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Fetal posterior cerebral artery: A retrospective evaluation of prevalence by 3D TOF MR angiography

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Abstract:
Background: *Fetal posterior cerebral artery is a common variant of the posterior cerebral artery (PCA) where in PCA receives majority or whole of its blood supply from internal carotid artery (ICA), rather than from basilar artery.* ***Materials and methods:*** *A retrospective study of 265 patients referred for magnetic resonance (MR) imaging of brain between January 2018 and September 2018 was done to determine the prevalence of various types of fetal posterior cerebral artery in patients of tertiary hospital in rural set up using three-dimensional (3D) time of flight (TOF) MR angiography.* ***Results:*** *Adult configuration of PCA was seen in 178 subjects (67.11%). Fetal configuration of PCA (partial, complete, and true fetal type) was seen in 63 subjects (23.75%) and transient configuration was seen in 24 patients (8.84%). Partial fetal PCA configuration was identified in 54 patients (20.37%), complete fetal configuration in 7 patients (2.64%) and true fetal configuration in 2 (0.75%) patients. Fetal PCA was unilateral in 50 subjects (18.85%) and bilateral in 13 subjects (4.9%). No statistically significant difference was found between the prevalence of fetal PCA in males and females.* ***Conclusion:*** *Fetal PCA configuration is one of the most common type of variation in posterior part of circle of Willis. It is important that radiologist is aware of this common variation as it can cause perfusion asymmetry and posterior circulation infarct secondary to ICA atherosclerotic disease.*

Keywords: *Fetal posterior cerebral artery, circle of Willis, time of flight MR angiography*

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I. Introduction:

Fetal posterior cerebral artery (fPCA) is a common variant of cerebral circulation. Most adult humans have the classic vascular anatomy in which both left and right PCAs originate from the basilar artery and are part of the vertebrobasilar system or posterior circulation. An anatomic variant of the posterior cerebral artery (PCA), known as fetal PCA is commonly seen in circle of Willis, where in PCA receives majority or whole of its blood supply from internal carotid artery (ICA), rather than from basilar artery. Thus, perfusion of the PCA territory is dependent on the ICA and this has got imaging and clinical implications.

II. Materials And Methods:

A retrospective study of 265 patients referred for MR imaging of brain between January 2018 and September 2018 was done to determine the prevalence of various types of fetal PCA in patients of tertiary hospital in rural set up using three-dimensional (3D) time of flight (TOF) MR angiography.

Study design: Retrospective observational study

Study location: Department of Radiodiagnosis & imaging, PES institute of medical sciences and research, a tertiary care hospital in rural set up in Kuppam, Chittoor district, Andhra Pradesh, India.

Study duration: January 2018 to September 2018

Inclusion Criteria: Patients who underwent 3D TOF MR angiography sequence

Exclusion criteria: Patients with tumors and infarct

Sample size: 265 patients met the study criteria and were included in the study

Scanning protocol: All patients underwent three-dimensional (3D) time of flight (TOF) magnetic resonance angiography (MRA) imaging using Spoiled Gradient Recalled Acquisition (SPGR) in Steady State sequence in 1.5 Tesla MRI scanner (GE Signa Explorer). 3D TOF scanning was done with the following parameters- repetition time (TR) of 25 ms, echo time (TE) of 4.2 ms, flip angle (FA) of 20 degrees, slice thickness 1.2 mm, number of slice 40/slab, number of slabs 3, maximum slices of 256, number of acquisitions 3, pixel size of 0.6 x 1.0 mm and matrix size of 384 x 224. Standard T1, T2, FLAIR (fluid attenuated inversion recovery), DWI (diffusion weighted imaging) and SWI (susceptibility weighted imaging) sequences were also acquired to detect brain abnormalities.

Image processing: MR angiography source images were viewed in workstation along with multiplanar reconstructed (MPR)images, maximum intensity projection (MIP) and volume rendered (VR) images.

Interpretation of images: Fetal PCA configuration was identified and classified under partial/ complete / true fetal types. Based on size relation between P1 segment and ipsilateral posterior communicating artery (PcoA), the following types are defined.

