar is absent or hypoplastic with hypoplastic distal vertebral arteries.
2) Saltzman type II: PPTA supplies the superior cerebellar arteries with the posterior cerebral arteries supplied by the posterior communicating artery
3) Saltzman type III: PPTA does not join the basilar artery, instead directly terminating as the
   - type IIIa: superior cerebellar artery
   - type IIIb: anterior inferior cerebellar artery
   - type IIIc: posterior inferior cerebellar artery

A characteristic tau sign 4 or trident sign is described as its appearance on sagittal CTA or MRA/MRI.



Case 4:

A 65-year-old male was referred to our department with history of dizziness and vomiting since 1 day.

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.

Azygous ACA is noted.

An azygos anterior cerebral artery is a rare variant of the circle of Willis where the two A2 segments of the anterior cerebral artery (ACA) join to form a single trunk. As a result, there is no anterior communicating artery. This organization is similar to that seen in lower primates.

Associations:

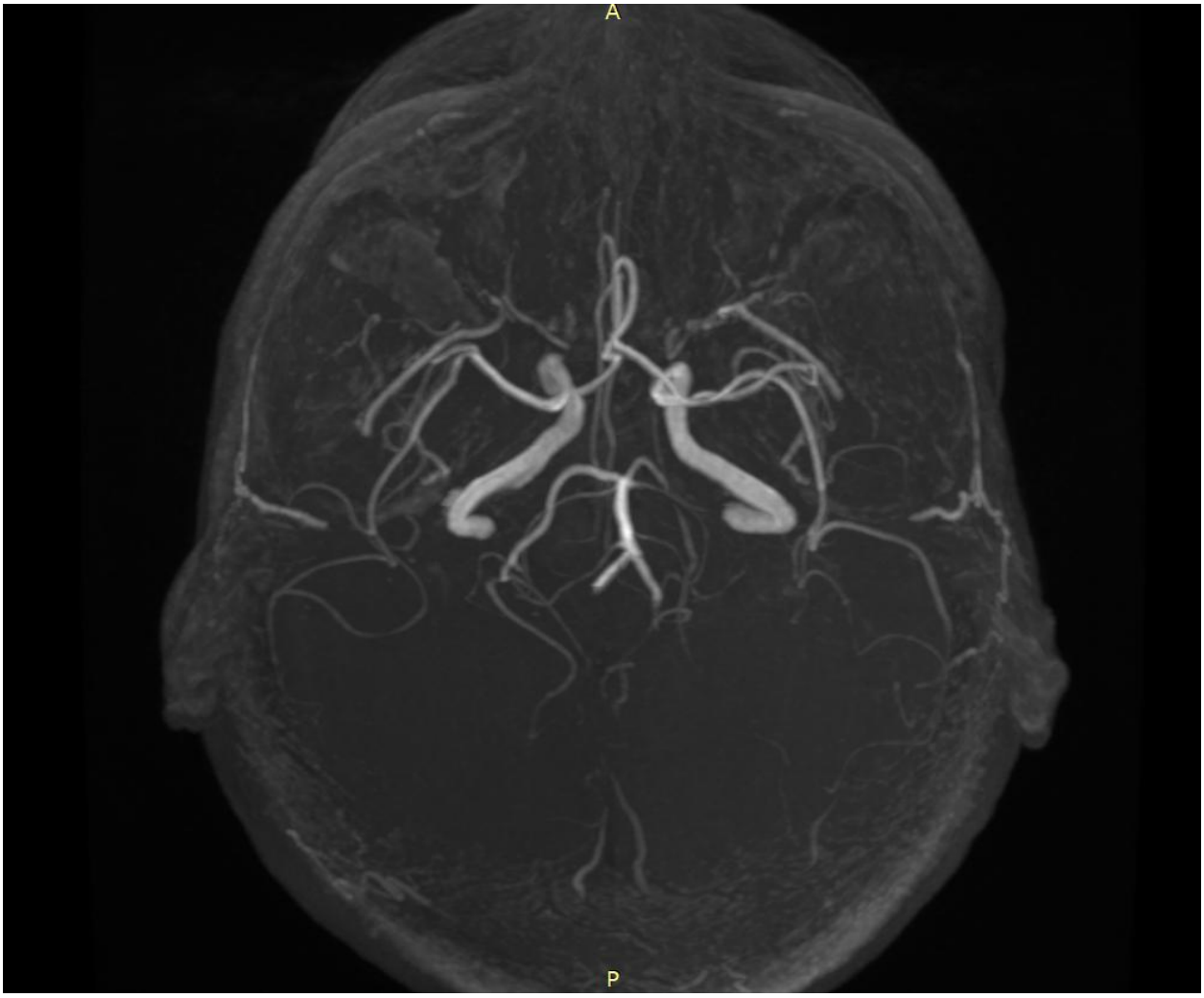
An azygos anterior cerebral artery is associated with numerous abnormalities, including 1:

