Anatomical Variability of the Posterior Communicating Artery

Abstract

Objective: Although posterior communicating artery (PCoA) is a smaller branch of the internal carotid artery, it gives the main contribution in the formation of circle of Willis (CW) by communicating with the internal carotid arterial system and the vertebro-basilar arterial system. The size of PCoA varies frequently. The present work aims to study the PCoA regarding its morphology, morphometry, and symmetry. **Materials and Methods:** This study was conducted on 170 human cadaveric brains. Brains were dissected carefully and delicately to expose all components of CW, especially PCoA. Morphological variations of PCoA were noted along with its morphometry and symmetry. **Results:** Morphological variations of PCoA were aplasia (3.52%), hypoplasia (25.29%), fenestration (0.58%), and persistent fetal pattern (16.47%). In the present study, we found the five different types of terminations of PCoA. Type I termination was the most common type, seen in 92.94% of cases, Type II termination was seen in 1.17%, Type III and Type IV terminations both were seen in 0.58%, and Type V was seen in 1.17%. The mean length of PCoA was 15.9 mm and 15.3 mm on the right and left sides, respectively. The mean diameter of PCoA was 2.1 mm and 1.9 mm on the right and left sides, respectively. Symmetry of PCoA was seen in 65.29% and asymmetric PCoA was seen in 34.70% of cases. **Conclusion:** The present study provides the complete description of PCoA regarding its morphology, symmetry, and morphometry. Awareness of these anatomical variations is important in neurovascular procedures.

Keywords: *Brain, circulus arteriosus, morphometry, posterior communicating artery, variation*

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Introduction

The posterior communicating artery (PCoA) is a smaller branch of the internal carotid artery (ICA). It runs backward to anastomoses with the posterior cerebral artery (PCA) to contribute in the formation of circle of Willis (CW). It forms the main communicating channel between the internal carotid arterial system and the vertebro-basilar arterial system.[1,2] The size of PCoA is usually very small but it varies frequently to form fetal PCoA.[2] The present work aimed to study the PCoA regarding its morphology, morphometry, and symmetry.

Materials and Methods

This study was done in the Department of Anatomy, Rural Medical College, PIMS, Loni, Maharashtra, India. The study was started by undertaking the Institutional Ethical Clearance (PIMS/PhD/RC/2013/28). This study was conducted on 170 pairs of PCoA studied from 170 formalin-preserved human cadaveric brains. The cadaveric bodies from which brains removed were of unknown age and unknown cause of death. The approximate age was 40–60 years. The brains with the gross morphological variations were excluded from the study. Arachnoid mater in the interpeduncular fossa was removed carefully to expose the CW and all its segments including the PCoA. Hence, the PCoA on the either side was carefully dissected. Morphological variations of PCoA were seen, noted, and well photographed. The complete arterial networks of the CW were carefully and delicately separated from brain tissue and pasted on the black plastic sheets for better view. Dimensions of the PCoA were measured with the help of a Vernier caliper. Thus, detailed morphological and morphometrical study of PCoA was performed.

Results

In the present study, in all specimens, we found the origin of PCoA from the ICA. It is a smaller branch arising from the posterolateral aspect of the cranial part of the ICA in the interpeduncular

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fossa. It arises just before the termination of the ICA into anterior cerebral artery (ACA) and middle cerebral artery (MCA). This point forms the lateral angle of the CW. After the origin, artery runs posteromedially and forms the posterolateral boundaries of CW [Figure 1]. Morphology, symmetry, and morphometry of PCoA were studied.

Morphology of posterior communicating artery

Morphological variations of PCoA were seen in 78 specimens (45.88%). Morphological variations noted were aplasia, hypoplasia, fenestration, and fetal pattern of P2 segment.

Aplasia was seen in six specimens (3.52%); two specimens on the right side and four specimens on the left side [Figure 2]. Hypoplasia was seen in 43 specimens (25.29%); 22 specimens on the right side and 21 specimens on the left side. It was bilaterally present in 12 specimens [Figure 3]. Fenestration was seen in one specimen (0.58%) on the right side [Figure 4].