Adult type: P1 segment > ipsilateral PcoA

Transient type: P1 segment = ipsilateral PcoA

Partial fetal type: P1 segment < ipsilateral PcoA

Complete fetal type: P1 segment is absent and ipsilateral PcoA continues as P2 segment of PCA

True fetal type: Two independent PCAs will be present. A large PcoA will independently continue as one PCA and the second PCA (often smaller) is continuation of ipsilateral P1 segment as P2 segment of PCA without any communication with PcoA.

Statistical analysis: Statistical analysis was performed using the STATA software (version 14). Categorical variables were entered as percentages. A chi-square test was used for statistical comparison between categorical variables of men and women. A p value of less than .05 was defined as statistically significant.

III. Results:

Study group consisted of 265 participants, out of which 132 are male and 133 are female. Mean age of participants is 37.18 years- 36.87 for men and 37.49 for women. Standard deviation is 19.53 and margin of error at 95% confidence interval is ±2.352 (±6.33%).

Adult configuration of PCA was seen in 178 subjects (67.11%)- 95 subjects were male (35.82%) and 83 subjects (31.29%) were female. Fetal configuration of PCA (partial, complete, and true fetal type) was seen in 63 subjects (23.75%). Transient configuration was seen in 24 patients (8.84%) with more prevalence in females compared to males (6.03% vs 3.01%).

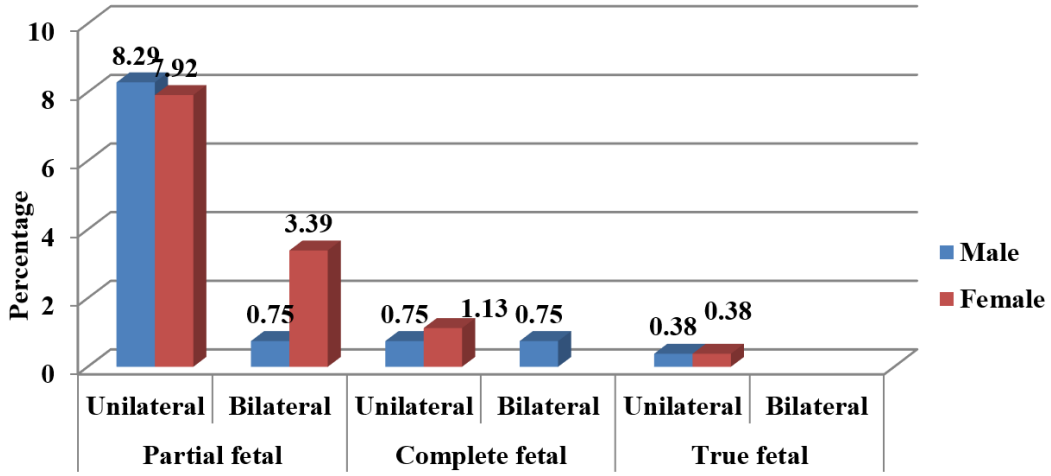
Partial fetal PCA configuration was identified in 54 patients (20.35 %), out of which 24 (9.04 %) are male and 30 (11.31 %) are female. Partial fetal PCA was unilateral in 43 patients (16.21 %) – 22 are male and 21 are female. Partial fetal PCA configuration was bilateral in 11 patients- out of which 9 are female. Female subjects showed higher percentage of bilateral fetal PCA configuration when compared to male subjects. Complete fetal configuration was seen in 7 patients- unilateral in 5 patients and bilateral in 2 patients. True fetal configuration was seen in 2 patients- one male and one female. Fetal PCA was unilateral in 50 subjects (18.85%) and bilateral in 13 subjects (4.9%). No statistically significant difference was found between the prevalence of fetal PCA in males and females.

Basilar artery terminated by dividing into two superior cerebellar arteries in two patients and both the P1 segments of bilateral PCA were non visualized in these patients resulting in bilateral complete fetal PCA configuration.

Table 1 showing variants of posterior cerebral artery.

