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Cerebrovascular ischemic changes associated with fetal posterior cerebral artery- descriptive retrospective study with magnetic resonance imaging and angiography of brain

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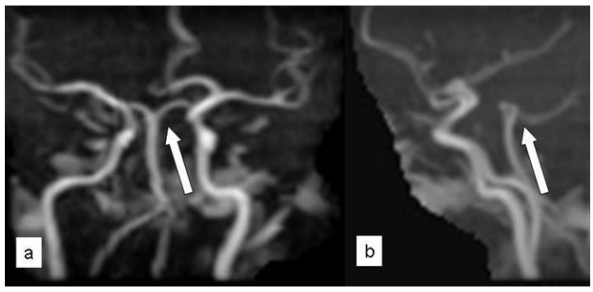
Abstract: *Objectives:* Circle of Willis, the main collateral pathway for cerebral circulation, is complete in only a portion of the population. There are many variations in the Circle of Willis. Fetal posterior cerebral artery, which is defined as posterior cerebral artery arising from internal carotid artery, is a common variant of the Circle of Willis. Though association between the fetal posterior cerebral artery and ischemia have been studied, no specific study has been conducted in the Indian population. We aim to identify the incidence of small and large vessel strokes in patients with fetal posterior cerebral artery using Magnetic Resonance Imaging (MRI) and Magnetic Resonance Angiography (MRA) of brain in the Indian population. *Materials and methods:* We retrospectively reviewed MR angiographies of the brain performed in our institution, in order to assess the posterior cerebral circulation and its association with small ischemic changes and large vessel strokes. *Results:* 92 of the 140 patients (65%) with fetal posterior cerebral artery (PCA) had small vessel ischemic changes. 72 patients (51.4%) had large vessel infarcts in any of the vascular territories. 35% of the patients included in this study showed infarcts in the middle cerebral artery (MCA) territory and 15 % showed infarcts in the PCA territory. *Conclusion:* Higher incidence of MCA infarcts in our study probably suggests that PCA cannot aid in collateral formation cases of reduced flow across the internal carotid artery and that fetal PCA could be an important risk factor in cerebrovascular ischemic diseases.

Keywords: Fetal, posterior cerebral artery, ischemic, infarcts, MRA

Introduction

Collateral circulation is very important in brain to maintain sufficient blood flow in cases of obstruction of the major vessels. Circle of Willis is the main primary collateral pathway for cerebral circulation [1]. It is complete in only a portion of the population [2]. There are many variations in the Circle of Willis. Normally the basilar artery bifurcates into right and left posterior cerebral arteries (Figure 1).

Fig-1: (a) Coronal and (b) sagittal Maximum intensity projection (MIP) of MRA shows normal bifurcation of basilar artery into bilateral posterior cerebral artery.



Fetal posterior cerebral artery, which is defined as posterior cerebral artery (PCA) arising from internal carotid artery, is a common variant of the Circle of Willis [3]. Fetal PCA may be either complete fetal PCA or partial fetal PCA. Complete fetal PCA denotes a posterior cerebral artery that completely originates from the internal carotid artery ICA with no connection with the basilar artery. Partial fetal PCA describes a posterior cerebral artery originating from internal carotid artery (ICA) with a small connection with the basilar artery [4].

Complete fetal PCA implies that it would not be possible for basilar artery to contribute to the collateral supply during ischemic insult. Hence there could be higher chances of infarcts occurring in people with fetal PCA when there is onset of ischemia. Further tentorium acts as a physical barrier to the development of leptomeningeal collaterals from cerebellar vessels to the posterior

cerebral artery territory. People with partial fetal PCA may fare better because of the chance to develop leptomeningeal collaterals between anterior and posterior circulation due to the small connection between PCA and basilar artery. We intended to study the incidence of small ischemic changes and large vessel strokes in Indian patients with fetal PCA with the hypothesis that fetal PCA would be a definite risk factor for the same.

