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High Resolution MR Angiography of the Posterior Cerebral Circulation: Variants, Incidence and Clinical Impact

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ABSTRACT

Objective: In the embryonic period, several developmental anomalies of the posterior cerebral circulation might occur. Digital subtractive angiography used to be the imaging technique of choice for the illustration of such variations. Nowadays, the development of MR imaging has led to a new entry in the diagnostic archer's quivery, the MR angiography, with which most of these variations may be diagnosed. Purpose of this study is to illustrate these anatomic variants, their incidence and their potential clinical significance. **Materials and Methods:** We retrospectively reviewed 282 MR angiographies performed in our institution, in order to assess the posterior cerebral circulation. The imaging findings (including both normal development and variations) were depicted. **Results:** In our study 61/282 (21.63%) MR angiographies were positive for imaging findings concerning variations of the vertebrobasilar system. These variations included abnormal origin of the vertebral artery (0.7%), unilateral aplasia or hypoplasia (8.86%), unilateral aplasia or hypoplasia of the distal part of the vertebral artery (3.85%), and unilateral or bilateral fetal posterior cerebral artery (7.7%). These results show that anatomic variations of the posterior cerebral circulation are not very uncommon in the population. **Conclusion:** High resolution Magnetic Resonance Angiography provides excellent interpretation of the vertebral arteries, allowing depiction of all anatomic variations. Knowing these anatomic variations is important, especially for clinicians and patients planning a surgical operation or an interventional radiology technique. Furthermore, it contributes to avoiding potential diagnostic pitfalls or to explaining unusual acute vascular cerebral events.

Keywords: MRA; Vertebral Arteries; Variants

1. Introduction

During embryonic period, several developmental anomalies of the vertebrobasilar system might occur. Knowing these anatomic variations is important, especially for clinicians and patients planning a surgical operation or an interventional radiology technique. Furthermore, the knowledge of a variation might prevent unnecessary imaging studies or contribute to avoiding diagnostic pitfalls.

Some years ago digital subtractive angiography (DSA) was the imaging technique of choice for the illustration of such variations. The potential complications of this technique along with the effect of ionizing radiation and the development of MR imaging have led to a new entry in the diagnostic archer's quivery, the MR angiography, with which most of these variations may be diagnosed.

Purpose of this study is to review our cases and to report not only anatomic variations but the occurrence and potential clinical significance as well.

2. Materials and Methods

During our study we retrospectively reviewed 282 MR Angiographies of the neck arteries and the circle of Willis which were performed between 2003 and 2010 in our institution. The vast majority of the aforementioned patients were submitted to our department for investigation of atherosclerotic carotid disease. All imaging was performed on a 1.5-T MRI Scanner (Philips Medical, Intera). The routine MRI protocol included: a survey in

sagittal plane, a 3D SPGR sequence without contrast media in coronal plane (mask), a bolus track (intravenous injection of gadolinium with fluoroscopic triggering in coronal plane) and a 3D SPGR after intravenous gadolinium injection in coronal plane (first pass) with parameters TR: 4.5 ms, TE: 1.5 ms, flip angle 30˚, Field Of View: 32 × 32, slice thickness 1.4mm, slice spacing 0.7 mm, central k-space filling, acquisition matrix 336 × 336 and reconstruction matrix 512 × 512. Subtraction images were performed. A dedicated workstation was used for the evaluation of the MR Angiograms employing post processing techniques, such as maximum intensity projection (MIP) and planar reformates (Multiplanar reformat MPR, curve planar reformat CPR).

We classified vertebral artery (VA) aplasia when the vessel was not imaged and hypoplasia when its diameter was <2 mm [1].

Unilateral distal aplasia or hypoplasia of the VA was recorded when the portion of the VA distal to the origin of the posterior inferior cerebellar artery (PICA) was either not seen or its caliber was smaller or equal to that of the anterior inferior cerebellar artery (AICA) respectively.

As fetal type posterior cerebral arteries (PCA) were classified all the cases where the vessel stems from the internal carotid artery (ICA) had larger diameters than those of the ipsilateral precommunicating segment of the posterior cerebral artery (P1) or continued distally as the posterior cerebral artery. On the other hand, as posterior communicating arteries were classified all the vessel stems arising from the internal carotid artery (ICA) and having diameters equal to or smaller than that of the ipsilateral precommunicating segments of the posterior cerebral arteries.

