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The Posterior Inferior Cerebellar Artery (PICA): An Anatomical and Clinical Analysis

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ABSTRACT

AIM: To study the operative approaches for posterior inferior cerebellar artery (PICA) aneurysms or understanding the different pathologies that can affect this artery, and to present detailed knowledge of this artery's anatomy.

MATERIAL and METHODS: The present study analyzed the different variations of the PICA's first two segments, the anterior medullary and lateral medullary segments, regarding the number of trunks, their emergency site, and the presence or absence of hypoplasia of this artery, through microsurgical dissection of 23 fresh cadaver brains.

RESULTS: Some striking variations were found, such as the absence of the left vertebral artery in one of the brains and the emergence of any PICA in another two brains studied. Moreover, variations such as hypoplastic arteries, missing trunks on one side and double or triple trunks, different emergence sites, significant PICA emergence from the superior part of the vertebral artery (59% of the trunks), and asymmetries between the right and left sides were recorded. The double origins of non-hypoplastic PICAs were found in 17% (n = 4) of patients.

CONCLUSION: The results obtained in the present study indicated the great importance of the studies and reviews on the different topographies of PICA; these studies and reviews expand the knowledge and consensus on the characteristics and implications of PICA's variations. The clinical implication of this knowledge and consensus is obtaining the best surgical strategies for clipping aneurysms and, in addition, the best choices for occlusion of the vessel affected if the territory of the main vessel has an adequate collateral circulation. From the results of the present study, it is evident that there was a significant PICA emergence from the superior part of the vertebral artery and that the double origin of non-hypoplastic trunks was also found in some patients; the latter is associated with a greater chance of aneurysms and other additional complications.

KEYWORDS: Anatomical study, Cerebellum, Intracranial aneurysm, Posterior cranial fossa, Posterior inferior cerebellar artery

ABBREVIATIONS: A: Artery, **Aa:** Arteries, **A.I.C.A:** Anterior inferior cerebellar artery, **B:** Basilar, **Br:** Branch, **d.A.I.C.A:** Dominant anterior inferior cerebellar artery, **Hem:** Hemispheric, **Labyr:** Labyrinthine, **Lat:** Lateral, **Med:** Medial medullary, **P.C.A:** Posterior cerebral artery, **P.I.C.A:** Posterior inferior cerebellar artery, **SAH:** Subarachnoid hemorrhage, **S.C.A:** Superior cerebellar artery, **Suboccip:** Suboccipital, **Tr:** Trunk, **V:** Vertebral, **V.B.J:** Vertebrobasilar junction, **Verm:** Vermian, **V4a, V4b and V4c.:** Intracranial segment portions of vertebral artery

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INTRODUCTION

The best management and choice for the operative approaches of the posterior fossa, as well as the best prediction of risks related to the involvement of structures that are there, invariably require the study and knowledge of the neuroanatomy of the region (27). Regarding arterial irrigation, three neurovascular complexes can be defined: a superior complex related to the superior cerebellar artery (SCA); a middle complex related to the anterior inferior cerebellar artery (AICA); and an inferior complex related to the posterior inferior cerebellar artery (PICA) (22), which is analyzed in this study and is also related to the glossopharyngeal, vagus, accessory, and hypoglossal nerves (cranial nerve pairs).

