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Normal Variant Of The Cerebral Circulation At MR Angiography

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Learning objectives

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Magnetic Resonance angiography (MRA) is used in many institutions for initial evaluation of the cerebral circulation for patients with acute stroke. Knowledge of the presence and clinical relevance of normal variants such as fenestrations, duplications, and persistent fetal arteries plays a crucial role in the diagnosis and management of acute stroke and may aid in surgical planning. Our aims are :-

- To review the spectrum of normal variant of the cerebral arteries at the MR Angiographic studies.

- To discuss the clinical implications of these variants.
- To increase awareness and recognition of uncommon but normal vessels and their differential diagnosis.

Background

Embryology of intracranial arterial circulation.

The main principles embryology of cerebral arteries are well-known , however the development of some anomalies remains controversial . Starting from the 5th week of gestation the embryogenesis of the cerebral arteries begins. From the primitive intracranial arteries, many arterial branches develop and form anastomoses among themselves; then, certain arterial segments regress.

At 5 weeks of gestation, two main arteries are present: the internal carotid arteries (ICA); and the bilateral longitudinal neural arteries (BLNA). The anterior circulation originates from the ICA, while the BLNA gives rise to the vertebrobasilar system. Normally, there are also transient anastomoses between these two main trunks: the trigeminal arteries; otic arteries; hypoglossal arteries; and proatlantal arteries. These arteries should regress later, the failure of their regression resulting in presence of these arteries in adults, so called persistent featal circulation.

During the same period of time, the ICA bifurcates into cranial and caudal divisions. Division occurs at what will later become the posterior communicating artery (PCoA). The cranial division gives rise to the anterior circulation, which includes the ACA, anterior choroidal artery and middle cerebral artery (MCA). The caudal division terminates as the PCoA - a normally definitive carotid - vertebrobasilar communicating artery that 'closes off' the circle posteriorly.

According to Padget the embryogenesis of the anterior circulation is the result of two important stages: first one , the cranial division of the ICA developed numerous arteries supplying the anterior part of the brain; and then, the regression of certain arterial segments in utero and, in some cases, during ex utero development into adulthood The embryological circle, which is more highly developed than the adult one, has three 'ACAs', with an anterior communicating plexus (ACoP) connecting these three arteries. The third 'ACA' follows the course of the two other 'ACAs' and is known as the median artery of corpus

callosum (MACC). The MACC and ACoP should then regress and failure to do so can lead to numerous anatomical variants, such as an accessory ACA due to a persistent MACC, or a double ACoA due to incomplete regression of the ACoP. Some segments that should persist may also abnormally regress (resulting in, for instance, aplasia or hypoplasia of the proximal ACA segment)

Yet, Baptista was partially refuted this theory who maintain that an accessory ACA detected in the adult brain and considered an anatomical variant has a different course from the embryological MACC. Therefore, it may not be an abnormally persistent embryonic vessel, but an additional vessel, resulting from the fusion of pericallosal branches. This theory could also explain other anatomical variations, such as an azygous or bihemispherical ACA

In addition, some anatomical variations of the MCA could be described as a variant of the anterior circle as the MCA is embryologically considered a collateral branch of the ACA.

MR Angiography Technique

MRA is a part of our routine protocol of brain for the stroke cases, During the past 6 years; approximately 1000 patients underwent cranial MR angiography with the 3D TOF technique at our institution. Thus, the scanning time was approximately 10 min. Maximum-intensity-projection images in the horizontal rotation view were routinely displayed stereoscopically over 180 For optimal interpretation and treatment planning, the method requires suitable

post-processing equipment, and an extensive knowledge of anatomy and anatomical variations. Anatomical variations of the cerebral arteries are commonly found,Indeed, diagnostic efficiency is seen to improve in parallel with a thorough understanding of both normal cerebral vascular anatomy as well as the variants that can mimic pathology.

Findings and procedure details

Normal anatomy (Fig.1)

Anatomical variations:-

The absence vessels may include agenesis , aplasia and hypoplasia :-

Agenesis as complete failure of an organ to develop.

Aplasia as lack of development (but its precursor did exist at one time).

Hypoplasia as incomplete development of the organ.

A). variants of the anterior circulation

1. Congenital absence of the internal carotid arteries

The congenital absence of the internal carotid arteries (ICAs) is a rare condition which diagnosed mostly in adult patient. Most cases have been demonstrated by catheter angiography or dissection studies. Its true diagnosis is important to avoid the misdiagnosis of thrombotic vessel, also has a great implication in the vascular mapping before the carotid or transsphenoidal surgery.

The agenesis of ICA may be unilateral (FIG.3&4) or bilateral (FIG.2&3).

The exact pathogenesis of these developmental anomalies has not been identified; it may be attributed to an insult to the developing embryo. Presumed etiology of unilateral absence have centered on mechanical and hemodynamic stresses placed on the embryo, including effects related to over folding of the embryo toward one side and constriction by amniotic bands. Till now, an explanation for bilateral absence has not been rendered.

Relatively few cases of absence of the ICA have been reported in children, suggesting that initially the collateral pathways are sufficient to support cerebral perfusion .While many cases of absence of the ICA may remain asymptomatic and go unrecognized, these patients may present later in life with symptoms related to cerebrovascular insufficiency. The entire anterior circulation may be dependent upon a single carotid artery or the vertebrobasilar system, either of which may become compromised by atherosclerosis. Congenital absence of the ICA usually discovered during evaluation of symptoms ultimately attributed to transient ischemic attacks, although no thromboembolic source or documented hypotensive episode were identified. Alternatively, such patient may present with mass effect from the enlarged collaterals, complications related to aneurysm, and, rarely, congenital Horner's syndrome. The estimated prevalence of cerebral aneurysms in the general population is 2% to 4%, but the reported prevalence of aneurysms in association with absence of the ICA is 24% to 34%. Increased flow through collateral vessels and altered flow dynamics are cited as plausible explanations for this increased prevalence. Reorganization of this anomaly is important in the setting of the

thromboembolic disease as emboli in one cerebral hemisphere may be explained by athersecrlosis on the vertebrobasilar or the contralateral common carotid arteries**.**The differential diagnosis of non visualized internal carotid artery is acquired thrombotic occlusion, that can easily differentiated by the abnormal signal within the artery and lake of prominent collaterals.