Persistent fetal pattern contributing in the formation of P2 segment was seen in 28 specimens (16.47%). This pattern was seen bilaterally in twenty specimens and unilaterally in eight specimens; six on the right side and two on the left side [Figure 5]. Adult type of PCoA artery was seen in 135 specimens (79.41%) [Figure 1]. In the remaining seven specimens, one of the PCoAs was showing aplasticity in six specimens, and in one specimen, fenestrated PCoA was present.

Termination of posterior communicating artery differs as per the morphological variations

In the present study, termination of PCoA was divided into five different types [Figure 6]. These are as follows:
1. Type I termination: Typical termination: Artery terminates by anastomoses with the PCA
2. Type II termination: Artery terminates by anastomosing directly with the basilar artery (BA)
3. Type III termination: Artery terminates in the fenestration
4. Type IV termination: Artery anastomoses with an extra loop present in the CW
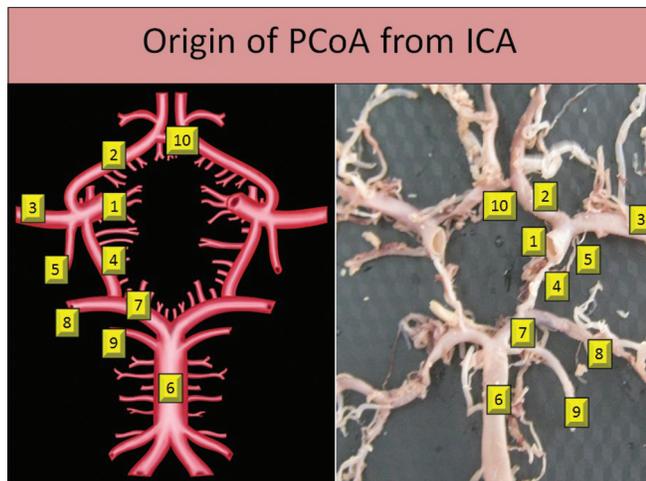

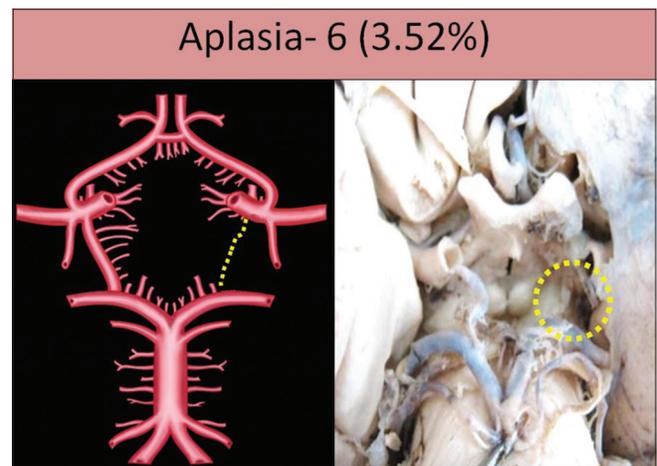Figure 1: Origin of posterior communicating artery from internal carotid artery

Figure 2: Aplasia of posterior communicating artery shown by dotted circle
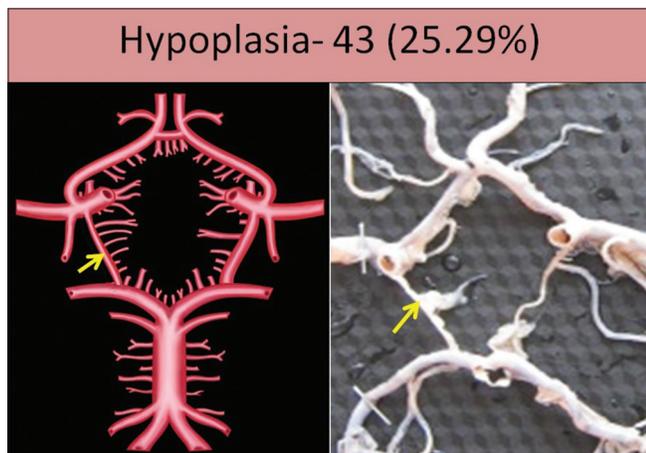