Going further into the structures and relations of the inferior complex, we can also include in it the most cranial portion of the spinal cord, bulb or medulla oblongata, inferior cerebellar peduncle, cerebellomedullary fissure, and suboccipital surface of the cerebellum. The PICA has the most complex way among the cerebellar arteries (16,26). Moreover, it can originate from below the foramen magnum to the vertebrobasilar junction (VBJ) (6), although it originates from the intracranial portion of the vertebral artery in 80%–95% of cases (1,17). The PICA is most commonly defined as having the following topography: arises from the vertebral artery near the inferior olive and passes posteriorly around the medulla (26) and having a variable course between the glossopharyngeal, vagus, and accessory nerves to reach the cerebellomedullary fissure (21,26,30) (Figure 1). However, as a result of these large variations, there are two different definitions for PICA and its origin: 1) the cerebellar artery that arises from the vertebral artery (33,35) (definition adopted in the present study) and 2) the cerebellar artery that irrigates the posteroinferior portion of the cerebellum and usually arises from the vertebral artery and that could also arise from the basilar artery (4,26,36). Thus, it is perceived that studies and reviews on the different variations of the PICA is of great importance as these establish a better knowledge and consensus regarding its characteristics and implications. These include syndromes and sets of signs and symptoms that affect patients with occlusion of these arteries, such as the complex Wallenberg syndrome, often associated with vertebrocerebellar symptoms (lesion of the lower cerebellar peduncle), sensitivities (lesion of the lateral spinothalamic tract and the spinal tract of trigeminal nerve and its nucleus), homolateral bulbar muscle weakness (lesion of the ambiguous nucleus and the center of vomit), and even autonomic dysfunctions, developing Claude Bernard–Horner syndrome (lesion of the descending pathways of the hypothalamus) (28). In addition, the anatomical knowledge of the anatomical variations of the PICA may have other practical neurosurgical applications, such as the best choice of clipping strategies and surgical exposures of aneurysms, according to the PICA segment that was affected (16); the choice of occlusion of the vessel affected by the aneurysm if the territory of the main vessel has an adequate collateral circulation (1,3,31); or even the double origin of the PICA, which is associated with the presence of aneurysms (15). In relation to these pathologies, the PICA's anatomy becomes even more important when choosing the best approach as the course of this artery is the primary determinant of the location of the aneurysm and of the direction in which the aneurysm was pointed (12).

The PICA is divided into five segments: 1) anterior medullary, 2) lateral medullary, 3) tonsillomedullary, 4) televelotonsillar, and 5) cortical (17,26). The present study focused on studying only the first two segments, the anterior medullary and lateral medullary segments, and aimed at analyzing PICA's different variations regarding the number of trunks, their emergency site, and the presence or absence of hypoplasia of this artery.

MATERIAL and METHODS

The PICA anatomical classification was made according to the arterial origin; that is, the following definition was adopted for the PICA: the cerebellar artery that arises from the vertebral artery (33,35). Moreover, the dominant PICA was defined as the well-developed PICA that originates as a common trunk from the vertebral artery when the homolateral AICA is completely absent; on the other hand, the dominant AICA was defined as the well-developed AICA that originates as a common trunk from the basilar artery, feeding both the original AICA and PICA territories (17,23). For the analysis of this, after approval by the Medical Research Ethics Committee of Santa Paula Hospital (0003/2019), throughout the year 2019, 23 cadavers (13 males and 10 females), with an average age of 56 years, were studied. The technique used in the anatomical study was microsurgery, from the dissection of 23 fresh brains in the department of pathology of the Faculty of Medical Sciences of the Pontifical Catholic University of São Paulo (FCMS PUC-SP) in Sorocaba, São Paulo, Brazil. Both hemispheres of the 23 cadavers' brains were dissected and studied. Regarding the coverage of the arterial territory considered for this analysis, we had the mean and inferior complex (related to the PICA) of the posterior fossa and the intracranial segments (V4) of the vertebral arteries. The mean complex (related to the AICA) was considered in the analysis because of the possibility that the dominant AICA, which supplies the original territory of the PICA when it is absent, originated there. The extracranial portion (below the foramen magnum) of the vertebral arteries was not analyzed in this study because of the limitations in the technique of brain removal. This study did not analyze the tonsillomedullary, televelotonsillar, and cortical segments of the PICA, restricting itself to the first two segments, the anterior medullary and lateral medullary segments, because of the objective of the study and its clinical implications, such as the origin of aneurysms mainly in these segments (10,12,16,37).

For the systematization and greater precision of the emergency sites of the structures studied, the intracranial or intradural segment (V4) of the vertebral arteries was subdivided into three consecutive portions of the same length, following the natural direction of the flow of this vessel toward the basilar artery: V4a; V4b; and, more rostral and ending at the VBJ, V4c (Figure 2). Each portion could be expected to have approximately 8.5 mm each, since, from previous studies, 80%–95% of PICA's cases originate from the intracranial portion of the vertebral artery, 8.6 mm from the foramen magnum and 16.9 mm from the VBJ (17), obtaining a sum of 25.5 mm as mean of the intracranial segment (V4) of the vertebral artery.