Material and Methods

We retrospectively reviewed the MRI with MRA studies of the brain done in our hospital between January 2013 and January 2015 for patients with fetal PCA on MRA. All patients who had undergone MRI and MRA of the brain were included in this study, irrespective of the presence or absence of history of stroke. Permission for this study was obtained from institute ethical committee.

The MRI with MRA studies of the brain were done on Hitachi Aperto 0.4 Tesla open MRI machine (Hitachi, USA). MRI brain protocol included T1, T2, T2 FLAIR (Fluid attenuation and inversion recovery), GRE (Gradient recalled echo) and Diffusion weighted images in axial plane; T2 FLAIR in coronal plane and T1 weighted spine echo sequence in sagittal plane. 3 D Time of fight sequence was used to acquire MRA images and they optimally evaluated the circle of Willis and the proximal 3- 4 cm of the major branches of Circle of Willis. Of the 520 MRA studies, only 140 patients had fetal PCA. Rest of the patients were excluded from the study. All these patients had complete fetal PCA. The studies were assessed by two radiologists with 8 and 15 years of experience, for the presence of unilaterality or bilateralism of the variant, occurrence of small vessel ischemic changes and large vessel stroke.

Results

Age of the patients ranged from 13 to 90 years with mean age of 54.9 years. Of the 140 patients, 80 were males and 60 were females. Figure 2 shows the laterality of the PCA in our study. 69 patients had fetal PCA on right side (Figure 3); 40 patients had fetal PCA on left side and 31 patients had bilateral fetal PCA (Figure 4).

Fig-2: Pie chart showing laterality of PCA in this study

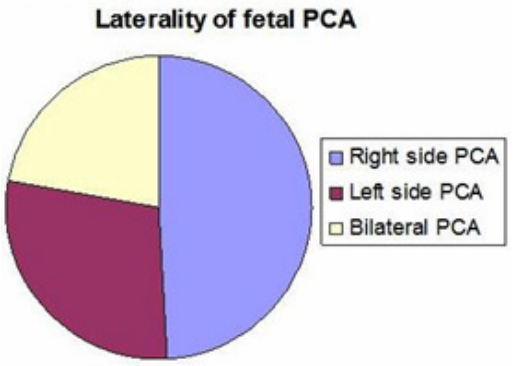


Fig-3: (a) and (b) Coronal Maximum intensity projection (MIP) of MRA shows fetal origin of right posterior cerebral artery.

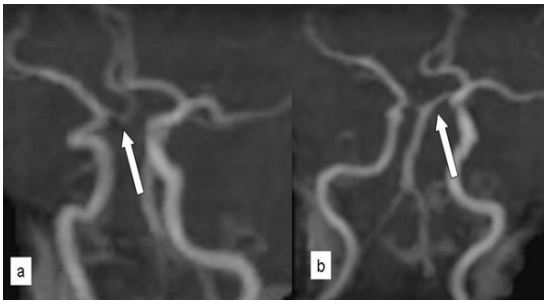
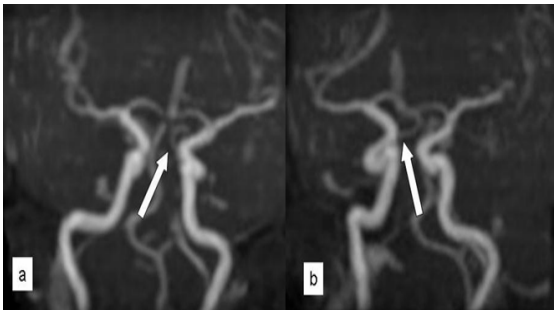


Fig-4: Coronal Maximum intensity projection (MIP) of MRA (a) and (b) shows fetal origin of bilateral posterior cerebral artery.



92 of the 140 patients (65%) had small vessel ischemic changes (Figure 5) and 48 (35%) of them had no ischemic changes (Figure 6). 68 of the 140 patients had no infarcts (Figure 7). Two patients had venous sinus thrombosis. One patient had subdural hemorrhage, one had arterivenous fistula and another had amyloid angiopathy. 72 patients (51.4%) had large vessel infarcts in any of the vascular territories. Of these 72 patients 21 had chronic infarcts and 51 of them had acute / sub acute infarcts. 21 of these patients had infarcts in the posterior cerebral artery territories (Figure 8).

