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The study of fetal-type posterior cerebral circulation on multislice CT angiography and its influence on cerebral ischemic strokes ☆

Roshan Kumar Arjal [1], Tingting Zhu [1], Yicheng Zhou *

Department of Radiology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China 430030

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ABSTRACT

Purpose: The purpose was to evaluate if patients with partial and full fetal-type posterior cerebral artery (PCA) could be more prone to lead to ischemic strokes on multislice computed tomographic angiography (MSCTA).
Methods: A total of 202 patients who had undergone MSCTA examinations were divided into three groups: patients with full fetal-type posterior (FTP), patients with partial FTP, and patients without FTP. The odds ratio of having ischemic strokes was calculated.
Results: The odds of having ischemic strokes in patients with full and partial FTP were 1.448 and 3.027, while *P* values were .391 and .0307, respectively.
Conclusion: Patients with a partial fetal-type PCA could be more prone to develop ischemic strokes.

1. Introduction

In states of hemodynamic compromise to the anterior circulation, the posterior circulation supplies the anterior circulation via the collaterals. In fetal life, when the P1 segment still has not developed, the posterior cerebral arteries (PCAs) are supplied by the intern carotid arteries (ICAs) through the posterior communicating arteries (PCoAs).Van Raamt et al. have proposed the term full fetal-type posterior (FTP) cerebral circulation for total absence of P1 segment (Fig. 1), while partial FTP to hypoplastic P1 segment (Figs. 2–3). In patients with fetal-type PCA, the lack of proper collaterals may pose an increased risk for ischemic injury to the anterior as well as posterior cerebral area. This would mean that the incidence of strokes would be more in such population than the population with normal cerebral circulation. However, not many studies have been done to find out whether or not these variations in PCA supply have a greater risk of having cerebrovascular accidents. This study intends to use the multislice computed tomography angiographic (MSCTA) techniques to analyze the variations in the PCA flow and to evaluate whether there is increased association with ischemic strokes.

2. Materials and methods

2.1. MSCTA data acquisition and postprocessing

The images were acquired using 64-slice GE Lightspeed VCT (Waukesha, WI, USA). The imaging parameters selected were 120 kVp, 400 mA, with exposure time of 5.0 s, gantry rotation time of 0.5 s, pitch of 0.984:1, speed of 39.37, thickness of 0.625 mm, detector coverage 40.0, and head first acquisition. The contrast agent used was Ultravist (iopromide) 370 (Bayer Healthcare) at the dose of 1 ml/kg. The images were then exported to GE Advantage work station 4.3. The images were postprocessed using multiplanar reconstruction, maximum intensity projection, and volume rendering. The final postprocessed images along with the axial slices were exported through picture archiving and communication system for analysis and reporting.

2.2. Patient selection

Two hundred and twenty-six patients who had undergone MSCTA examinations at Tongji Hospital in the years 2011 and 2012 were randomly selected; the images were postprocessed and then analyzed for variations and evidence of strokes. Patients who had history of head trauma, previous illness, cerebral surgery, or diseases with known increased prevalence of cerebral strokes such as moya-moya disease, arteriovenous malformations, vasculitis syndromes, etc were excluded from this study. Twenty-four patients were excluded from the study according to the above exclusion criteria. Therefore, a total 202 patients were analyzed for evidence of full or partial FTP and ischemic strokes. A full fetal-type PCA (full FTP) was considered when there was no evidence of

* Corresponding author. Department of Radiology, Tongji Hospital, No.1095 Jiefang Avenue, Qiaokou District, Wuhan, China 430030. Tel.: +86 15342224671.
E-mail address: cjr.zhouyicheng@vip.163.com (Y. Zhou).
[1] The first two authors contributed equally to this paper.

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Fig. 1. Left-sided full FTP in a 55-year-old male. Volume reconstruction of the same patient showing the full FTP.

P1 segment of the PCA (nonfilling of P1) with ipsilateral ICA supplying the PCA via PCoA (Fig. 1). The PCA was considered partial FTP when P1 segment was present but with incomplete contrast filling and/or smaller caliber than the ipsilateral PCoA (Figs. 2–3). Ischemic strokes or infarction on CT scan images was defined as areas of low density (Figs. 2-3) in the arterial territory in a patient with symptoms explained by the involved territory and exclusion of other causes like tumors, traumatic lacerations or old hematomas, or enlarged perivascular spaces.