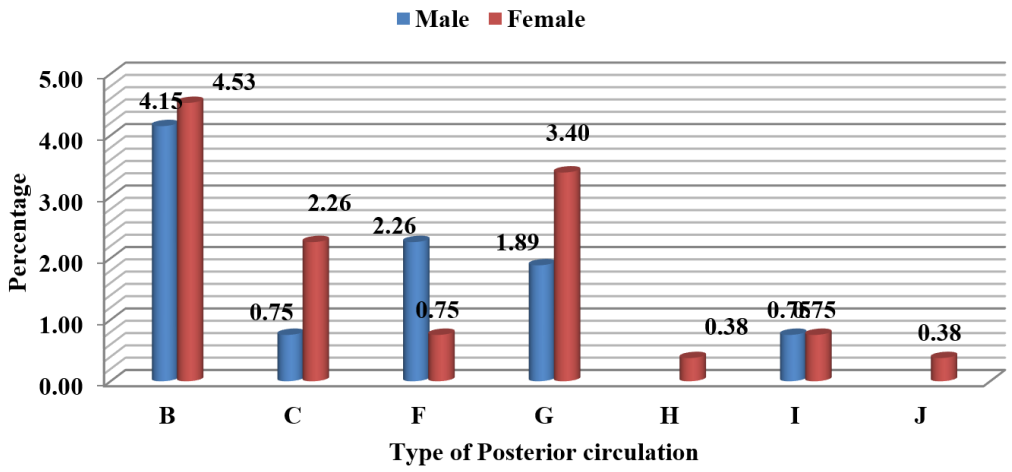
Variants of PCA		Subjects (Percentage)		
		Male	Female	Total
Transient	Unilateral	8 (3.01)	14 (5.28)	22 (8.09)
	Bilateral	-	2 (0.75)	2 (0.75)
Partial fetal	Unilateral	22 (8.29)	21 (7.92)	43 (16.21)
	Bilateral	2 (0.75)	9 (3.39)	11 (4.14)
Complete fetal	Unilateral	2 (0.75)	3 (1.13)	5 (1.87)
	Bilateral	2 (0.75)	-	2 (0.75)
True fetal	Unilateral	1 (0.38)	1 (0.38)	2 (0.75)
	Bilateral	-	-	-

Graph 1 showing types of fetal PCA



According to the classification used by Chen et al [1] in their study on morphological variants of circle of Willis, fetal type of PCA is included in types B,C,F,G,H,I and J as mentioned below.
Type B- PCA originates predominantly from the ICA. This variant is known as a unilateral fetal type PCA; the PcoA on the other side is patent.
Type C- Bilateral fetal type PCAs with both pre-communicating segments of the PCAs patent.
Type F- Unilateral fetal type PCA and hypoplasia or absence of the pre-communicating segment of the PCA.
Type G- Unilateral fetal type PCA and hypoplasia or absence of the contralateral PcoA.
Type H- Unilateral fetal type PCA and hypoplasia or absence of both pre-communicating segment of the PCA and the PcoA.
Type I- Bilateral fetal type PCAs with hypoplasia or absence of both pre-communicating segments of the PCAs.
Type J- Bilateral fetal type PCAs with hypoplasia or absence of the pre-communicating segment of either PCA.
Prevalence of different types of fetal PCAs, based on the classification used by Chen et al [1] is mentioned in the following table 2 and graph 2.

Type of Posterior circulation	Subjects (Percentage)		
	Male	Female	Total
B	12 (4.52)	12 (4.52)	24 (9.05)
C	2 (0.75)	6 (2.26)	8 (3.01)
F	6 (2.26)	3 (1.13)	9 (3.39)
G	5 (1.89)	9 (3.40)	14 (5.29)
H	-	2 (0.75)	2 (0.75)
I	2 (0.75)	2 (0.75)	4 (1.51)
J	-	1 (0.38)	1 (0.38)