3. Results

In our study 61/282 (21.63%) MR angiographies were positive for imaging findings upon variations of the vertebrobasilar system. These variations included abnormal origin of the vertebral artery (0.7%), unilateral aplasia or hypoplasia (8.86%), unilateral aplasia or hypoplasia of the distal part of the vertebral artery (3.85%), and unilateral or bilateral fetal posterior cerebral artery (7.7%). Our findings are presented in **Table 1**.

Abnormal origin of the vertebral artery was found in two patients. In the first, MR Angiography revealed a right VA originating from the innominate artery, as well as fetal right PCA. In the second patient, the left VA originated from the aortic arch between the left common carotid artery and the left subclavian artery **(Figure 1**). This patient also had a unilateral fetal PCA.

In two patients, the whole vertebral artery was absent. In another two patients only the distal vertebral artery after PICA was absent. One of them had also a high grade stenosis of the contralateral VA (**Figure 2**). This is why this patient subsequently presented with a right mesencephalic and right thalamic infarct.

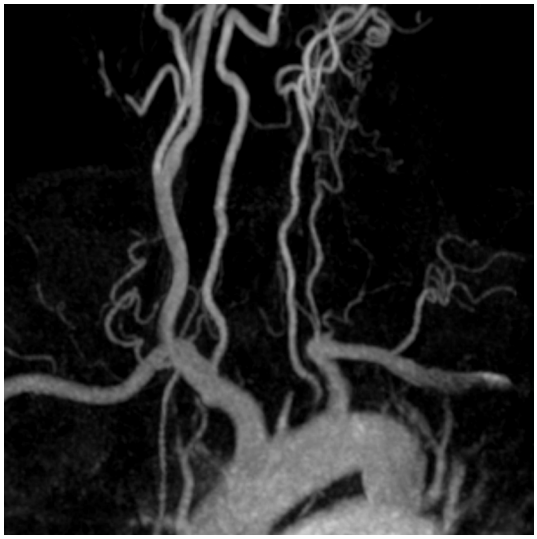

Figure 1. Maximum Intensity Projection (MIP) image in the sagittal plane. There is anomalous origin of the left vertebral artery from the aortic arch between the left common carotid artery and the left subclavian artery.

Table 1. Vertebrobasilar system anatomic variations in 282 MR angiographies.

Type of Variation	Number of patients	Concomitant features	Occurrence (%)
Anomalous origin of VA			
-Right VA origin from innominate	1	Fetal right PCA	0.35
-Left VA origin from aortic arch	1	Fetal right PCA	0.35
Unilateral VA aplasia	2	-	0.7
Unilateral VA hypoplasia	23	bovine arch (2 patients)	8.16
Unilateral distal VA aplasia	2	bovine arch (1 patient)	0.35
Unilateral distal VA hypoplasia	10	fetal PCA (2 patients)	3.5
Fetal PCA			
-Unilateral	20	hypoplastic distal VA (1 patient) bovine arch (1 patient)	7
-Bilateral	2	hypoplastic VA (1 patient)	0.7

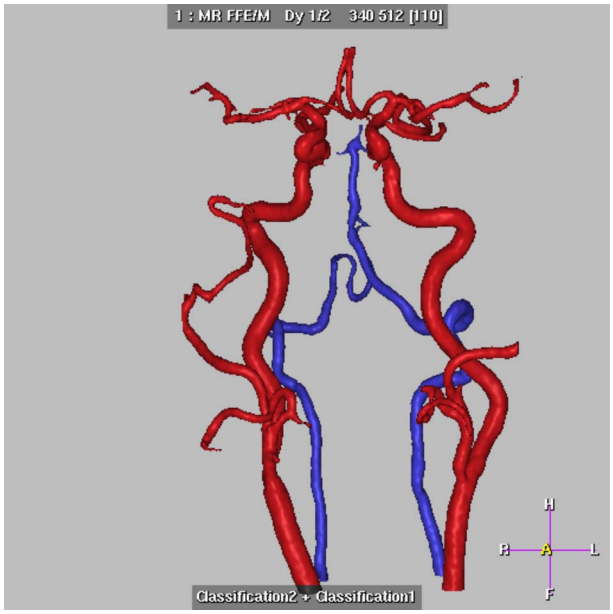

Figure 2. MRA with 3D Reconstruction in the coronal plane. There is absence of the distal part of the right VA beyond PICA origin. There is also a high grade stenosis of the distal part of the left vertebral artery. This patient subsequently presented with a right mesencephalic and right thalamic infarct.