2.3. Image analysis

The postprocessed images were evaluated for variations in the posterior cerebral circulation, while the axial CT scan images were evaluated for evidence of ischemic strokes. All the images were analyzed and reported by expert radiologists who were blinded to this study.

2.4. Statistical analysis

The patients were divided into groups: (a) patients with partial and full FTP, (b) patients with either partial or full FTP, and (c) patients without evidence of FTP. The analysis was done in three different scenarios:

I. Full FTP predisposes a patient to ischemic stroke.
II. FTP (full and partial) predisposes a patient to ischemic stroke.
III. Partial FTP predisposes a patient to ischemic stroke.

To analyze the first scenario, the patients were divided into two groups: (a) patients with full FTP and (b) patients with normal PCA. The patients with partial FTP were excluded from analysis.

To analyze the second scenario, the patients were again divided into two groups: (a) patients with FTP (full and partial) and (b) patients with normal PCA.

To analyze the last scenario, the patients were again divided into two groups: (a) patients with partial FTP and (b) patients with normal PCA. The patients with full FTP were excluded from analysis. All the results were tabulated into 2×2 contingency table, and thereafter, calculation of odds ratio and two-tailed *P* value using Fisher's Exact Test was done using online statistical software. The results were considered significant when the calculated *P* value was <.05.

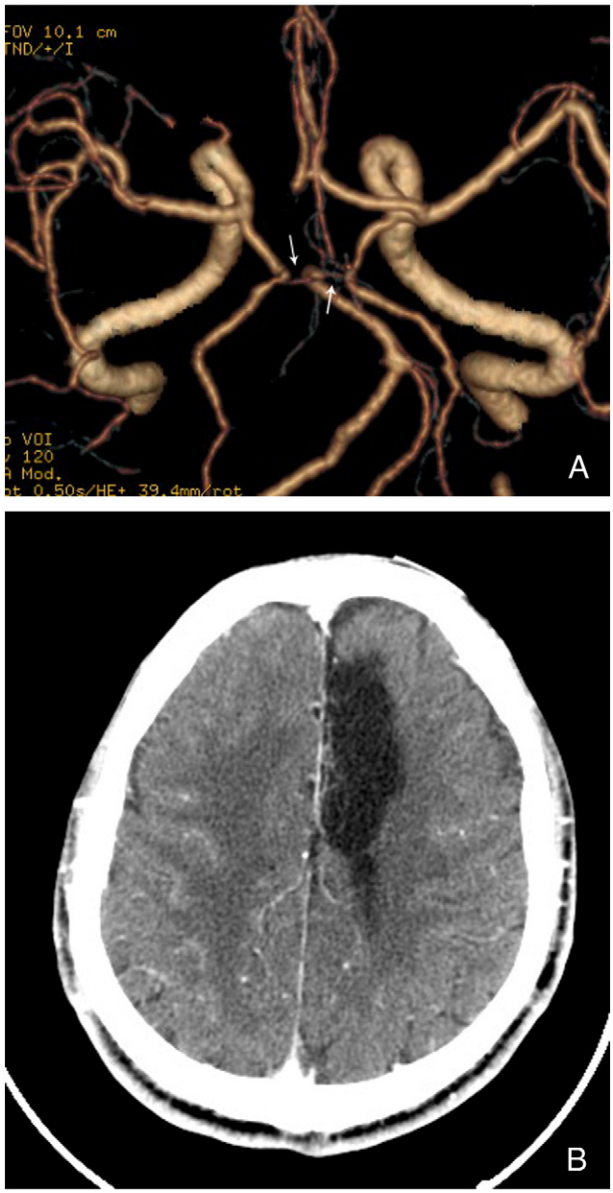

Fig. 2. (A) A 48-year-old male with bilateral partial FTP. Volume reconstruction of the same patient showing the partial FTP. (B) The same patient shows the old infarct of left anterior cerebral infarct.

3. Results

A total of 226 patients who had undergone CT angiographic examination were randomly selected for this study. Out of them, 24 patients who did not meet the inclusion criteria were excluded from the study. Out of the remaining 202 patients analyzed, 122 were males, while 74 were females. The patients were between 1 and 90 years old, with most them of belonging to 40 to 70 years and with the mean age of 51.83years. Dizziness and/or vertigo was the most common presenting symptom (54 patients) followed by headaches (45 patients) and focal neurological deficits. Other important presenting complaints were seizures, loss of consciousness, and ataxia. Fifteen patients were asymptomatic, while no history was available in 33 patients.