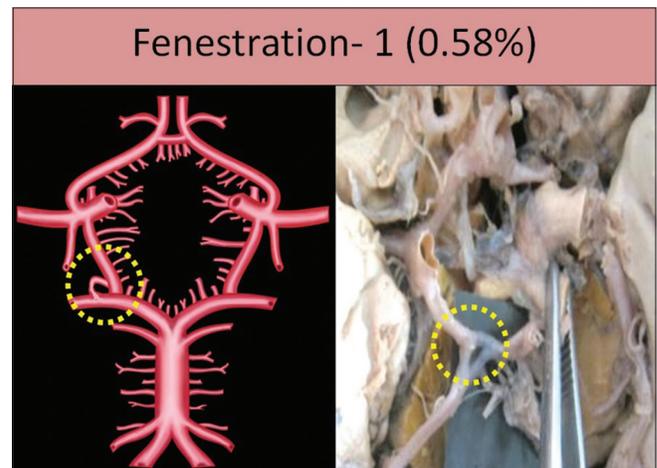Figure 3: Hypoplasia of posterior communicating artery shown by arrow

Figure 4: Fenestration of posterior communicating artery shown by dotted circle

5. Type V termination: Artery does not anastomoses with any artery and directly supply the posterior aspect of cerebrum.

Type I termination

This is the typical termination of PCoA in which the artery anastomoses with the PCA to divide it into P1 and P2 segments. This was the most commonly found pattern of termination. It was seen in 158 specimens (92.94%) [Figure 7].

Type II termination

Artery anastomoses directly with the BA at its termination. The terminal end of PCoA instead of anastomosing with PCA joins with the termination of BA. In this type of variation, the PCoA joins the lateral angle of CW with the posterior angle of CW excluding the contribution of PCA from the CW. This was observed in two specimens, both on the left side (1.17%) [Figure 8].

Type III termination

Artery terminates in the fenestration; at the site of anastomosis of PCoA and PCA, there was a large triangular fenestration. It was seen in a single specimen [Figure 9].

Type IV termination

Artery anastomoses with an extra loop present in the CW: in this type of variation, PCoA runs posteromedially forming the boundary of CW and then it anastomoses with an unnamed extra loop present in the CW. It was forming an extrasegment in the posterior boundary of CW. After anastomoses with an extra loop/segment, PCoA runs posterolaterally to supply the posterior aspect of cerebrum to form an additional P2 segment of the PCA. This type was found in only one specimen on the left side in the present study (0.58%) [Figure 10].

Type V termination

Artery does not anastomose with any artery and directly supply the posterior aspect of cerebrum: in this type, CW remains incomplete due to failure of communication between PCoA and PCA. PCoA runs posterolaterally to supply the posterior aspect of cerebrum to form an additional P2 segment. This type was seen in two specimens (1.17%), one on the right side and other on the left side [Figure 11].
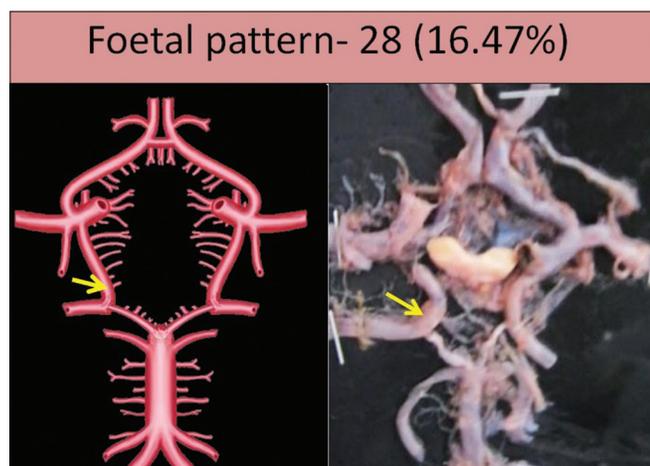
Morphometry of posterior communicating artery

Along with the morphological variations, morphometrical observations of PCoA were done and tabulated [Table 1].