Fig-5: Axial Maximum intensity projection (MIP) of MRA shows fetal origin of right posterior cerebral artery. (b) Axial T2 FLAIR image shows punctuate small vessel ischemic change in right parietal white matter

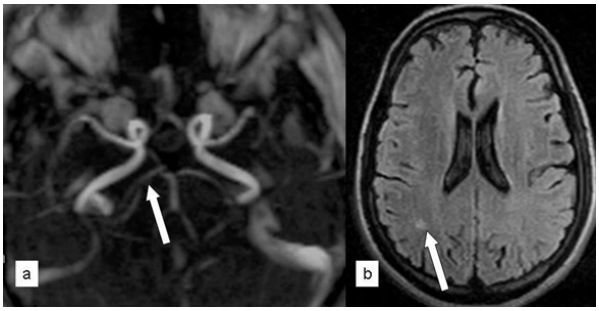


Fig-6: Chart showing incidence of small vessel ischemic changes in persons with fetal PCA

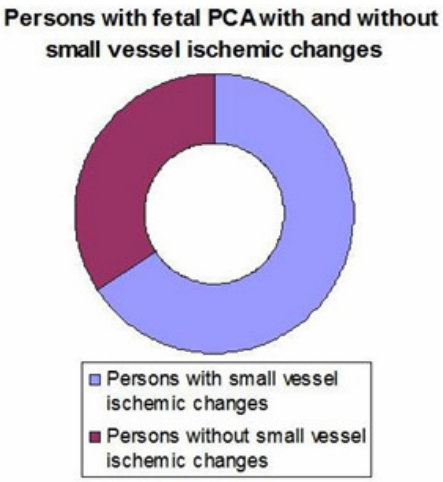


Fig-7: Pie chart showing incidence of infarcts in persons with fetal PCA

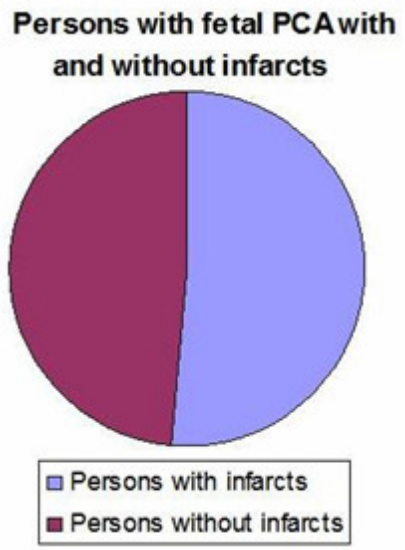


Fig-8: Bar diagram showing distribution of infarcts in persons with fetal PCA and infarcts

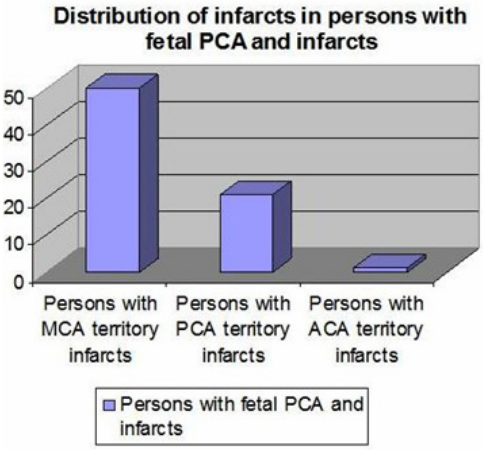


Fig-9: (a) Axial T2 FLAIR image shows infarct in right pre central region. (b) Axial MRA image shows fetal origin of right posterior cerebral artery.