Thus, four different sites for PICA emergencies were systematized for registration: V4a, V4b and V4c vertebral artery subdivisions, and the VBJ. The caudal portion of the basilar artery was a possible site for dominant AICA emergencies (Figure 2). In addition, the findings of arterial hypoplasia from the PICA were recorded, as well as the number of trunks or the absence of them.

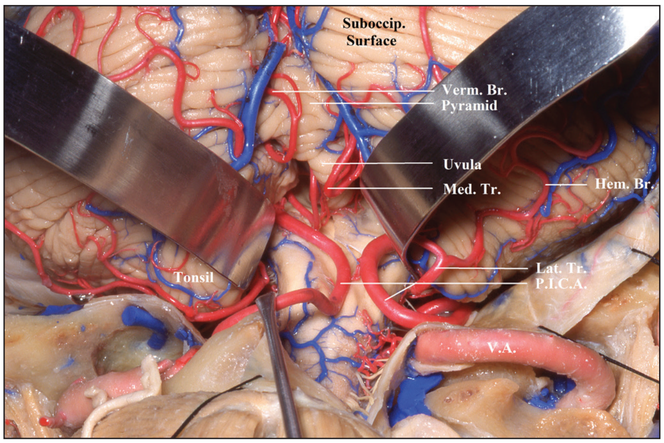

Figure 1: PICA relationships. Both PICAs enter the cerebellomedullary fissure, pass around the tonsils, and exit the fissure to supply the suboccipital surface. **A.,** artery; **Br.,** branch; **Hem.,** hemispheric; **Lat.,** lateral; **Med.,** medial medullary; **P.I.C.A.,** posterior inferior cerebellar artery; **Suboccip.,** suboccipital; **Tr.,** trunk; **Verm.,** vermian; **V.,** vertebral.

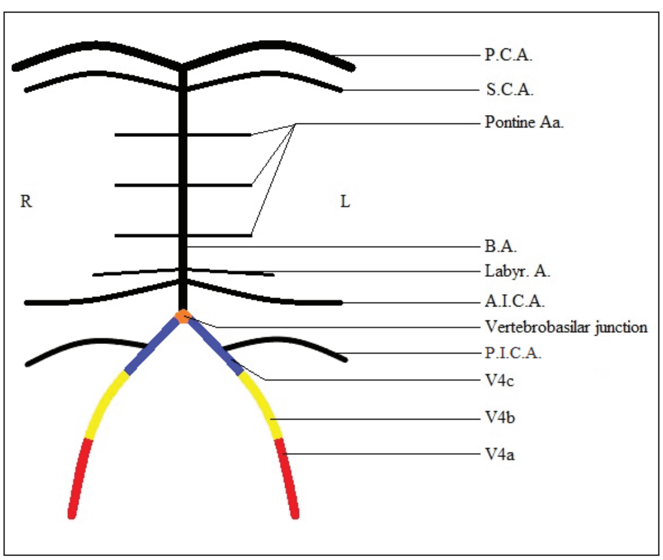

Figure 2: Vertebrobasilar system scheme with the possible emergency site's PICA, according to the study's methodological division. In this figure, the PICA was represented emerging from its most frequently observed location in this study. **A.,** artery; **Aa.,** arteries; **A.I.C.A.,** anterior inferior cerebellar artery; **B.,** basilar; **Labyr.,** labyrinthine; **P.C.A.,** posterior cerebral artery; **P.I.C.A.,** posterior inferior cerebellar artery; **S.C.A.,** superior cerebellar artery; **V4a, V4b and V4c.,** intracranial segment portions of vertebral artery (V4).

RESULTS

Some striking variations were found, such as the absence of the left vertebral artery in one of the brains and the emergence of any PICA in another two brains studied, in which bilateral dominant AICA trunks were found. Moreover, several variations of the PICA were recorded, such as hypoplastic arteries, missing trunks on one side and double or triple trunks, different emergency sites, and asymmetries between the right and left sides; all variations are described in Table I. No dominant PICA trunks were found in any analyzed cerebellar hemispheres.