The length of PCoA was taken from its origin to the point of union with the PCA, and diameter was measured at the middle of the artery.

Mean length of PCoA was 15.9 mm and 15.3 mm on the right and left sides, respectively. Mean diameter of PCoA was 2.1 mm and 1.9 mm on the right and left sides, respectively.
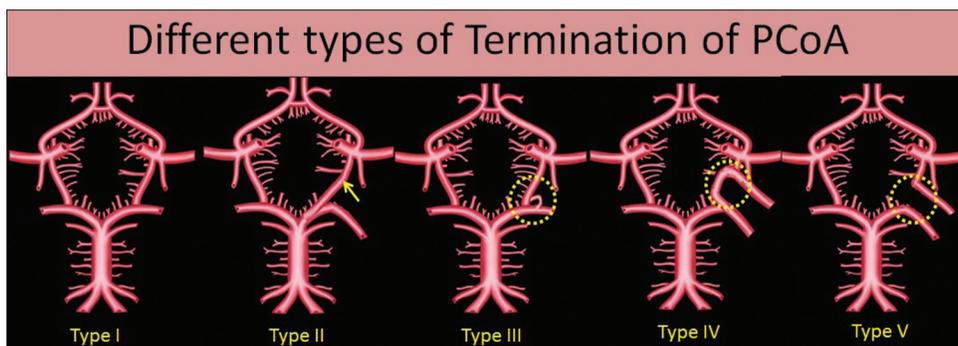

Figure 5: Remnant of fetal pattern of posterior communicating artery shown by arrow

Figure 6: Schematic diagram of different types of termination of posterior communicating artery

Table 1: Morphometry of posterior communicating artery (mm)								
PCoA	Length				Diameter			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
Right PCoA	5	26	15.3	0.46	1	5	2.1	0.12
Left PCoA	5	26	15.3	0.43	1	5	1.9	0.11

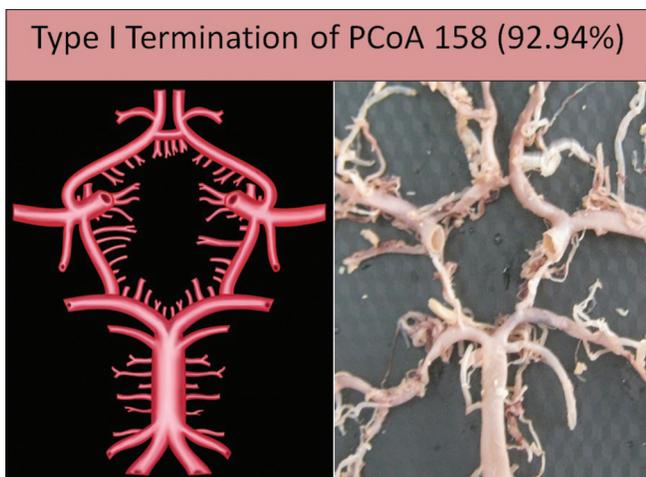PCoA – Posterior communicating artery; SD – Standard deviation

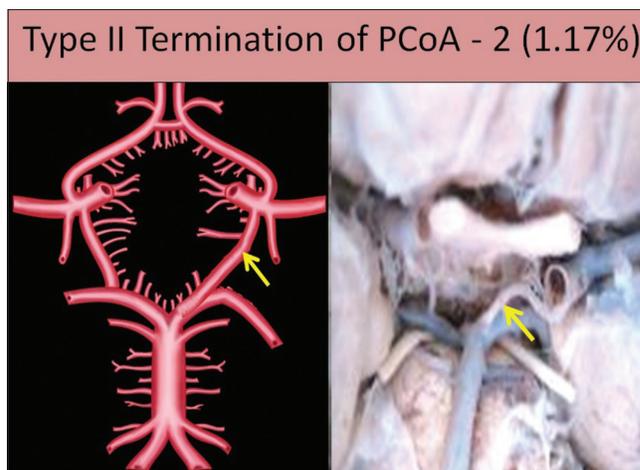Figure 7: Type I termination of posterior communicating artery