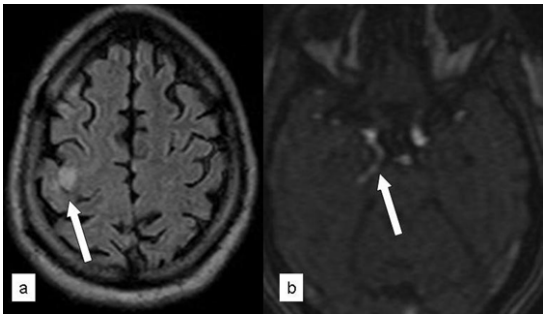
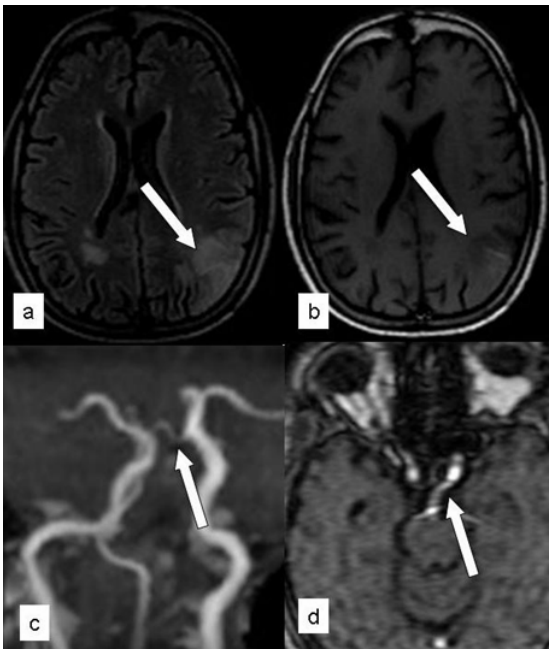


Fig-10: (a &b) Axial T2 FLAIR and T1 image shows infarct with hemorrhagic transformation in left parietal region. (C&d) MRA images show fetal origin of left PCA.



50 patients had infarcts in the middle cerebral artery (MCA) territories (Figures 9 and 10). One patient had an infarct in the anterior cerebral artery territory. 6 patients had infarcts in both middle and posterior cerebral artery territories. 35% of the patients included in this study showed infarcts in the MCA territory and 15 % showed infarcts in the PCA territory.

Discussion

The arterial anatomy of the circle of Willis can be studied using digital subtraction angiography, CT angiography (CTA) and MRA. Though digital subtraction angiography has high temporal resolution and is considered the investigation of choice, it is quite invasive. CT angiography is less invasive but, it entails administration of iodinated contrast and radiation exposure. MRA, on the other hand, is non invasive and non radiation intensive without the need for contrast [5-6]. Fetal posterior cerebral artery, defined as posterior cerebral artery (PCA) arising from internal carotid artery, is a common variant of the Circle of Willis and is seen in ~ 11-29% of the population [5].

It may be classified as partial or complete, depending on the presence or absence of communication with the basilar artery. Incidence of fetal PCA in our study was 26.9 % which is similar to the incidence described in various populations so far [7]. Unilateral fetal PCA constituted 20.9 % of this with bilateral fetal PCA constituting about 6 % in our study. Prevalence of unilateral fetal PCA ranged from 4-29% and bilateral fetal PCA ranges from 1-9% in a previous review of literature [7]. There has always been speculation over the issue of variants of circle of Willis and their association with stroke, more so with the presence of fetal PCA. There have been studies to assess if fetal PCA contributes to ischemia or infarct [4, 7-10]. Some of the studies have used CTA as a tool [9-10] while others have used CTA as well as MRA [4].

Previous studies have found that patients with fetal PCA had higher incidence of infarcts than those without [11-12]. Two cross-sectional studies of circle of Willis with MRA in patients with ICA occlusion, showed absence of border zone infarcts when normal posterior communicating arteries were present without fetal PCA [13-14]. Partial or complete fetal PCA, as denoted by a small or absent ipsilateral posterior communicating artery, is a risk factor for cerebral infarct when internal carotid artery occlusion is present [13]. Hendrikse et al concluded that the presence of collateral flow via the posterior communicating artery in the circle of Willis is associated with a low prevalence of border zone infarcts, in patients with unilateral ICA occlusion [14]. This indirectly implies that presence of fetal PCA would predispose to higher incidence of border zone infarcts. Arjal et al found that there is increased risk of stroke with partial fetal PCA than that with complete fetal PCA, which is contrary to the logical assumption that complete fetal PCA would predispose more to strokes [10].