2. Azygos Anterior Cerebral Artery

A solitary midline A2 trunk supplies theanterior cerebral artery territories bilaterally . azygos anterior cerebral artery may be a sequlea of persistence of the embryonic median artery of the corpus callosum. The prevalence of azygos anterior cerebral arteries is 0.2%-4.0%. This variant may be isolated and less common asscocited with other congenital abnormalities such as holoprosencephaly, various neuronal migration anomalies. It may be a predisposition to aneurysm formation. The clinical relevance of this anomaly is considered in the event of anterior cerebral artery occlusion secondary to thromboembolic disease or surgical error, the resultant ischemia affects both hemispheres.

3. Bihemispheric Anterior Cerebral Artery

This anomaly is characterized by hypoplasia of one A2 segment, with bilateral anterior cerebral artery territories supplied by the contralateral A2 segment (Fig 6). The prevalence of this anomaly is 2%-7%. The differentiation of this variant from an azygos anterior cerebral artery is easy by the The presence of a hypoplastic A2 segment . The clinical relevance of the both variant is similar with regard to occlusion. Occlusion of the dominant A2 segment results also in ischemia of both hemispheres .

4. A1 Segment Absence or Hypoplasia

The complete absence of an A1 segment is seen in 1%-2% whereas the hypoplasia of an anterior cerebral artery A1 segment is present in about 10% of autopsies . (Figs 7&8). In these cases, the contralateral anterior cerebral artery may supply part or all of the territory of the normal anterior cerebral artery via a large anterior communicating artery The clinical relevance of this anomaly is considered in the event of thromboembolic disease, these conditions result in a diminished collateral supply and therefore an increased risk of infarction

5. Absent Anterior Communicating Artery.

The anterior communicating artery is not always depicted at conventional angiography, but this does not necessarily mean that the artery is absent. Definitive absence of the anterior communicating artery has been found in 5% of surgical dissections.

6. Duplicated and Accessory Middle Cerebral Artery

Duplicated middle cerebral artery is a smaller middle cerebral artery branch arising from the distal carotid artery.

Accessory middle cerebral artery is a small artery branch arising from the anterior cerebral artery courses parallel to the M1 segment of the middle cerebral artery, supplying the anterior-inferior region of the frontal lobe. (36).

The recurrent artery of Heubner (medial striate artery) and accessory middle cerebral artery phylogenetically represent a primitive vascular anastomosis with the piriform cortex, with one or the other vessel usually predominating. During normal development, the recurrent artery of Heubner provides the main blood supply to the piriform cortex, while the accessory middle cerebral artery undergoes regression. The clinical relevance of this anomaly is considered in the event of middle cerebral artery occlusion as it may provide collateral blood supply to the distal middle cerebral artery territory.

B): **variants of the posterior circulation**

1. Fetal Origin of the Posterior Cerebral artery.

In this variant the P1 segment of the posterior cerebral artery is either hypoplastic or totally absent and the P2 segment frequently arises directly from the supraclinoid ICA as a continuation of the Pcom. This variation is called the "fetal origin of the posterior cerebral artery," and its reported incidence is 10% on the right, 10% on the left, and 8% bilaterally (Figs 9-10& 11). [1].

In the presence of this anomaly, the caliber of the posterior communicating artery may be the same as or greater than that of the ipsilateral P1 segment, and the dominant blood supply to the occipital lobes comes from the internal

carotid artery. Fetal origin of the posterior cerebral artery occurs when the embryonic posterior cerebral artery fails to regress.

2. Common Posterior Cerebral an Superior Cerebellar Artery Trunk

The reported prevalence of a common trunk of the posterior cerebral and superior cerebellar arteries is 2%-22%. However it doesn't have any reported clinical significance.

3. Basilar artery fenestration

Fenestration is defined as a division of the arterial lumen into distinctly separate channels, each with its own endothelial and muscularis layers, while the adventitia may be shared.

The reported prevalence of the basilar artery fenestration is about 0.6% of angiographic examinations and approximately 5% of autopsies. The common location of basilar artery fenestrations is the proximal basilar trunk, close to the vertebrobasilar junction . The reported frequency of aneurysm formation in cases of basilar artery fenestration is 7% .

The presumed theory for development of this variant based on the embryologic development of the basilar artery. In the fetus, it is formed by the fusion of bilateral longitudinal neural arteries during the 5th gestational week. As this fusion progresses, bridging arteries that temporarily connect the longitudinal neural arteries regress. If the bridging arteries fail to regress, the result is fenestration of the basilar artery.

C): ***Persistent Carotid-Vertebrobasilar Anastomoses***

1.Persistent trigeminal Artery-

The persistent trigeminal artery is the most cephalically located and frequently occurring persistent carotid-vertebrobasilar anastomosis. Its incidence is reported to be 0.1-0.6% in large angiographic series. The persistent trigeminal artery has two types, the lateral type and the medial type . Both are equally common.