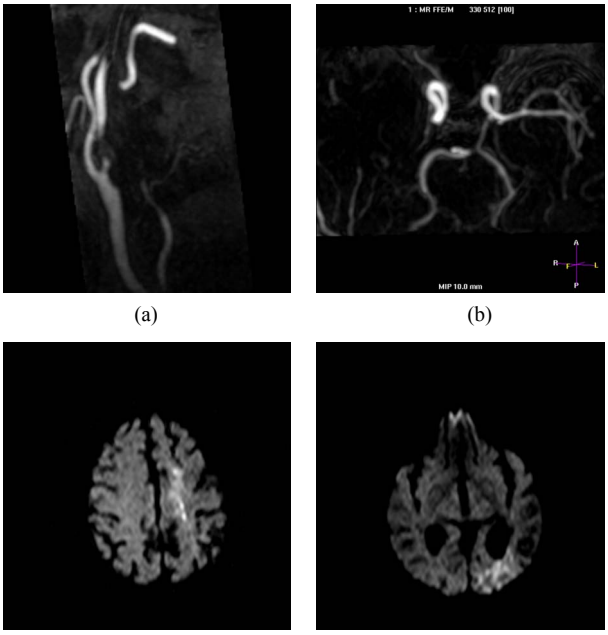

Figure 3. (a) Maximum Intensity Projection (MIP) image in the sagittal plane illustrating a high grade stenosis in the proximal part of the left internal carotid artery; (b) MIP image in the axial plane (same patient) illustrating the left PCA originating from the ipsilateral ICA; Figure 3(c) and (d): Brain MRI, diffusion image, illustrating acute infarct in watershed area (c) and also in the posterior circulation in this patient (d).

A significant number of patients presented with a hypoplastic vertebral artery, either with whole vessel hypoplasia (23 patients) or with hypoplastic distal VA (10 patients). Unilateral fetal PCA was noted in 20 patients and bilateral fetal PCA in 2 patients. It is worth noting that one patient with a left fetal PCA also had a high grade stenosis in the proximal part of the left ICA. Before intervention, this patient presented with acute neurologic symptoms due to acute infarcts in watershed area and in the posterior circulation. This was explained by embolic material from the left atheromatous ICA, the vessel which also supplied the posterior circulation in this patient (**Figures 3(a)-(d)**).

4. Discussion

High resolution Magnetic Resonance Angiography was initially employed as an alternative non invasive imaging method, comparing with the invasive Digital Subtraction Angiography, for the estimation of carotid artery stenosis. The main purpose of this method was to attain the smallest possible voxel size, for accurate depiction of the degree of stenosis, based on the North American Symptomatic Carotid Endarterectomy Trial (NASCET), European Carotid Surgery Trial (ECST), or Carotid Stenosis Index (CSI) criteria. The collateral benefit in the development of this method was the better interpretation of the vertebral arteries, which are smaller caliber vessels than carotid arteries. So, High Resolution Magnetic Resonance Angiography became an extremely helpful tool for non invasive imaging of the vertebrobasilar system.

During the embryonic period, eight pairs of intersegmental cervical arteries form the primitive carotid-vertebral anastomoses with the most caudal intersegmental artery being defined as the primitive proatlantal artery. The vertebral arteries are developed as plexiform longitudinal anastomoses among the six cervical intersegmental arteries (C1 - C6). Apart from the sixth intersegmental artery (which progress to the adult subclavian artery), the rest proximal connections among the intersegmental arteries and the dorsal aorta regress. Basilar artery (BA) is formed in the 5- to 9-mm embryo by the fusion of the longitudinal vertebral arteries across the midline [2].