Out of 202 CTAs analyzed, 54 (26.7%) patients had fetal-type PCA. Out of those, 34 (16.8%) of them had full FTP, where there was no

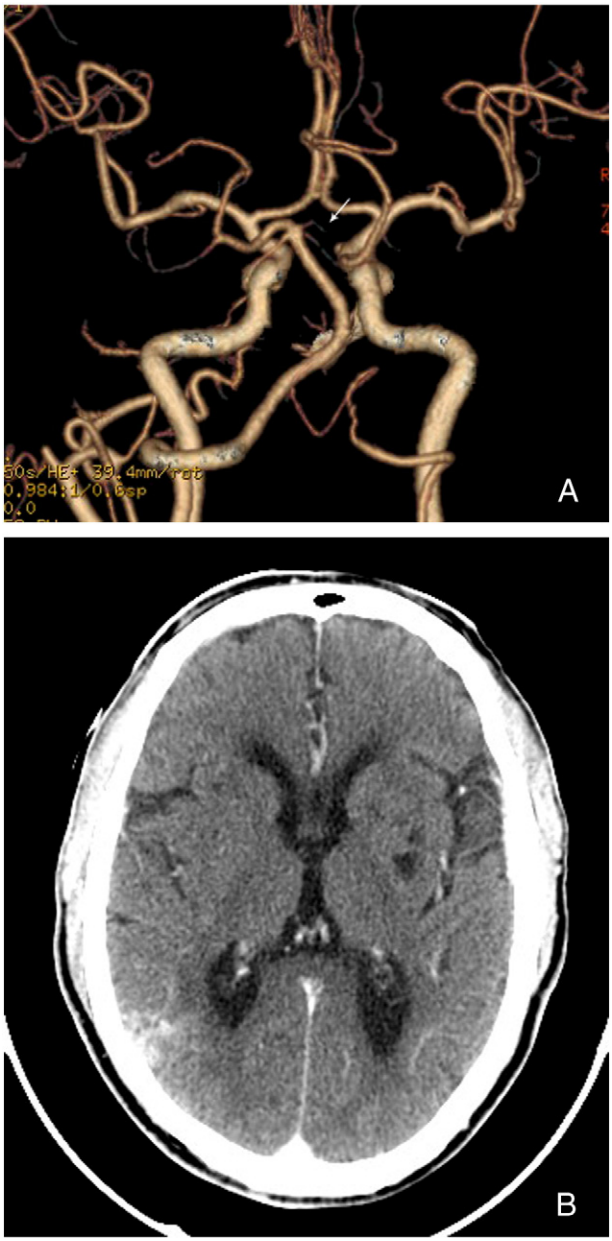

Fig. 3. (A) A 48-year-old male with left-sided partial FTP. Volume reconstruction of the patient showing the partial FTP. (B) Multiple infarcts in left basal ganglia.

evidence of P1segment (Fig. 1), while 20 (10%) had partial FTP, where P1 was still present but smaller in caliber or with incomplete filling of contrast agent than the ipsilateral PCoA (Figs. 2–3).

Most of the patients with FTP were males, with 21 out of 34 having full FTP and 15 out of 20 having partial FTP (Figs. 2–3), respectively. The mean age of presentation for full FTP was 54.17 years, while that for partial FTP was 51.45 years. Out of the 20 patients with partial FTP, 9 had right-sided, 6 had left-sided, and 5 had bilateral partial FTP. Twenty-four (70.5%) patients with full FTP had dizziness or headache, while only 6 of the 20 (30%) patients with partial FTP had similar symptoms. Similarly, only 4 out of 34 (11.7%) patients with full FTP had significant neurological symptoms, whereas 10 out of 20 (50%) patients with partial FTP had neurological symptoms in the form of focal deficits, ataxia, diplopia, or seizures.

Evidence of stroke on axial CT scans was present in 75 patients out of the total 202 patients (37.1%). Out of those, 56 patients (27.72%) had ischemic stroke, 16 (7.9%) had hemorrhagic stroke, while 2 patients (0.99%) had both. Therefore, 58 patients (28.7%) in total had CT evidence of ischemic stroke.

Table 1
2×2 contingency table for comparing patients having ischemic stroke and full FTP with ischemic stroke and normal PCA

	Patients with ischemic strokes	Patients without ischemic stroke
Patients with full FTP	11	23
Patients with normal PCA	37	112

Analysis of the above data using Fisher's Exact Test yields the following results: odds ratio=1.448, two-tailed *P* value=.391.