The persistent trigeminal artery is also classified according to the configuration of the ipsilateral posterior cerebral artery (F. 12). In the Saltzman type 1 persistent trigeminal artery, the posterior communicating artery is absent. In the Saltzman type 2 persistent trigeminal artery, the ipsilateral posterior cerebral artery arises directly from the ICA and the P1 segment is absent, which indicates a fetal origin of the posterior cerebral artery. The basilar artery is usually hypoplastic caudad to the anastomosis in both Saltzman types.

The lateral type originates from the precavernous segment of the ICA and courses posterolaterally along the trigeminal nerve; it anastomoses with the mid portion of the basilar artery.

The medial-type persistent trigeminal artery is also called the "intrasellar persistent trigeminal artery" or the "transhypophyseal persistent trigeminal artery." It arises from the precavernous ICA and courses posteromedially. It compresses the pituitary gland and penetrates the dorsum sellae, and it anastomoses with the midbasilar artery. This persistent trigeminal artery type is clinically important because transsphenoidal surgery for pituitary adenoma is dangerous in patients who have this variant.

2**. *Persistent hypoglossal artery.-***

The persistent hypoglossal artery is the second most common carotid-vertebrobasilar artery anastomosis after the trigeminal artery. Its incidence is reported to be 0.02-0.1% . The persistent hypoglossal artery leaves the ICA as a large extracranial branch. It

passes through the hypoglossal canal, and the basilar trunk originates from the persistent hypoglossal artery.

Definitive diagnosis of the persistent hypoglossal artery can be made by recognition of an anomalous artery in the enlarged hypoglossal canal .

3. **Persistent Otic Artery.**

The existence of an otic artery is a matter of controversy. It is an artery arising from the petrous internal carotid artery within the carotid canal, coursing laterally through the internal auditory canal, and anastomosing with the proximal basilar artery.

Images for this section:

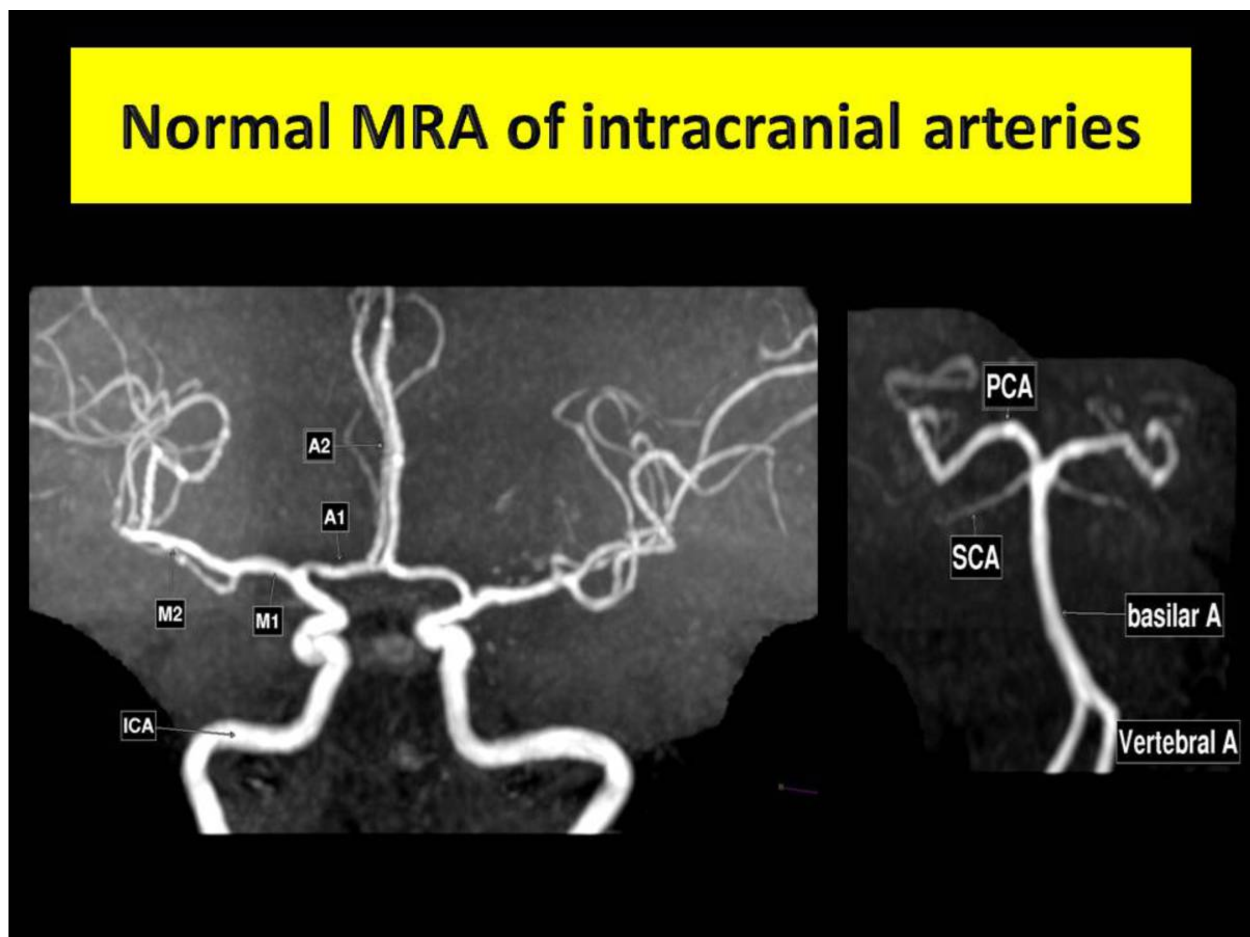

Fig. 1

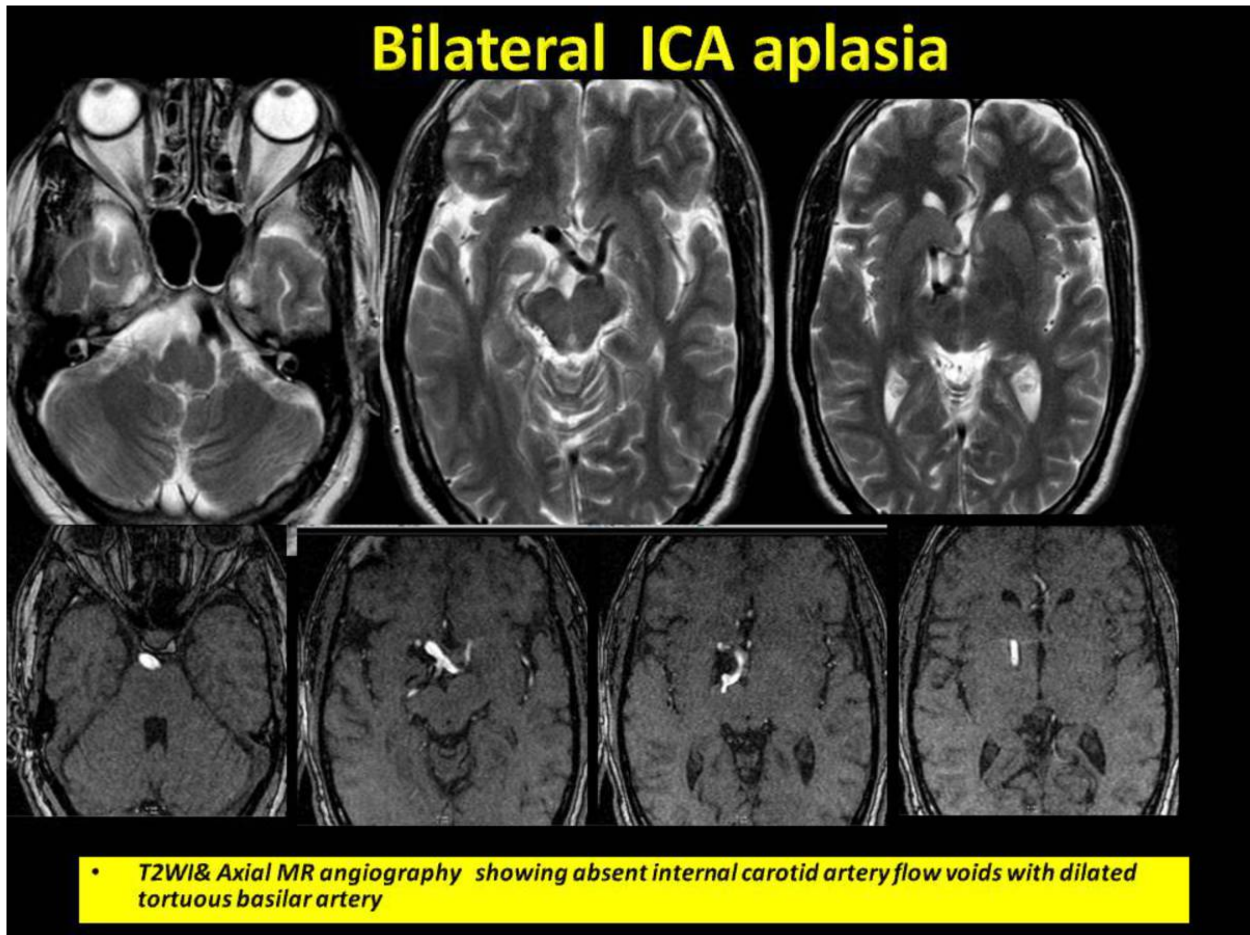

Fig. 2

Fig. 3

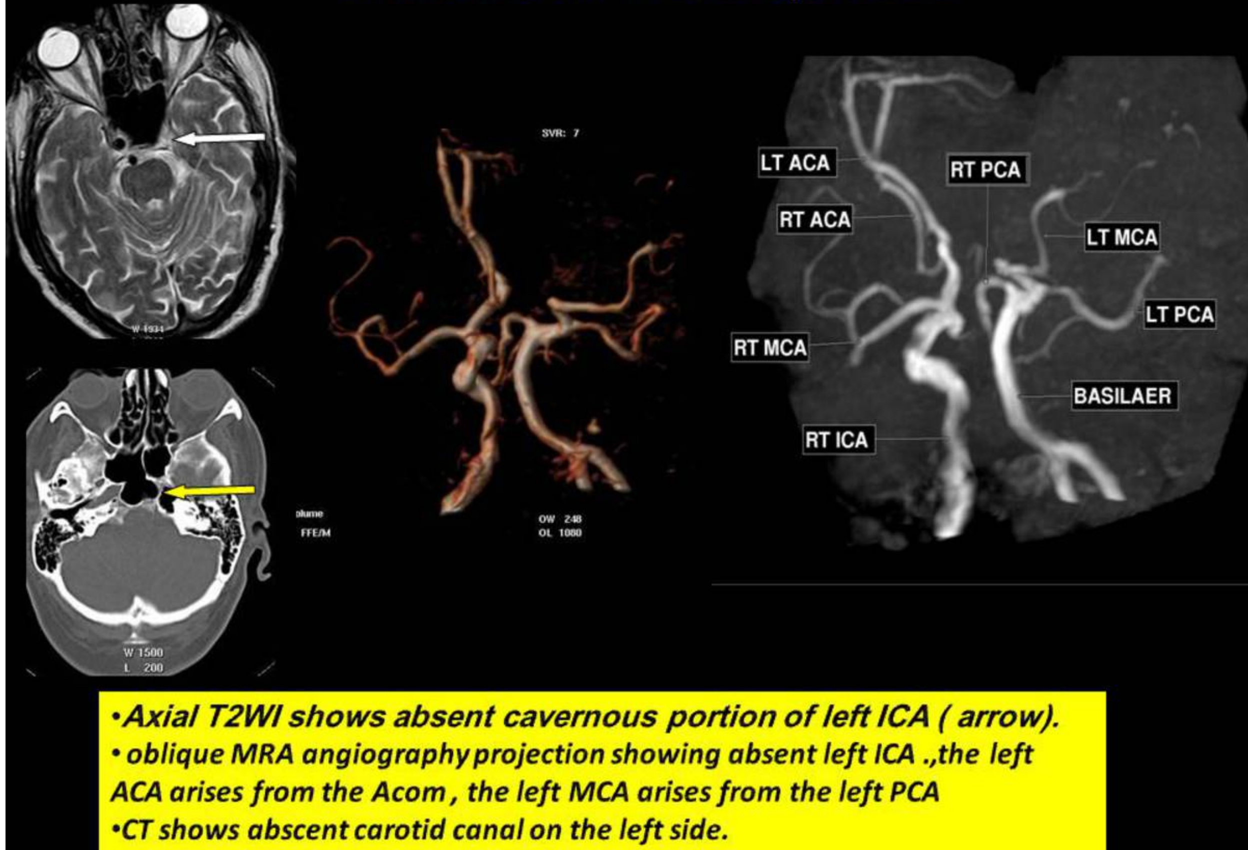

Fig. 4

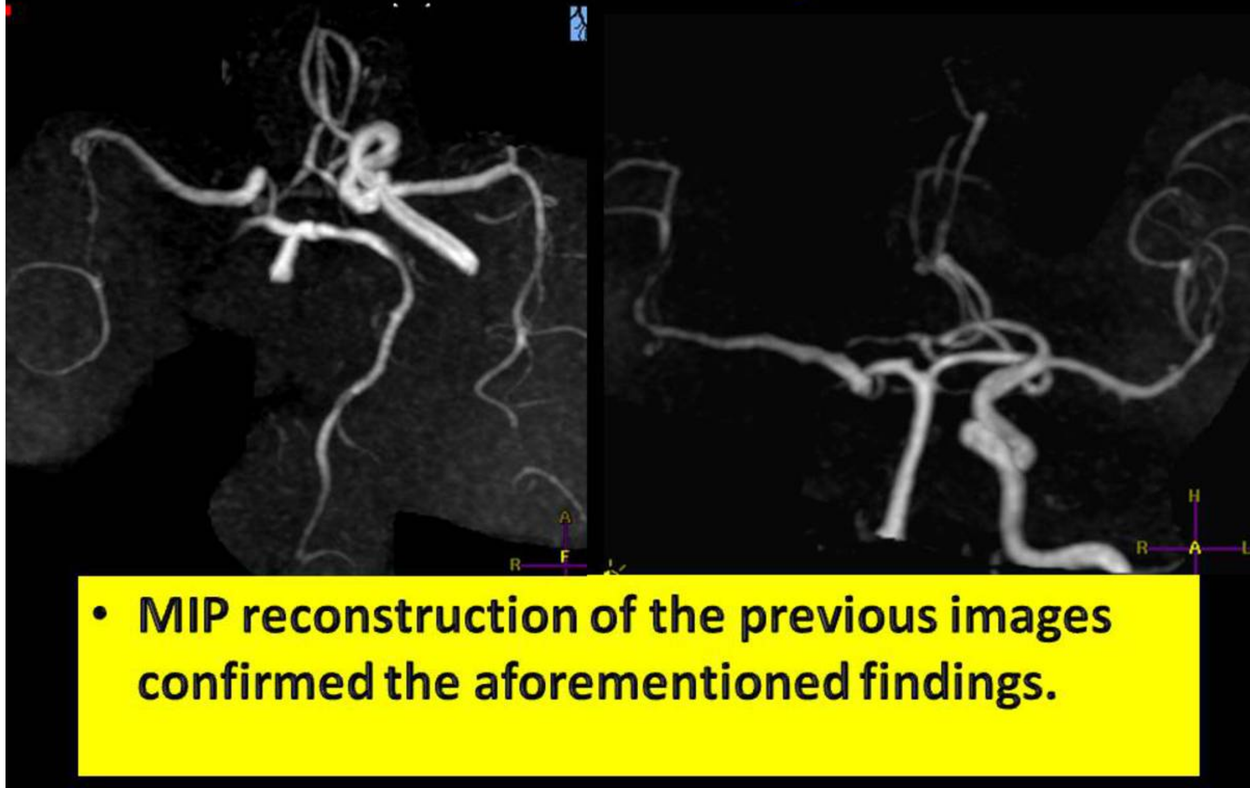

Fig. 5

Fig. 6

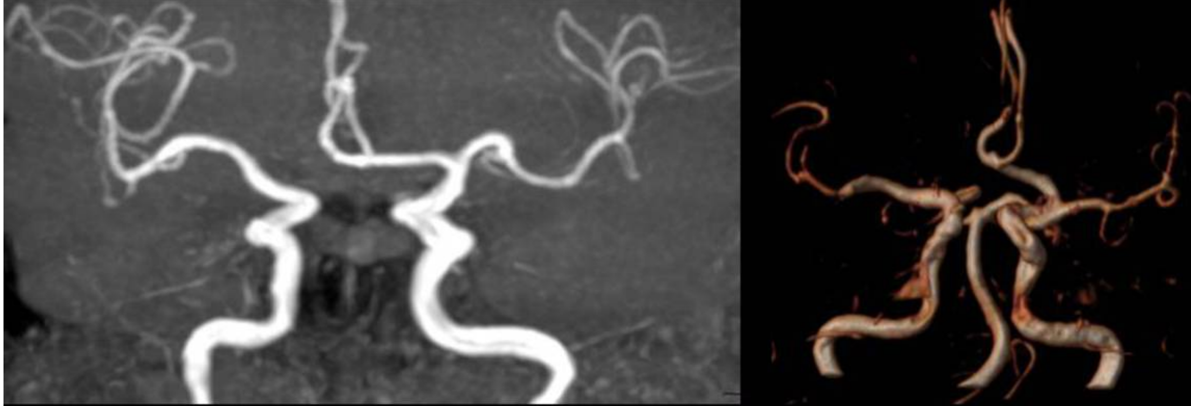

Fig. 7

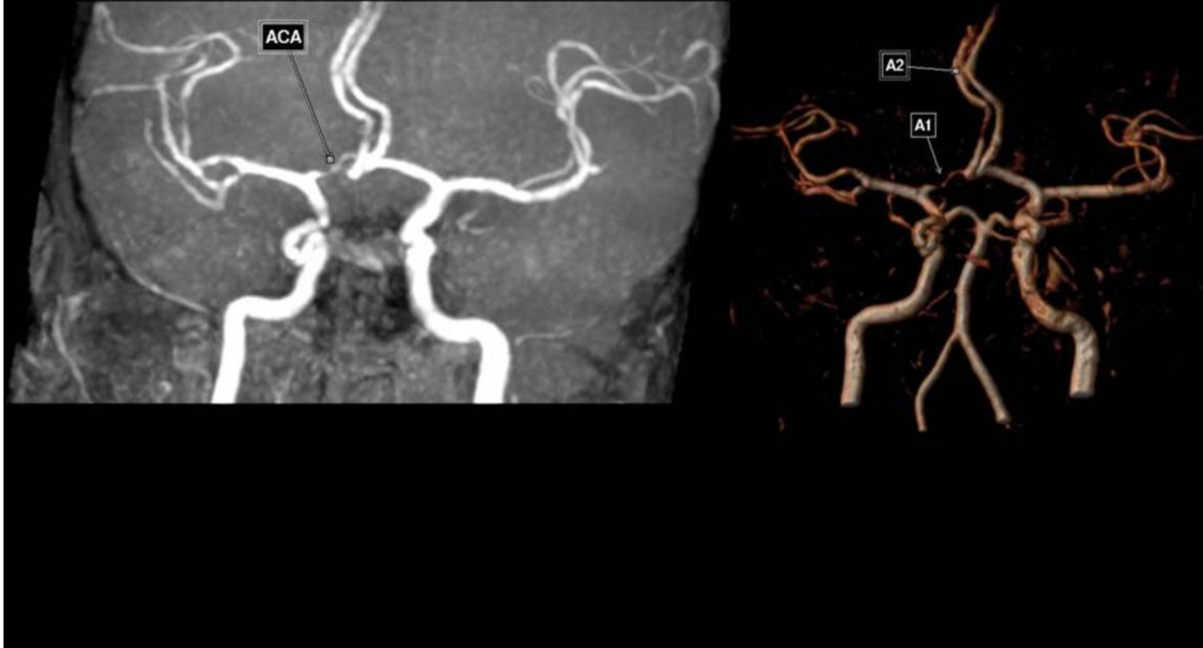

Fig. 8

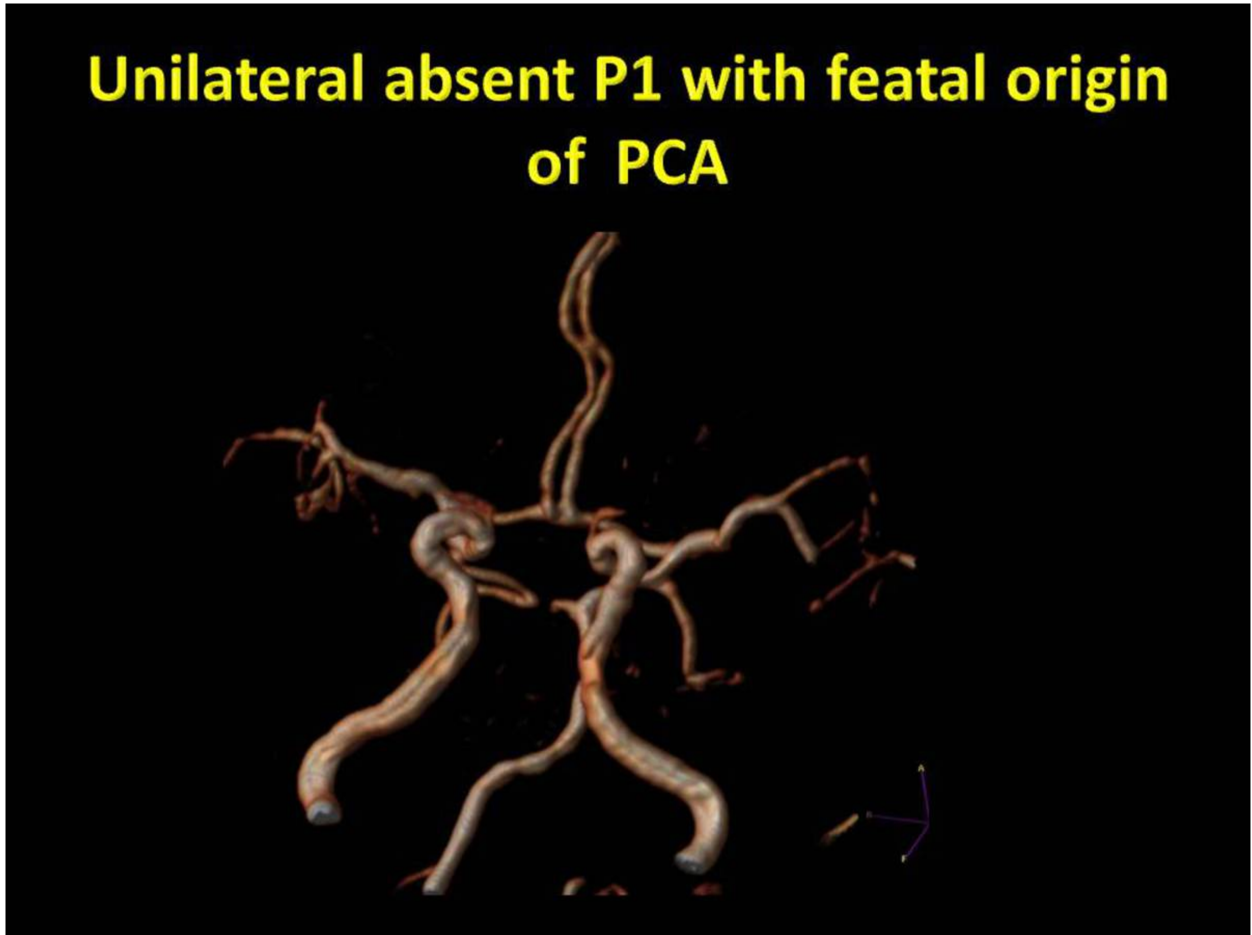

Fig. 9

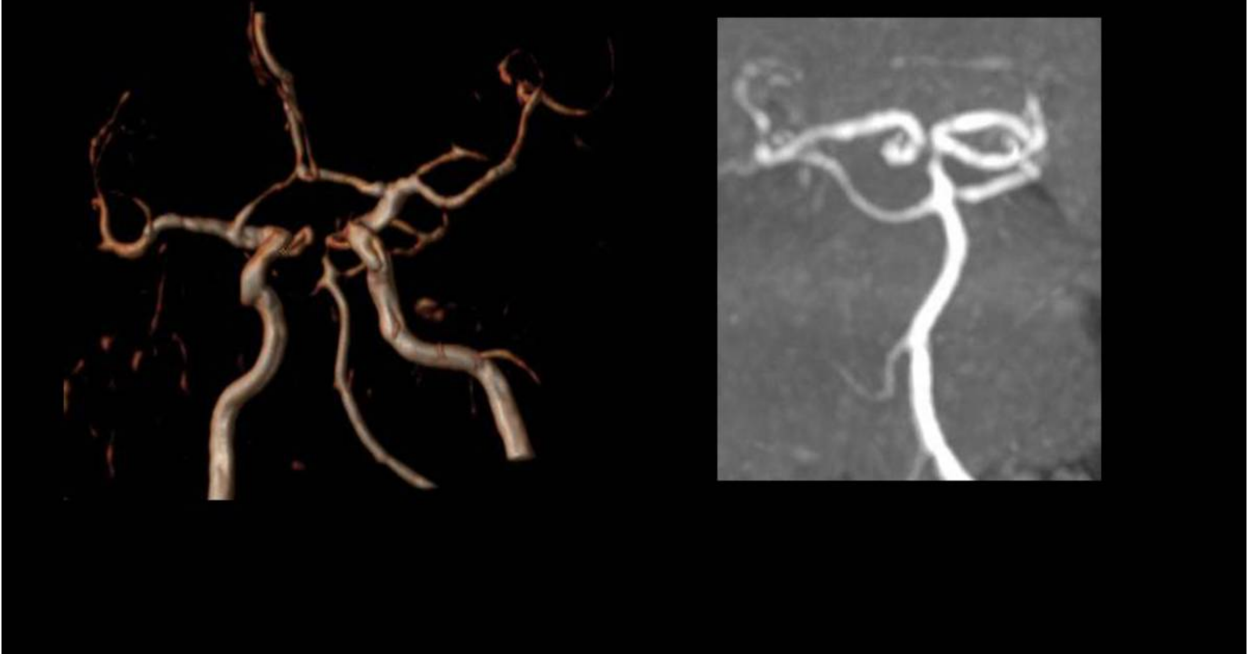

Fig. 10

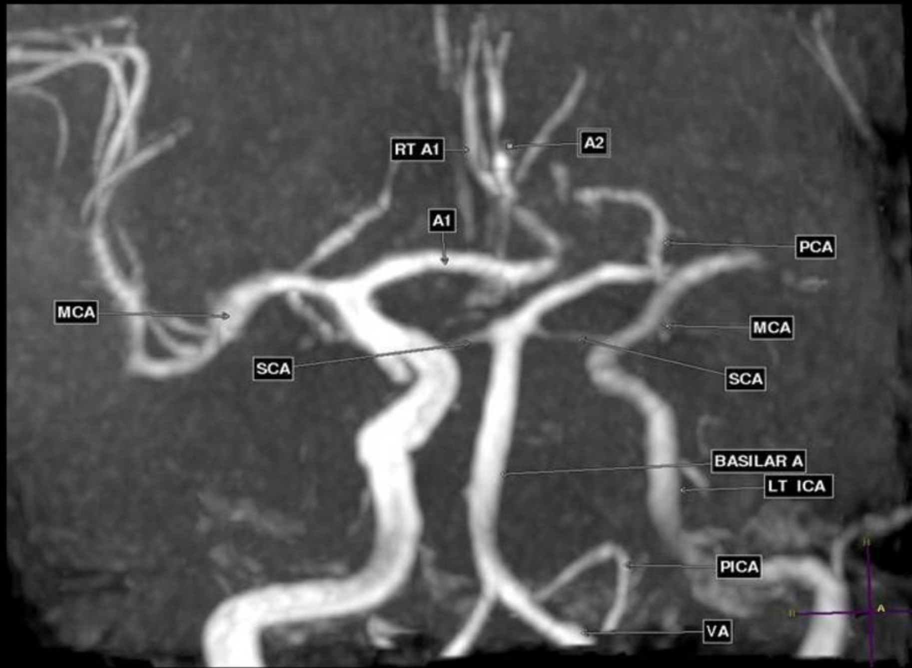

Fig. 11

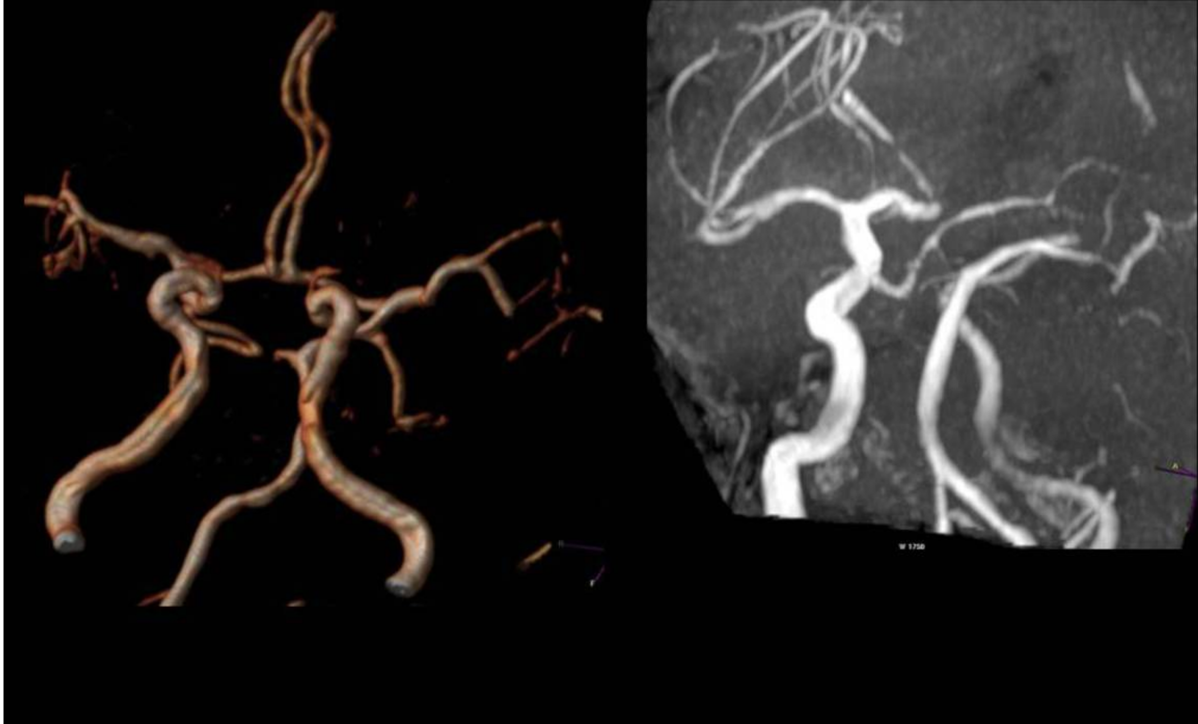

Fig. 12