A study on occipital lobe infarcts with MRA showed that the controls more often had a fetal PCA than the patients with infarcts (15 controls vs. 3 patients), implying that fetal PCA could be protective against occipital lobe infarcts[15]. In our study too, the incidence of PCA infarcts (15%) were less than that of MCA infarcts (35%), implying a similar situation. Complete fetal PCA implies that the blood flow to the PCA territory comes entirely from the internal carotid artery and it would not be possible for basilar artery to contribute to the collateral supply during ischemic insult. Apart from that, it also means that there is a larger burden on the internal carotid artery in terms of the parenchymal territory supplied. Resultantly there would be higher incidence of border zone infarcts in case of luminal narrowing and reduced flow within the internal carotid artery. Also there would be higher chances of infarcts in MCA and well as PCA territories in people with fetal PCA when there is onset of ischemia, as basilar artery cannot participate in the primary collateral formation.

Leptomeningeal vessels are small < 1mm anastomoses which connect two different vascular territories with the direction of blood flow based on the hemodynamic and metabolic circumstances of the two connected territories. The vessels can be formed throughout the distal regions of the complete brain, between the anterior, middle and posterior cerebral arteries [16]. Development

of leptomeningeal vessels between the PCA and the MCA will not be adequate in patients with fetal PCA and hemodynamically significant stenosis of internal carotid artery (ICA), because they are derived from the same vessel (internal carotid artery). Further, tentorium acts as a physical barrier to the development of leptomeningeal collaterals from cerebellar vessels to the posterior or middle cerebral artery territory [7]. People with partial fetal PCA may fare better because of the chance to develop leptomeningeal collaterals between anterior and posterior circulation due to the small connection between PCA and basilar artery. Contribution of anterior collateral flow would also be important in determining the extent of MCA infarction. A preserved sufficient anterior cerebral artery (ACA) leptomeningeal collateral flow could help in more neuroparenchymal tissue being saved in the anterior and medial parts of the MCA territory. A good ophtalmic reverse collateral flow could also balance out the loss of basilar contribution to ICA flow.

92 of the 140 patients (65%) with fetal PCA had small vessel ischemic changes which imply a fetal PCA as a possible risk factor. 72 patients (51.4%) had large vessel infarcts in any of the vascular territories. 21 of these patients had infarcts in the posterior cerebral artery territories. 50 patients had infarcts in the middle cerebral artery (MCA) territories. 6 patients had infarcts in both middle and posterior cerebral artery territories. 35% of the patients included in this study showed infarcts in the MCA territory and 15 % showed infarcts in the PCA territory.

Higher incidence of MCA infarcts in our study probably suggests that PCA cannot aid in collateral formation cases of reduced flow across the internal carotid artery and that fetal PCA could be an important risk factor in cerebrovascular ischemic diseases. Limitations of our study include smaller sample size of the study and retrospective study that included all patients with fetal PCA irrespective of clinical presentation. Infarcts and ischemic change were studied only in the group of patients with fetal PCA. It was not compared with those without fetal PCA. Patients with infarcts were analysed irrespective of the lateralism of the fetal posterior cerebral artery and the side of infarcts. Ideally, the study population should be divided into the following 4 groups:

1) Fetal PCA with hemodynamically significant ipsilateral ICA stenosis.
2) Fetal PCA with no hemodynamically significant ipsilateral ICA stenosis.
3) No fetal PCA with hemodynamically significant ipsilateral ICA stenosis.
4) No fetal PCA with no hemodynamically significant ipsilateral ICA stenosis,

and incidence of infarcts studied in them.

Hence, a detailed case control study with a larger sample size and age matched groups on the above lines, would better reveal the exact significance and role of fetal PCA as a risk factor for cerebrovascular ischemic diseases.

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