Out of 34 patients with full FTP, 14 (41.1%) had CT evidence of stroke, with 11 (32.3%) having ischemic strokes and 3 (8.8%) having hemorrhagic strokes. Of the 34 patients, 15 had right-sided abnormality, 12 had left-sided abnormality, while 7 had bilateral abnormality. Four out of 15 patients with right-sided full FTP had ischemic infarct, 6 out of 12 patients with left-sided partial FTP had ischemic infarct, while 1 with bilateral full FTP had ischemic infract as evidenced by axial CT scans. Eight of the patients had associated ipsilateral, and 2 had contralateral A1 hypoplasia, agenesis, or stenosis.

Out of 20 patients with partial FTP, 9 had ischemic stroke and 1 patient had both ischemic and hemorrhagic stroke. Thus, there were 10 patients (50%) with ischemic strokes. Ischemic stroke was present in four out of six patients with left-sided partial FTP (66.6%), four out of nine patients with right-sided partial FTP (44.44%), and two out of five with bilateral partial FTP (40.0%). Six patients with partial FTP had either an associated ipsilateral A1 hypoplasia, agenesis, or stenosis, while two patients had ICA aneurysm.

The patients were then divided into groups: (a) patients having partial and full ATP, (b) patients having either partial or full FTP, and (c) patients without FTP.

3.1. Scenario 1: full FTP predisposes to ischemic stroke

To investigate whether full FTP predisposes a patient to stroke or not, the data were divided into two groups: (a) patients with full FTP and (b) patients with normal FTP. Patients with partial FTP were excluded from the analysis. The 2×2 contingency table is as follows (Table 1):

The results show that although the odds for having ischemic stroke are higher in full FTP, the results are not significant as the calculated two-tailed *P* value is more than .05.

3.2. Scenario 2: FTP (partial and full) predisposes to ischemic stroke

To investigate whether full FTP predisposes a patient to stroke or not, the data were divided into two groups: (a) patients with FTP (partial and full FTP) and (b) patients with normal FTP. The 2×2 contingency table is as follows (Table 2):

The results show that the odds of having ischemic stroke in these patients are higher than the normal population, but the two-tailed *P* value is slightly more than .05, which means that the result is not significant.

Table 2
2×2 contingency table for comparing patients having ischemic stroke and FTP with ischemic stroke and normal PCA

	Patients with ischemic strokes	Patients without ischemic stroke
Patients with FTP (partial and full)	21	33
Patients with normal PCA	37	112

Analysis of the above data yields using Fisher's Exact Test the following results: odds ratio=1.926, two-tailed *P* value=.0552.

3.3. Scenario 3: partial FTP predisposes to ischemic stroke

To investigate whether partial FTP predispose a patient to stroke or not, the data were divided into two groups: (a) patients with partial FTP and (b) patients with normal FTP. Patients with full FTP were excluded from the analysis. The 2×2 contingency table is as follows (Table 3):

The results show that the odds of having a stroke are quite high in patients with partial FTP, and the calculated two-tailed *P* value is less than .05, which suggests that the association is significant.

4. Discussion

4.1. Overview of FTP

The cerebral blood flow can be divided into two: the anterior circulation derived and the posterior circulation [1–3]. The anterior and the posterior circulations' interconnections form an arterial circle popularly known as the circle of Willis (CoW) [4]. Autopsy studies have shown the complete CoW to be present in only 21% to 52% of the population [5]. The rest have one or the other form of cerebral circulation variations. In the fetal-type posterior CoW (FTP), there is a hypoplastic or absent P1 segment of the PCA and an embryonic derivation of the PCA from the ICA through the PCoA. The fetal configuration or origin of PCA is further divided into full fetal-type PCA (full FTP) and partial fetal-type PCA (partial FTP), as proposed by Raamt et al. [6]. This division defines a full FTP as a configuration where there is no P1 segment (Fig. 1), while partial FTP has some connection but with caliber less than ipsilateral PCoA (Figs. 2–3) [6]. The fetal configuration is a fairly common variant. This study shows the prevalence of FTP to be 26 %, with partial FTP being 10% and full FTP being 16.8%, which is almost similar to the results of some other studies. Lochner et al. reviewed the prevalence of FTP to be between 15% and 46% based on anatomic and angiographic studies [7], while van Raamt et al. have reviewed it to be 11%–29% for unilateral partial FTP, 1%–9% for bilateral partial FTP, 4%–26% for unilateral full FTP, and 2%–4% for bilateral full FTP [6].