Figure 8: Type II termination of posterior communicating artery
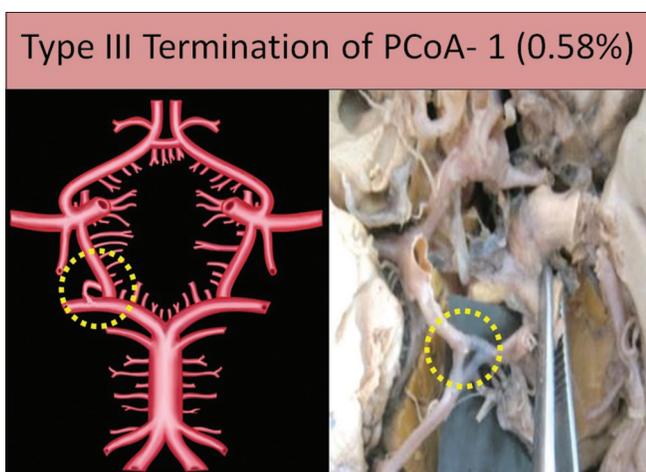
Figure 9: Type III termination of posterior communicating artery
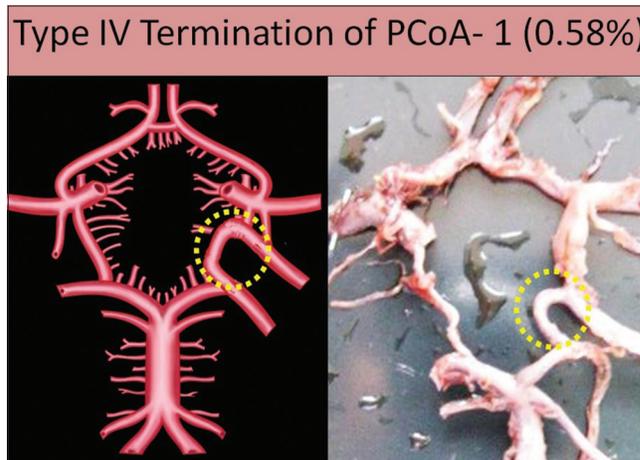
Figure 10: Type IV termination of posterior communicating artery
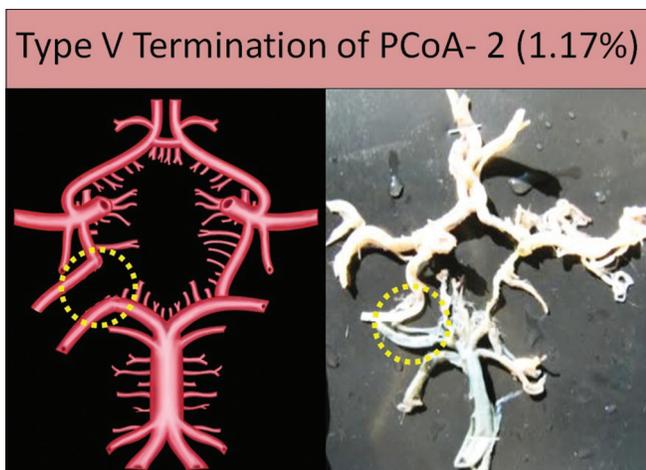
Figure 11: Type V termination of posterior communicating artery

Figure 12: Symmetrical posterior communicating artery

Symmetry of posterior communicating artery

Symmetry of PCoA was seen in 111 specimens (65.29%) [Figure 12], and asymmetry was seen in 59 specimens (34.70%) [Figure 13].