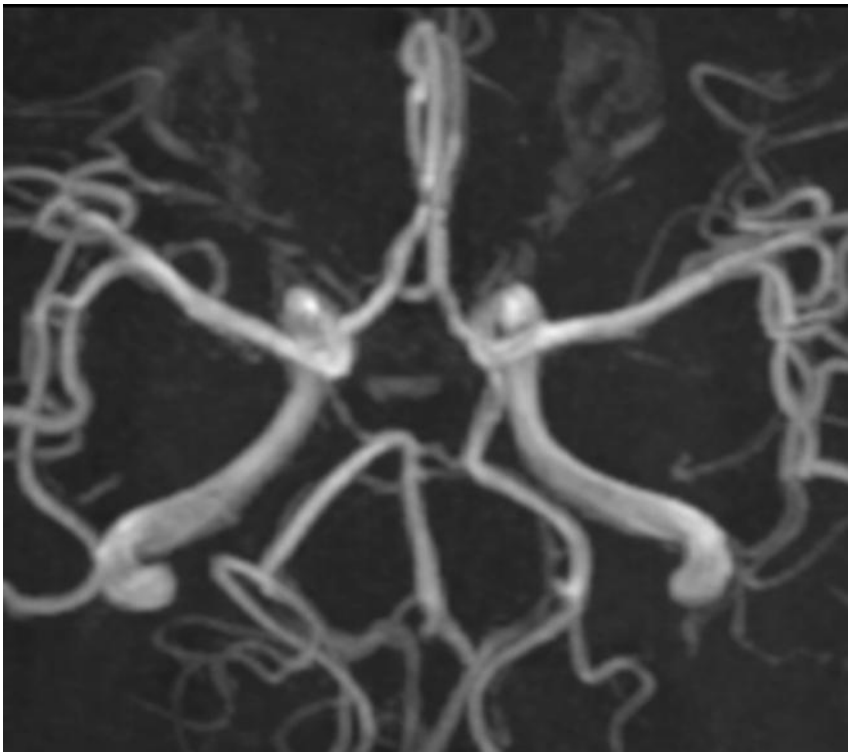


Figure 1: Axial MIP image showing unilateral fetal PCA on left side with patent right PcoA- Type B