4.2. MSCTA

Multislice CT scanners have the advantage of faster scan times, higher spatial resolution, ability to use different postprocessing techniques, lowered dose of contrast agent, and increased patient throughput [8–10]. MSCTA has been a major advance in noninvasive examination of the vessels. Various studies have proven that the sensitivity and specificity of MSCTA in diagnosing vascular variants are quite high [11–19]. Studies also show that MSCTA is highly accurate in diagnosing vascular stenosis or occlusion in patient with strokes.

4.3. FTP with correlation to cerebral ischemic strokes

The results of this study prove that patients with a partial FTP have a strong chance of having an ischemic stroke in the future cerebral ischemic strokes (odds ratio=3.027, *P* value=.0307). The strokes were not limited to particular area of the brain. De Monye et al., in their study, had shown that there is no significant association of fetal PCA and strokes in the PCA territory [20,21]; however, the study did not classify the FTP into full or partial, and unlike our study, their study only looked into ischemic strokes in the PCA territory. The results of this study suggest that the reasons for ischemic strokes in patients with partial FTP may be multifactorial. Some of the factors involved could be the following:

1. The cerebral circulation is highly plastic and adaptive, but contained in a closed space. Being in a closed space makes the circulation prone to changes in flow dynamics. If the flow is redirected to one part, then other areas may suffer with less flow. This could result in hypoperfusion of those areas and thus may lead to ischemia of those areas. This "steal phenomenon" is not uncommon in cerebral circulation. The abnormal posterior cerebral arterial flow may "steal" the blood from the anterior circulation and result in ischemia of the anterior circulation.
2. A full FTP could be a fully developmental anomaly, and thus, the cerebral collaterals may be well developed and adapted to the altered hemodynamics more efficiently. This explanation does not seem to hold true in partial FTP, which could be an acquired condition. One of the major conditions which could have resulted in apparent partial FTP is atherosclerotic diseases. The intimal thickening and plaques may result in luminal narrowing evident on CTA just as decreased caliber of P1 with respect to ipsilateral PCoA. As atherosclerosis is a generalized condition, other vessels may be subsequently involved and result in ischemic stroke in those involved areas. The relation of severe atherosclerosis with ischemic strokes is already proven by many previous studies, and so it is considered one of the most important risk factors for cerebral ischemic diseases and is true for Asian countries as well [22–26]. Thus, the criteria of partial filling or decreased caliber as compared to ipsilateral PCoA for classification of partial FTP may be misleading.
3. One of the factors responsible, as proposed by van Raamt et al. is the lack of development of leptomeningeal collaterals in the fetal configuration of CoW [6]. This is because both the anterior and the posterior territories are now derived from the ICA, and moreover, the tentorium prevents the cerebellar circulations from forming the collaterals with the PCA territory. However, this explanation only is true in full FTP where the PCA is exclusively supplied by the ICA. This study failed to show any associations of full FTP with ischemic strokes. The partial FTP variant will have some flow derived from the vertebrobasilar system, and so the leptomeningeal vessels are not prevented from forming the collaterals. Nonetheless, even in partial FTP, there may not be a forward flow, and P1 segment may be supplied in retrograde by the PCoA, and thus, the above condition may still hold true.

There are certain limitations of this study which may have an influence on the outcome.

1. The first one is the small sample size. Although there is an impressive outcome, the small number of cases makes the study less reliable. We propose to continue this study with a larger sample size.
2. The second limitation of this study is that this is a cross-sectional study; it cannot determine whether the ischemic stroke is a result of altered flow dynamics of the CoW caused by partial FTP or if partial FTP is the result of altered flow dynamics caused by the ischemic stroke!
3. The final limitation is in patient selection. There is a possibility of some selection bias, as all these patients had presented to the hospital with some sorts of complaints related to the cerebrovascular system.

Table 3
2×2 contingency table for comparing patients having ischemic stroke and partial FTP with ischemic stroke and normal PCA

	Patients with ischemic strokes	Patients without ischemic stroke
Patients with partial FTP	10	10
Patients with normal PCA	37	112

Analysis of the above data yields using Fisher's Exact Test the following results: odds ratio=3.027, two-tailed *P* value=.0307.

5. Conclusion

Our study may imply that the patient with partial FTP may be predisposed to get an ischemic stroke. However, the small number of sample size, noncomparison with digital subtraction angiography, and possibility of selection bias limit the study, and thus, we propose to conduct the study with a larger sample size which could be more representative of the general population. Despite these limitations, it is important to recognize individuals who present partial FTP as being at risk for developing stroke.

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