Discussion

PCoA is the main communicating channel of the CW; it joins ICA and vertebro-basilar arterial system. The present study describes the morphological variations of

Figure 13: Asymmetrical posterior communicating artery
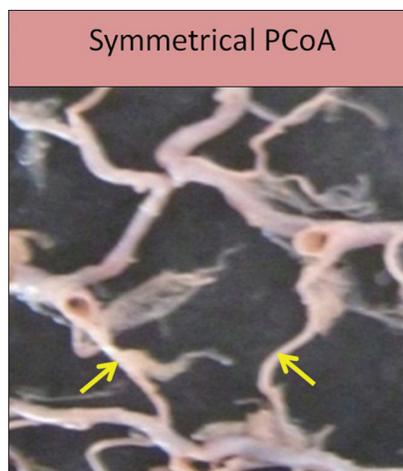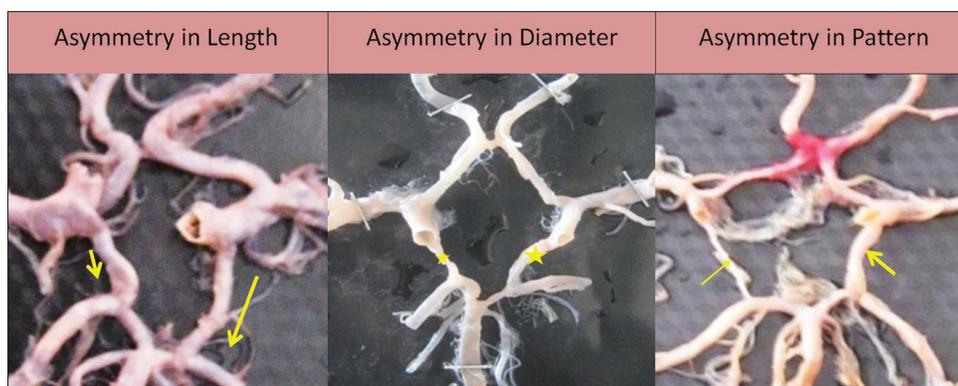
	Asymmetry in Length	Asymmetry in Diameter	Asymmetry in Pattern

Table 2: Comparison of morphological variations of posterior communicating artery

Variation type PCoA	Present study	Kapoor *et al.*[3]	Alpers *et al.*[4]	Al-Hussain *et al.*[5]	Merkkola *et al.*[6]	Windle[7]	Eftekhar *et al.*[8]	Ardakani *et al.*[9]	Saha *et al.*[10]
Absent	3.52	1	-	13	46%	12.5	10	19.9	38.2
Hypoplasia	25.29	-	-	-	-	25	60	43.3	23.3
Fenestration	0.58	-	-	33	-				
PCA formation	16.47	-	14.6	77	-				
Symmetrical	65.29	-	-	-	-				
Asymmetrical	34.70	-	-	29	-				

PCA – Posterior cerebral artery; PCoA – Posterior communicating artery

Table 3: Comparison of size of posterior communicating artery

Authors	Adult type percentage	Fetal type percentage
Present study	79.41	16.47
Eftekhar *et al.*[8]	-	27
Padget[11]	50	-
Vriese[12]	58	-
Riggs and Rupp[17]	76	17
Saeki and Rhoton[18]	70	30
Zeal and Rhoton[19]	58	40

PCoA in 45.88% of cases. Morphological variations noted were aplasia, hypoplasia, fenestration, and fetal pattern. Morphological variations of PCoA were discussed with the available literature in Table 2.

The number of morphological variations associated with the PCoA can be explained on the embryological basis. The blood vessels of the brain develop from a primitive plexus of vascular channels. Certain vascular channels develop and persist and certain channels disappear in accordance with contemporary needs and relations of the areas to be supplied.[11]

In the initial period of development, up to the 14-mm stage in the human embryo, all the cerebral arteries ACA, MCA as well as PCA are primarily derived by the carotid arterial system. Vertebro-basilar system develops later. Thread-like PCoA is due to the "atrophy" of the vestigial connecting branch completing CW during the developmental process.[12]

When the BA develops completely, it begins to supply blood to the posterior part of the brain. Thus, PCoA develops properly and acquires its adult form. If this development does not take place, it shows development of hypoplasia of P1 segment of PCA and an ipsilateral fetal type of PCoA.[13-15]

In one of our articles, we have reported various patterns of BA termination. One of the patterns observed was the nonfurcation of BA. In that pattern, BA instead of termination showed its direct continuation into a single PCA, either of the right or left side. This pattern suggests aplasia of one of the PCAs. It was present in 2.94% of cases.[16]

This pattern shows nondevelopment of anastomosis between PCoA and BA through PCA. Thus, PCoA cannot acquire its adult configuration and remains as the fetal type.