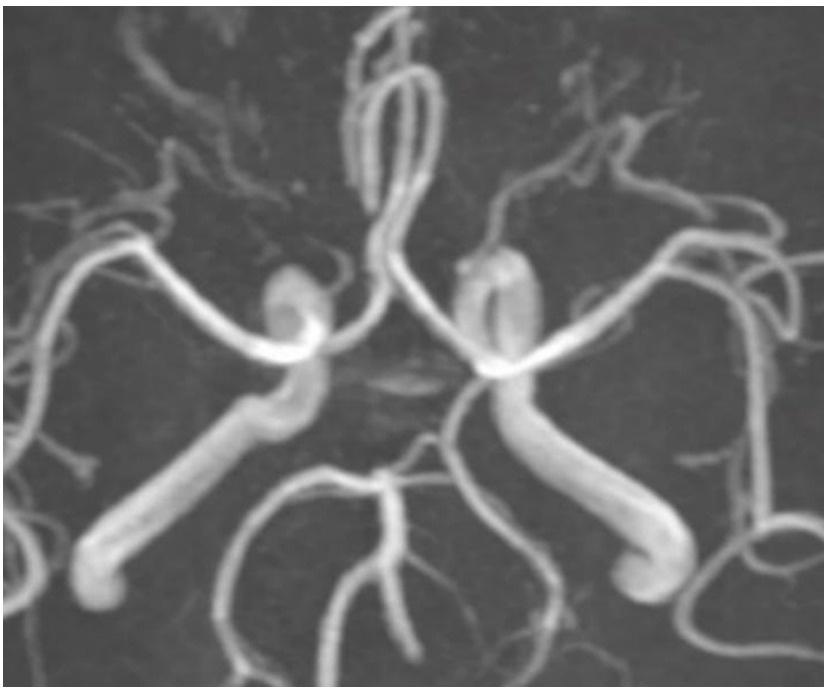


Figure 2: Unilateral fetal PCA with non-visualization of right PcoA- Type G

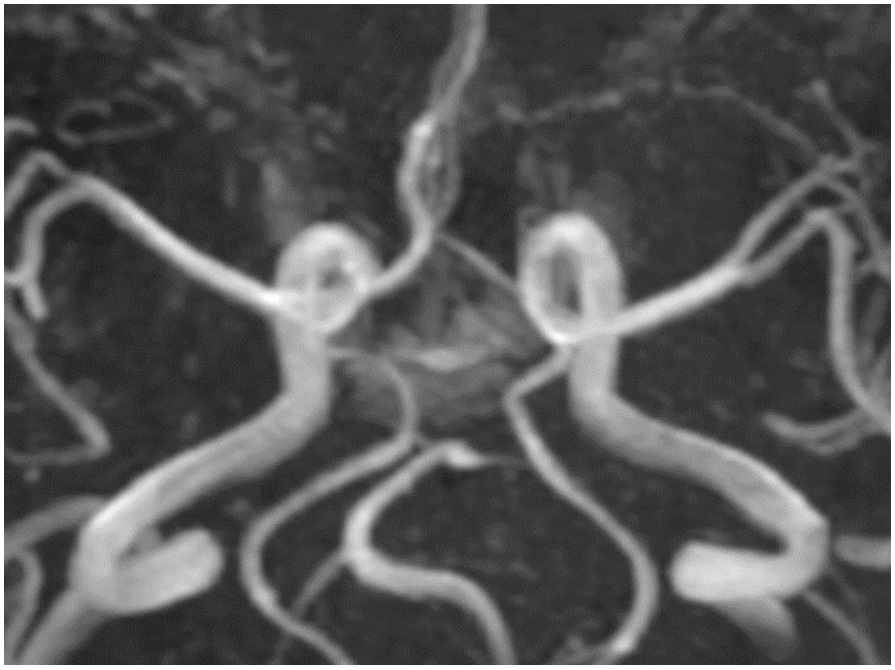


Figure 3: Axial MIP image showing bilateral partial fetal PCA- Type C posterior circulation.

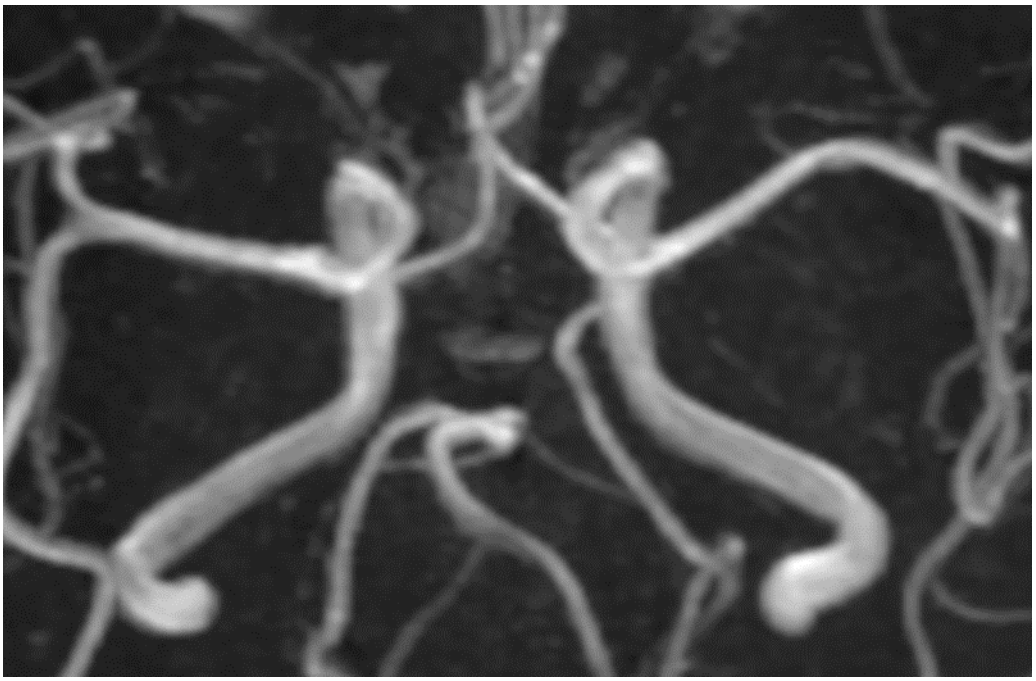


Figure 4: Axial MIP image showing unilateral complete fetal PCA on left side with non visualization of right PcoA- Type H