- Dysgenesis of the corpus callosum
- lobar holoprosencephaly 3
- septo-optic dysplasia
- porencephalic cysts
- arteriovenous malformations (avm)

Case 5:

A 40-year-old male was referred to our department with history of blurred vision and behavioural abnormality for 2 years, DM, H/O CVA 2 years back.

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.



Two middle cerebral arteries are seen originating from the distal end of the left internal carotid artery suggestive of duplicated MCA – variant.

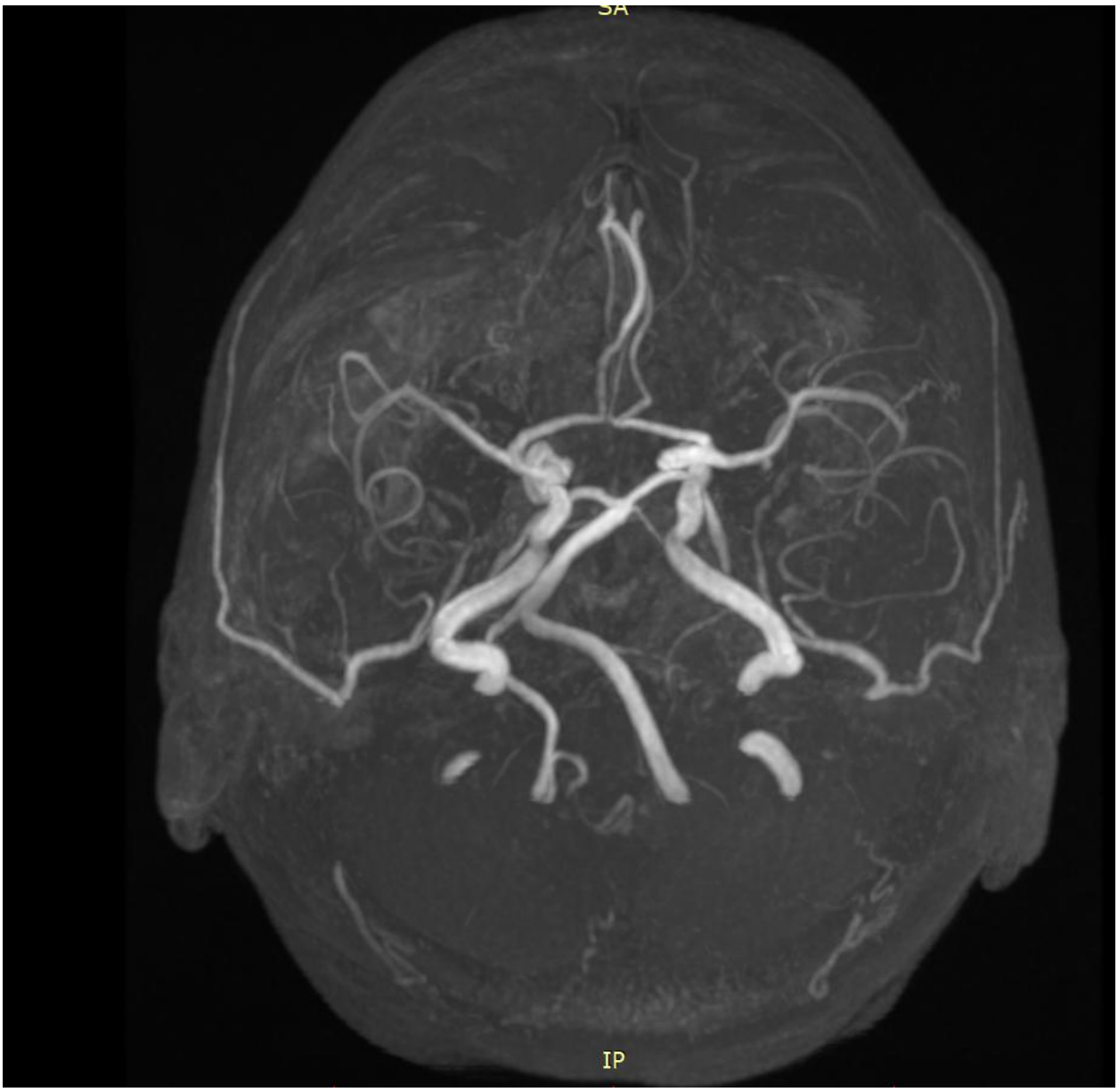
A duplicated middle cerebral artery is an anatomical variant in which there are two middle cerebral arteries originating from the distal end of the internal carotid artery.