Conclusion

MR angiography is used in many institutions as a part of the stroke protocol for initial evaluation of the cerebral circulation for acute infarction as well as the subarachnoid hemorrhage. Comprehensive MRA examination that includes a review of three-dimensional and maximum intensity projection images of the intracranial arteries and axial images allow identification of most abnormalities and normal variants. Knowledge of the presence and clinical relevance of normal variants plays a crucial role in the diagnosis and management of acute stroke and subarachnoid hemorrhage and may aid in surgical planning.

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References

1. Okahara M, Kiyosue H, Mori H, Tanoue S, Sainou M, Nagatomi H. Anatomic variations of the cerebral arteries and their embryology: a pictorial review. Eur Radiol 2002;12:2548-2561.
2. Jayaraman M.V., Mayo-Smith W.W. Multi-detector CT angiography of the intra-cranial circulation: normal anatomy and pathology with angiographic correlation *Clin Radiol* 2004 ; 59 : 690-698
3. Owada Y, Sakuta Y. Bilateral carotid artery agenesis with corpus callosum hypogenesis - a case report. No-To-Shinkei 1995;47:589-94.
4. Claros P, Bandos R, Gilea I, et al. Case report: major congenital anomalies of the internal carotid artery-agenesis, aplasia, and hypoplasia. Int J Pediatr Otorhinolaryngol 1999;49:69-76
5. SM desai,RS Kashyape .Images , bilateral agensis of the internal carotid arteries ,MR and MR angiography . Indian J Radiol imaging August 2007 , volume 17 ,issue 33.
6. Caldemeyer KS, Carrico JB, Mathews VP. The radiology and embryology of anomalous arteries of the head and neck. *AJR* 1998;170:197-203

7. Saltzman G. Patent primitive trigeminal artery studied by cerebral angiography.*ta Radiol* 1959;51: 329-336

8 . Meaney JF, Sallomi DF, Miles JB. Transhypophyseal primitive trigeminal artery: demonstration with MRA. *J Comput Assist Tomogr* 1994;18:991-994.

9. Luh GY, Dean BL, Tomsick TA, Wallace RC. The persistent fetal carotid-vertebrobasilar anastomoses. *AJR* 1999;172:1427-1432