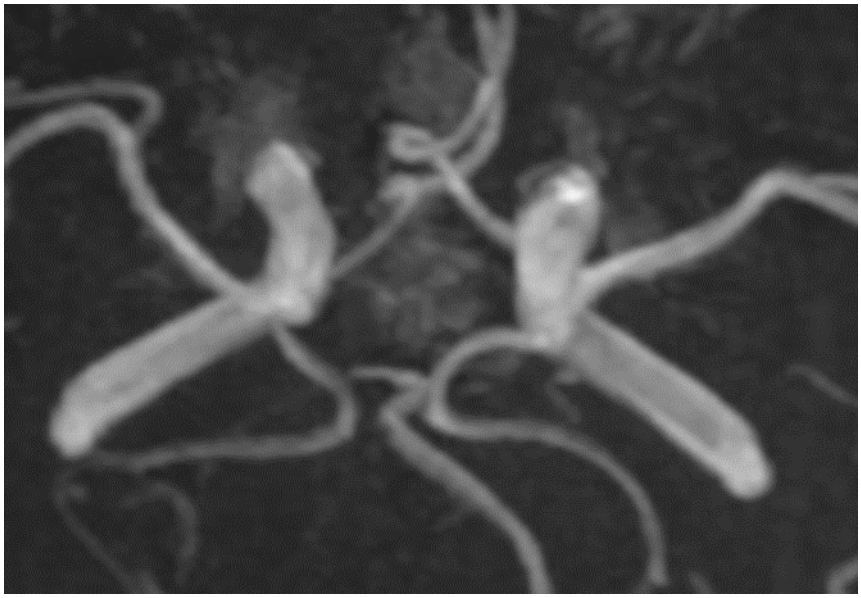


Figure 5: Axial MIP image showing bilateral complete fetal PCA- Type I

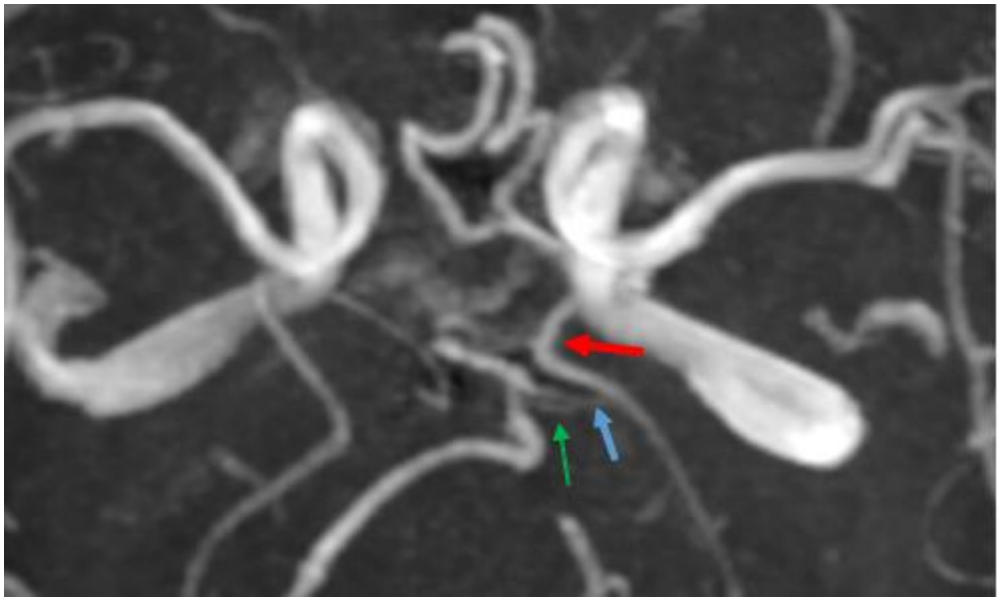


Figure 6: Axial MIP image showing true fetal PCA configuration on left side- red arrow pointing towards PcoA continuing as PCA, blue arrow pointing to P1 segment continuing as another left PCA and green arrow showing left superior cerebellar artery. Non visualization of right A1 segment is also noted.