Of the total of 23 brains studied, at least one PICA trunk was found in 91% (n=21) of cases, and in 38% (n=8) of these, only hypoplastic trunks were observed. In the latter, 37% (n=3) of times double (n=2) or triple (n=1) origins were found; 50% (n=4) of times single trunks on both sides were also found. Only in one case was a single hypoplastic trunk observed on the left, with no other PICA trunks on either side, observing a dominant AICA trunk on the right.

In one case, there was no vertebral artery and PICA emergency site on the left, and in another two cases, there was no PICA emergency site bilaterally from the passage of the vertebral arteries through the foramen magnum in its intracranial path to the VBJ, observing dominant AICAs feeding both the original AICA and PICA territories bilaterally in these latter two cases and in the left in the first case. From the brain in which the left vertebral artery did not exist, the PICA emerged from the V4c segment of the right vertebral artery, constituting a unique and well-vascularized change. The double origins of non-hypoplastic PICAs were found in 17% (n=4) of patients, and in three of these, the contralateral branches of the PICA were hypoplastic and unique; in the other, no trunk of the PICA was observed. A case of triple origin of the PICA was also recorded, with all non-hypoplastic trunks emerging from the V4c segment of the left vertebral artery. Contralaterally in this same patient, a single, non-hypoplastic origin of a trunk was found in the V4c segment of the right vertebral artery. No PICA's trunks were unilaterally observed, whether hypoplastic or not, in 21.7% (n=5) of all dissected brains, and PICA's trunks were bilaterally absent in 8.7% (n=2) of all cases, as previously described above. Another finding of the study was the presence of at least one hypoplastic branch of the PICA in 46% (n=21) of all 46 cerebellar hemispheres.

As for the most common origin sites of the PICA, out of a total of 49 trunks studied, 25 of which were hypoplastic and 24 were non-hypoplastic; the results obtained indicated that 59% (n=29) originated in segment V4c, 15 on the right and 14 on the left. The second most common emergency site was the VBJ, with 31% (n=15) of the trunks originating there, 5 on the right and 10 on the left. Only on the left side did PICA originated in segments V4b and V4a, 4 and 1 trunks, respectively. Furthermore, all PICA's trunks arose from the posterior, posterolateral, or lateral surface of the vertebral

Table I: Results of the Number of Trunks in Each Location

Patient	Number of right emerging trunks					Number of left emerging trunks				
	P.I.C.A.				d.A.I.C.A.	P.I.C.A.				d.A.I.C.A.
	V4a	V4b	V4c	V.B.J.	B.A.	V4a	V4b	V4c	V.B.J.	B.A.
1	0	0	0	1	0	0	0	0	1	0
2	0	0	1*	0	0	0	0	2	0	0
3	0	0	0	0	1	0	0	0	2	0
4	0	0	1	0	0	0	0	3	0	0
5	0	0	1	1	0	0	0	1*	0	0
6	0	0	2*	0	0	0	0	1*	0	0
7	0	0	1	0	0	0	0	1	0	0
8	0	0	0	0	1	0	0	0	0	1
9	0	0	0	1*	0	0	0	0	1*	0
10	0	0	0	1*	0	0	0	0	1*	0
11	0	0	1	0	0	0	0	0	1	0
12	0	0	1*	0	0	0	0	1*	0	0
13	0	0	0	0	1	0	0	0	1*	0
14	0	0	0	1*	0	1*	1*	0	1*	0
15	0	0	1	0	0	0	0	1*	0	0
16	0	0	1*	0	0	0	0	1*	0	0
17	0	0	0	0	1	0	1*	0	1	0
18	0	0	0	0	1	0	0	1	0	0
19	0	0	1	0	0	**missing vertebral artery**			0	1
20	0	0	1, 1*	0	0	0	0	1	0	0
21	0	0	1*	0	0	0	1*	1*	0	0
22	0	0	1*	0	0	0	1	0	1	0
23	0	0	0	0	1	0	0	0	0	1
Total	**0**	**0**	**15**	**5**	**6**	**1**	**4**	**14**	**10**	**3**

P.I.C.A.: *Posterior inferior cerebellar artery,* ***d.A.I.C.A.:*** *Dominant anterior inferior cerebellar artery,* ***V4a, V4b e V4c:*** *Subdivisions of the intracranial segment of the vertebral artery,* ***V.B.J.:*** *Vertebrobasilar junction,* ***B.A.:*** *Basilar artery,* ****:*** *hipoplastic trunk*

artery, and no aneurysm or unruptured cerebral aneurysm was observed in the posterior circulation. As for the caudal portion of the basilar artery, nine trunks of dominant AICAs originated there, six on the right and three on the left; all of them supply the original territory of the PICA.