Hypoplasia of the PCoA is the most commonly found anomaly in the literature.[1] In the present study, the incidence of the hypoplastic PCoA was 25.29%. Fenestration of the PCoA was the least commonly found variation of the present study in 0.58% of cases.

PCoA can be divided into three different types as follows:
A. Adult configuration
B. Transitional configuration and
C. Fetal or embryonic configuration.

In adult configuration, diameter of PCoA is larger than the P1 diameter. In transitional configuration, diameter of both PCoA and P1 is same and they contribute approximately

Table 4: Comparison of morphometry of components of posterior communicating artery (mm)

PCoA	Present study	Pai *et al.*[22]	Uz and Mine[23]	Krabbe-Hartkamp *et al.*[24]	Moore *et al.*[25]
PCoA length	15.7	12.13	11.94	-	-
PCoA diameter	2.2	1.25	1.42	1.2	1.45

PCoA – Posterior communicating artery

equal contribution in the formation of P2 segment of PCA. Fetal or embryonic configuration shows the direct continuation of PCoA as P2 segment of PCA. In the present study, we have divided the PCoA into only adult and the fetal type of configuration. Data are compared with the available literature in Table 3.

For the shunt operations to assess the feasibility, knowledge of the normal size of these vessels is essential. Vessels with 1 mm diameter or less than that are considered abnormal.[3,20]

Dimensions of the PCoA vary greatly. Its hypoplasia was most frequently seen in arteries forming CW. It was mostly seen in PCoA followed by P1 and P2 segments of PCA.[20,21] Morphometric observations of PCoA are compared with the previous studies as shown in Table 4.

Morphometrical observations could be useful for different stent procedures in treating neurovascular diseases. This knowledge is also useful for microneurosurgeries in revascularization and cerebral bypass surgeries treating aneurysms or occlusion.

In addition to this, the present study also describes the symmetry of PCoA. There is hardly any study describing the symmetry of PCoA.

In normal circumstances, occipital lobes of cerebrum enjoy nutrition both from vertebro-basilar and internal carotid system of arteries. In different morphological variations, the situation changes.

In aplasia of PCoA or P1, blood supply to the occipital pole retains from a single source.

In such cases, collateral circulation lacks. Blood supply may get hampered due to hemodynamic factors affecting vessel wall to change in the development of aneurysm or occlusion.

Complete absence of PCA is never seen, only its origin from BA or ICA changes. Aplasia of P1 seen in the present study is in 2.35% of cases.[26] The present study shows aplasia of PCoA in 3.52% and hypoplasia in 25.29% of cases.

Collateral circulation through CW becomes important in occlusive vascular diseases of the brain. Compensatory circulation will be more effective in the presence of a normal and complete CW.

PCoA plays an important role for effective establishment of collateral circulation through CW. If one of these arteries is thin, hypoplastic or thread like, collateral circulation through the circle may be impaired, partially or completely. For establishment of better collateral circulation, connections between the two sides of the CW as well as the connections between the internal carotid and vertebro-basilar systems are equally important.

Conclusion

These are some interesting facts about the PCoA found in the present study. Hypoplasia of PCoA artery was the most frequently found variation while the fenestration of PCoA is the least found variation. Origin of PCoA shows least morphological variation while the terminal portion of PCoA shows most variety. The present study for the first time described about the different terminations of PCoA.

Morphological variations of PCoA were discussed in detail. Along with this, the present study has described adult and fetal configuration of PCoA in detail. In addition to this, the present study also describes the symmetry of PCoA. The present study adds knowledge by describing the morphological variations of PCoA.

This study provides the complete description of PCoA regarding its morphology, morphometry, and symmetry. Awareness of these anatomical variations is important in neurovascular procedures.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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