IV. Discussion:

Prevalence of fetal PCA was seen in 23.75% of subjects in the current study, while its was 30.77%, 22.87 % and 30.4% in studies by Chen HW et al[(1)], Naveen SR et al[(2)] and Shaikh R and Sohail S[(3)] respectively. Karatas A et al[(4)] showed adult type of PCA in 87%, fetal type in 9% and transitional in 4% of subjects. Yeniceri et al[(5)] found adult type of PCA in 85% cases, fetal configuration in 13% cases and transitional configuration in 2% cases. Prevalence of fetal PCA was much higher in the current study, when compared to studies by Karatas A et al[(4)] and Yeniceri et al[(5)].

Development of fetal PCA:

At 4- to 5.7- mm stage of embryo (28–30 days), the ICA, develops as a cranial extension of the paired dorsal aorta. Paired longitudinal neural arteries appear along the hindbrain and fuse to form the basilar artery at the 5- to 8-mm stage. The caudal divisions of the ICA anastomose with the neural arteries and become posterior communicating arteries (PcoAs). At the 40-mm stage (8 weeks) the PCAs are an extension of the PCoAs. The vertebrobasilar system develops and thus participates in the supply of the PCA through the P1 segment. In this phase, the component vessels of the circle of Willis all have the same caliber. In the remaining fetal period, the

circle of Willis develops into one of three variants: an adult configuration, a transitional configuration or a fetal configuration[6].

Implications of fetal PCA:

In case of occlusion of major arteries, the most rapidly recruited collaterals are the communicating arteries of the circle of Willis. In a fetal type of PCA, there is an embryonic derivation of the posterior cerebral artery from the internal carotid artery. In case of complete fetal PCA, this results in large area being perfused by the anterior circulation as PCA is supplied by ICA. In addition, leptomeningeal collaterals fail to develop between the ICA and the vertebrobasilar system since both the middle cerebral artery (MCA) and the PCA are connected to the internal carotid system and are present above the physical barrier of the tentorium while the rest of the vertebrobasilar system is below the tentorium[6,7]. Partial fetal PCA has less impact on the vascular anatomy of the cerebral circulation: more area is perfused by the anterior circulation as PCA is mostly supplied by ICA, but the leptomeningeal collaterals may develop between anterior and posterior circulation due to the small connection that PCA has with the basilar artery. Therefore, patients with fetal type of PCA could be at more risk for developing vascular insufficiency[6,7]. Patients who also have a missing contralateral A1 segment, thus having to feed the arterial territory of the anterior cerebral artery (ACA), MCA and PCA with single ICA could be even more at risk.

In the presence of fetal PCA, thromboembolism in the anterior circulation may result in paradoxical PCA territory infarction with or without concomitant infarction in the territories of the MCA or ACA[8,9].

Shahan CP et al[10] in their study evaluated the impact of circle of Willis anatomy in traumatic blunt cerebrovascular injury-related stroke and found that normal COW anatomy is not protective. But, increased collateral flow provided by a fetal PCA is likely protective and suggested for further prospective, multi-institutional trials.

Wentland et al[11] retrospectively reviewed MRI perfusion studies and found that faster perfusion transit times are seen for parameters ipsilateral to fetal origin of the PCA in proportion to the degree of arterial asymmetry. Knowledge of this normal variation is critical in the interpretation of perfusion studies because this left-right perfusion asymmetry could mimic cerebrovascular pathology.

Potential consequences of this fetal variant of the circle of Willis on risk of stroke have been demonstrated, but studies are conflicting. Some of the postmortem studies showed increased stroke burden in patients with fPCA[6,12,13]. Monye et al[14] in their study in 2008 on living subjects using CT angiography, however, failed to demonstrate increased risk for cerebral ischemia in patients with fPCA. Subsequently, some studies have found that patients with a partial fPCA could be more prone to develop ischemic stroke and suggested further larger trials to evaluate the same[7,15].

He and Wan[17] in their study found that female gender is an independent risk factor for intracranial aneurysm, and fPCA and female gender are independent risk factors for ICA- PCoA aneurysm.

V. Conclusion:

Fetal PCA configuration is one of the most common type of variation in posterior part of circle of Willis. Current study can be used as a reference for prevalence of fetal PCA. It is important that radiologist is aware of this variation as it can cause perfusion asymmetry, posterior circulation infarct secondary to ICA atherosclerotic disease and is associated with increased risk of ICA- PCoA aneurysm.

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