■ DISCUSSION

The PICA has the most complex and variable course of the cerebellar arteries (17), divided into two loops and five segments (all of which may not be present) according to their different relations with the brain stem and cerebellum. The medullary anterior segment exists from PICA's origin, passing in contact with the roots of the hypoglossal nerve and running in a posterior direction to its distal anatomical limit, an imaginary line that passes through the most prominent portion of the olive (the existence of this segment usually occurs when the PICA originates at the upper portion of the vertebral artery (26)). The second segment, the lateral medullary segment, exists from the passage of the PICA through the most prominent portion of the olive to the emergency site of the glossopharyngeal, vagus, and accessory nerve roots. The third segment, the tonsillomedullary segment, extends to the level of the tonsillar midportion (includes the caudal loop) and sends, together with the telovelotonsillar segment (described below), important branches to the choroid plexus; in addition, this segment may produce some perforating vessels playing, together with the first two segments of the PICA, a fundamental role in bulb irrigation (13,16). The fourth segment, the telovelotonsillar segment, originates in the ascending portion near the cerebellar tonsil and extends to the cortical surface of the cerebellum (includes the cranial loop, with variable location); in its path, besides the fibers already described for the choroid plexus, it emits perforator branches for the dentate nuclei (13). Finally, the fifth segment, the cortical segment, extending to the cerebellar vermis and hemisphere, has many areas of overlapping arterial territory with the SCA (13,16). The anatomical knowledge of these segments is fundamental for surgical approaches in the region, especially in aneurysm cases, although rare (corresponding to 0.5%–3% of intracranial aneurysms) (12,18,25), according to their location among the possible portions of the PICA. This is because there are those that invariably contribute branches to the brainstem and therefore must be necessarily preserved (anterior and lateral medullary segments), needing careful dissection and analysis for preventing inadvertent occlusion of the small perforating arteries at the time of clipping. On the other hand, the telovelotonsillar and cortical segments do not participate in the brainstem blood supply and can be sacrificed (16). The majority of these aneurysms arise at the PICA-vertebral junction, usually along the rostral one-half of the origin of this artery (17), and a much smaller proportion, herein termed distal PICA aneurysms, arises from more peripheral PICA segments (10,12,16,37), which are often associated with arteriovenous malformations (16,17). Moreover, the course of this artery is the primary location determinant of the aneurysm and of the direction in which the aneurysm was pointed (12). Pointing out that no aneurysm or unruptured cerebral aneurysm was observed in the posterior circulation in the present study is important; this configures a limitation for the complete anatomical analysis of the occurrence of PICA's aneurysms.

The consequences of PICA's occlusion, commonly the consequence of thrombosis from atherosclerotic stenosis that is already present (5,26), can be very diverse, with effects ranging from silent clinical occlusion to infarction of the brainstem or cerebellum's parts, causing swelling, hemorrhage, and death (26,34). Approximately all PICA's occlusions result in cerebellar or medullary infarction (5,7), causing an infarct in the lateral medulla, dorsally to the inferior olivary nucleus, referred to as the Wallenberg's lateral medullary syndrome, which is associated with vertebrocerebellar symptoms (lesion of the lower cerebellar peduncle), sensitivities (lesion of the lateral spinothalamic tract and the spinal tract of the triplet and its nucleus), homolateral bulbar muscle weakness (lesion of the ambiguous nucleus and the center of vomit), and even autonomic dysfunctions, developing Claude Bernard–Horner syndrome (lesion of the descending pathways of the hypothalamus) (28).