Several anatomic variations of the vertebral arteries have been reported in the literature. However, most studies refer either to certain variations reported during a study of the circle of Willis (for example fetal PCA variant) or describe isolated case reports. Furthermore, the incidence of these anatomic variants differs in these various studies due to the different methods used (autopsy, angiography and Doppler ultrasound).

The results of autopsy studies concerning the origin of the vertebral arteries, report that the most common variant is a left VA with a direct origin from the aortic arch

located between the left common carotid artery and left subclavian artery, with an incidence of 1.6% - 5.8% [3-7]. The lowest percentage has been reported in an Indian study (1.6%) [5]. Incidence of this variant in our study was much lower (0.35%) and close to the results of a recent angiographic study in Greece where the reported incidence was 0.79% [6]. Furthermore, in our study, a right VA arising from the innominate artery was reported at 0.35% of the cases. Up to date as far as we know, throughout the literature there are only case reports describing this specific variant [8].

Unilateral asymmetry or severe hypoplasia of the VA is governed by a prevalence which is up to date unknown due to differences in the definitions and the examining techniques used. Based on autopsy findings and angiograms, the frequency of vertebral artery hypoplasia has been reported to range from 2 to 6%, except in Asia, where it was higher (15.7% - 20.2%) [9-14]. Furthermore, two previous MRA studies report an incidence of 26.5% and 10.4% respectively [15,16]. Our results (8.15%) are close to those reported in the population of Taiwan by Chuang *et al.* [16].

Up to our knowledge there is no article in the literature reporting the incidence of complete VA aplasia. However, unilateral distal VA aplasia has been reported with an incidence of 0.2% in angiographic studies or with 4.6% in a recent MR study (combining BPAS-MRI and MRA) in asymptomatic patients [4,17,18]. The authors of the latter study could not explain this large difference. Our results (0.35%) are quite closer to those reported in the angiographic studies. In the same MR study, a 5.06% incidence of a hypoplastic distal VA was reported [18]. Furthermore, another MR study (also combining BPAS-MRI and MRA) reported an incidence of unilateral distal hypoplasia or aplasia of the VA of 6.8% [19].

Finally, the incidence of fetal PCA has been reported to be 10% on the right, 10% on the left side and 8% bilaterally [20,21]. The reported incidence in our study is much lower (7% unilateral and 0.7% bilateral).

In conclusion, our study showed that anatomic variations of the vertebral arteries are not very uncommon in the population, since almost one in five patients presented with a variation. Diagnosis of these variations is very significant. Variations of the VA origin may predispose to intracranial aneurysms formation although they do not result in cerebral hemodynamic perturbation predisposing to cerebrovascular disorders [8]. This is why such patients should undergo a thorough search for coexisting aneurysms [22]. Additionally, VA origin variants are important in order to avoid potential diagnostic pitfalls or in order to properly plan an aortic arch surgery/endovascular intervention.

A lot of controversy is raised concerning the clinical significance of VA hypoplasia (VAH) and whether it should be regarded as a normal variant or a predisposing factor for posterior circulation ischemia [23-27]. Giannopoulos et al considers VAH as a normal variant when solely encountered and as a contributing factor to posterior circulation stroke when it is combined to other risk factors [30]. Furthermore, there is some evidence supporting an association among migraine with aura and VAH [28,29].

In the presence of fetal PCA variant, since carotid artery is the dominant blood supplier, thrombosis or embolism of the ICA may cause ischemia or infarction of the occipital pole [30-33]. Thus, MR angiography is signifycant in patients with occipital lobe ischemia, especially in the cases where carotid endarterectomy is a therapeutic option. In addition, knowledge of this variant is important in planning therapy of a cavernous carotid aneurysm, fistula or carotid sheath tumors (carotid ligation or balloon occlusion).

5. Conclusion

Variations of the vertebrobasilar system are quite common imaging finding of MR angiographies if one considers that they constitute approximately one fifth of the angiographies included in our study. These variations include abnormal origin, aplasia or hypoplasia (either total or of the distal part of the vertebral artery), persistent embryonic branches and fetal PCA. Knowledge of these anatomic variations is important not only for the design of a surgical operation or of an interventional radiology technique but also to avoid potential diagnostic pitfalls or to explain unusual acute vascular cerebral events.

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