The duplicated artery supplies the anterior temporal lobe.

Case 6:

A 67-year-old male was referred to our department with history of dementia for 10 years.

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.

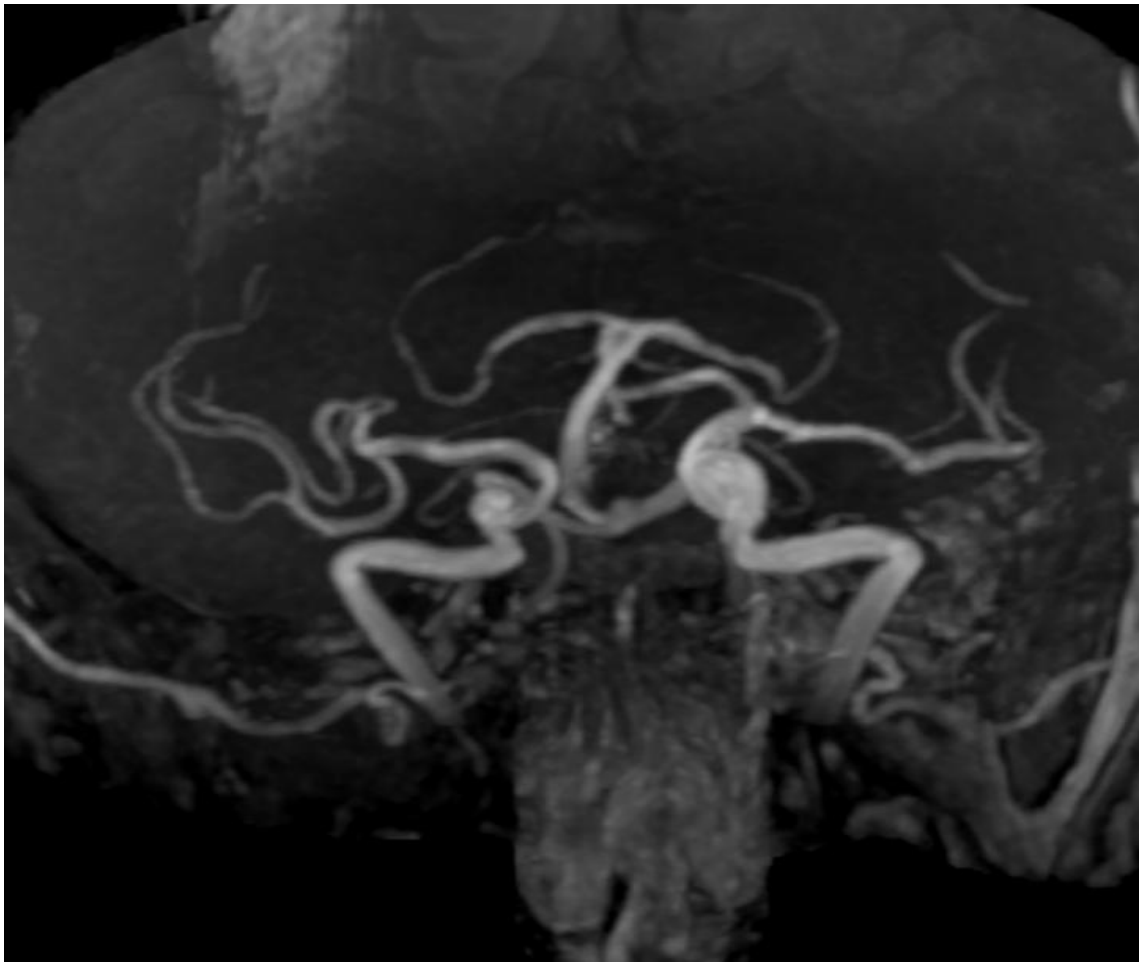


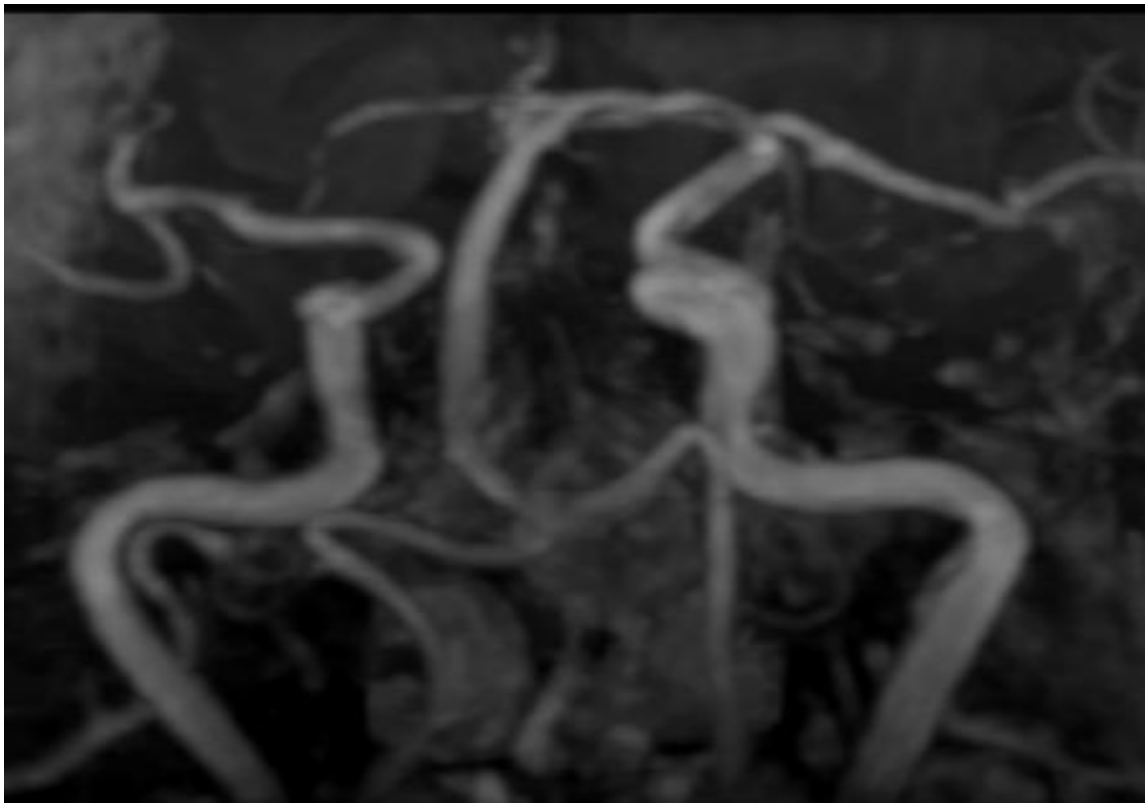
There is trifurcation of ACA –Normal anatomical variant.
A non-enhanced TOF angiogram shows an incidental finding of anterior cerebral artery trifurcation with triplication of the A2 segment, the third one originates from the anterior communicating artery.

Here is a case of anterior cerebral artery trifurcation, an uncommon anatomical variant of the anterior cerebral artery.

Case 7:
A 65-year-old male was referred to our department with history of suspected TIA

MR Angiograms were obtained for craniocervical vessels using 2D & 3D TOF sequences.





Anomalous shape of the basilar artery between the origins of the superior cerebellar and posterior cerebral arteries in the form of a reversed triangle with central signal void (fenestration).

Basilar artery fenestration (or more simply, basilar fenestration) is the most common intracranial arterial fenestration and most common congenital anomaly of the basilar artery. This anatomic variant is characterized by duplication of a portion of the artery that are connected proximally and distally.

An arterial fenestration is a segmental duplication wherein a single lumen divides into two lumens, both lined by endothelium, that rejoin to one distally.

Fenestrations vary in size. At one extreme, basilar septation is a rare variant considered to be a miniature/aberrant basilar fenestration. At the other extreme, complete duplication can be considered extreme fenestration of the basilar artery.

Fenestration may predispose to basilar artery aneurysm formation, presumably due to abnormal flow dynamics, but the magnitude of risk is inconsistent across studies. Fenestration-associated aneurysms most often occur at the vertebrobasilar junction, followed by the basilar trunk, and are usually saccular in morphology. The reported prevalence of aneurysms in cases of basilar fenestration is 7%.

Thromboembolic posterior circulation infarcts have been reported with basilar artery fenestration.

2. Discussion

Morphological variations are quite frequent in the CW in humans. Because of the variability, clinical manifestation may vary considerably from one individual to another, and the effectiveness of collateral circulation may be greatly influenced. Whether this is a risk factor for stroke should be subject to further investigation also knowing the anatomical variants helps to avoid misdiagnosis.

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