In our study, the most frequent origin of PICA trunks (59%) was the V4c vertebral artery portion, a little closer to the VBJ, therefore, than some previous studies have pointed out (16,17,20,26), with the V4c segment located between the VBJ and approximately 8.5 mm below it. This may have important implications, such as the higher prevalence of the anterior medullary segment once the probability of anterior medullary segment presence is increased if the PICA originates from the vertebral artery superior portion, because the vertebral artery laterally goes to the medulla below to the anterior surface of the medulla above (26). Another relevant finding was the double origin of PICA non-hypoplastic trunks in four patients, which, from previous studies, was associated with the appearance of aneurysms (15), as well as when the PICA has a low origin, with treatment becoming more dangerous (24). However, curiously, in three of these cases, the contralateral PICA trunk was hypoplastic and unique, suggesting a potentially dangerous perfusion asymmetry for strokes in the cerebellar territory of this artery.

Another important finding was the bilateral absence of the PICA's trunk in two of the dissected pieces, which was also observed in previous studies (2,11,19,29,32). However, an alternative to this possible bilateral absence of the PICA may be the emergence below the foramen magnum, since a limitation of the present study was not to have observed portions of the vertebral artery below this foramen. Thus, one could have an emergency case of extra cranial-extradural PICA origin, already quite registered in previous studies

Table II: Absent Unilaterally and Bilaterally PICA Documented in the Literature

References	Absent unilaterally PICA		Absent bilaterally PICA	
	Case/ total nº	**Incidence (%)**	**Case/ total nº**	**Incidence (%)**
Greitz and Sjogren (11), 1963	...	...	2/30	6.4
Bebin (2), 1968	48/312	15.4	9/312	3
Margolis (19), 1974	...	15	...	2.5
Salamon and Huang (29), 1976	...	26	...	2
Lister et al. (17), 1982	8/25	32	0/25	0
Sharifi and Ciszek (32), 2013	...	...	1/50	2
Present	5/23	21.7	2/23	8.7

(8,14,17), and supposed association with other conditions such as aneurysms (8). Our study results also demonstrated that 21.7% of all dissected brains have unilaterally absent PICA, which can be compared with the results of other different studies in Table II. In these cases, when the PICA is absent on one side, the contralateral PICA or the ipsilateral AICA supplies most of the area normally supplied by the absent PICA (26). However, if the PICA is absent on both sides, an event rarely found (Table II), the AICAs are larger in caliber to overcome the lack of blood supply that might occur because of absent PICAs (32). In the present study, no PICAs were found in 9 of the 46 cerebellar hemispheres, a number slightly higher than that found in some previous studies (2,17), and dominant AICAs were present in all nine of these cerebellar hemispheres, feeding the PICA territory.

Similarly, as for the number of PICA hypoplastic trunks, the present study observed a considerably higher amount (51%) than expected compared with previous studies, which was found in 5%–16% of cerebellar hemispheres (19,29). This can due to different reasons, such as the different parameters for classifying the PICA as hypoplastic, differences between ethnic groups and populations, or the sensitivity and accuracy of the methods and tools used. However, an even more plausible reason is the nomenclature that includes the cerebellar arteries that arise from the vertebral artery as PICAs (9), which was considered valid by our study.

CONCLUSION

Our study results demonstrated that the studies and review on different PICA's variations are of great importance, expanding knowledge and consensus of their characteristics and provisions. The clinical implications of this are the clipping strategies best choice and aneurysms surgical exposures according to PICA segment that was affected (16) or the occlusion of the vessel affected by the aneurysm if the main vessel's territory has an adequate collateral circulation (1,3,31). From the results of the present study, there was a significant PICA emergence from the superior part of the vertebral artery, which is associated with a higher prevalence of the anterior medullary segment. Furthermore, the double origin of non-hypoplastic trunks was also found in some patients, which is associated with a greater appearance of aneurysms (15) and other additional complications (24).

AUTHORSHIP CONTRIBUTION

Study conception and design: RTT, CP, PHPA

Data collection: RTT, CP, PHSPA, PHPA

Analysis and interpretation of results: RTT, CP

Draft manuscript preparation: RTT, CP, PHPA

Critical revision of the article: RTT, PHPA

Other (study supervision, fundings, materials, etc...): GRI, AC, MLPB

All authors (RTT, CP, PHSPA,GRI, AC, MLPB, PHPA) reviewed the results and approved the final version of the manuscript.

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