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Posterior inferior cerebellar artery variation at the medullospinal junction

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ABSTRACT

INTRODUCTION: Previous studies indicated that the posterior inferior cerebellar artery (PICA) plays a role in spasmodic torticollis, a condition caused by vascular compression of the spinal accessory nerve root. Literature reported a high frequency of PICA variations within the posterior cranial fossa and medullo-spinal junction, leading to potential misdiagnosis by clinicians. This study aims to describe PICA variation by origin.

METHODS: The dissection of 14 embalmed cadavers and 28 PICA was examined under magnification to investigate the posterior cranial fossa and posterior spinal cord.

RESULTS: In our examination of the 28 PICA from 14 cadavers, four distinct types of PICA origin were identified: extradural origin was found in 25% (n=7), intradural origin was found in 57% (n=16), origin from basilar artery wer 11% (n=3) and anterior inferior cerebellar artery (AICA) and PICA ariginated from common trunks were 7% (n=2). A bilateral intradural origin was highly reported, 50% (n=14), and a unilateral extradural and basilar origin were less reported in this study, 4% each (n=1).

CONCLUSION: This study reveals variations in PICA origin, highlighting the complexity of cerebrovascular anatomy in neurosurgical procedures. Understanding these variations is crucial for enhancing surgical preparations, minimizing complications, and improving patient outcomes. Further research is needed to validate these findings

Keywords: Posterior inferior cerebellar artery, Variation, Vertebral artery, intradural segment, extradural segment

INTRODUCTION

The posterior inferior cerebellar artery (PICA) is one of the vertebral artery branches that originates at an average distance of 16 to 17 mm under the vertebrobasilar junction [1]. Previous authors have reported PICA involvement in pathological processes such as spasmodic torticollis caused by vascular compression of the spinal accessory nerve root [2]. Among the causes of that compression there are an aneurysm, craniovertebral junction congenital malformation, posterior fossa tumors, and foramen magnum tumours. The incidence of PICA aneurysms is rare, but if present, the surgical treatment is difficult because of their deep replacement under the medulla and their close

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relation to the cranial nerves IX, X, XI [3]. Usually, the vertebral artery and the posterior inferior cerebellar artery are blood vessels that play an important role in spasmodic torticollis due to the neurovascular compression of the spinal accessory nerve, characterized by either intermittent or clonic, uncontrollable tonic spasm of neck muscles [2].

The PICA typically branches from the vertebral artery (VA) in the segment between the foramen magnum and the vertebrobasilar junction [4]. Additionally, it may originate from the extradural part of the vertebral artery [5]. The VA consists of four segments extending from the subclavian artery until two contralateral arteries converge to form a single basilar artery anteriorly at the lower border of the pons [6]. The first segment begins at the subclavian artery and extends to the entrance of the transverse foramen of C6. The second segment runs within the transverse foramina from C6 to C2. The third segment is the last extracranial segment, extending from C2 to the transverse foramen of the atlas, then curving to lie in the groove of the posterior arch of the atlas until it pierces the dura mater. The first three segments are described as the extradural segments of the VA [7]. The PICA has a mean diameter of 2 mm; despite this small diameter, it supplies critical brain areas. Consequently, occlusion of this artery, whether due to trauma or surgery, may cause infarction in the brainstem and cerebellum [8]. PICA has five segments along its course on the lateral side of the medulla and cerebellum: the anterior medullary segment, the lateral medullary segment, the tonsillomedullary segment, the telovelotonsillar segment, and the cortical segment [9]. The first segment arises from the vertebral artery, crosses the roots of the hypoglossal nerve (CN XII), and takes a posterior direction toward the roots of three lower cranial nerves: the glossopharyngeal nerve (CN IX), vagus nerve (CN X), and accessory nerve (CN XI) lateral to the olive, an imaginary line that passes through the most prominent portion of the olive, separating the first two segments of PICA. The existence of the first portion usually occurs when the PICA arises from the upper portion of the vertebral artery [10]. The third segment starts from the roots of CN IX, X, and XI, making a caudal loop that extends to the mid-portion of the cerebellar tonsil, sending important branches to the choroid plexus [1]. The fourth segment begins at the ascending portion near the cerebellar tonsil, extends to the cortical surface of the cerebellum, and makes a cranial loop with a variable location on its way to the fifth segment, giving perforating branches to the dentate nuclei [10]. Finally, the fifth segment extends to the cerebellar vermis and hemisphere, featuring many overlapping arterial territories with the superior cerebellar artery (SCA) [9].

Numerous researchers have previously reported a high frequency of variations of PICA, including unilateral absence, bilateral absence, duplication of the PICA, and fenestration of PICA [1] . Moreover, PICA may originate from the extradural segment, the intradural segment of the VA, or it may arise from a persistent trigeminal artery. Additionally, PICA originating from the anterior inferior cerebellar artery (AICA) and PICA variants have been rarely reported by researchers [10].

PICA has also been reported to be involved in various neurovascular compression syndromes, such as medullary compression syndrome, glossopharyngeal neuralgia, hemifacial spasm, and spasmodic torticollis due to compression of the spinal accessory nerve [4]. Numerous variations of PICA exist in the posterior cranial fossa and medullospinal junction, which may lead to misdiagnosis by clinicians and angiographic interpretation of PICA in the region or lead to intra-operative dissection challenges or injuries. However, various literatures on different variations of PICA have been reported, but there is a lack of an all-inclusive description of the pattern of this important artery in Rwanda; hence, this study aims to describe PICA variation based on its origin.

METHODS

The posterior cranial fossa and posterior spinal cord of 14 embalmed cadavers (2 females and 12 males) with an average age of 35 years were dissected. The cadavers were embalmed by femoral artery cannulation, using a Winckler's fluid containing 1% glycerin, 10% phenic acid, 5% formol solution, 5% alcohol, 5% chloral hydrate, 1.25% sodium sulfate, 1.25% magnesium sulfate, and 2.5% potassium nitrate. The brain was further fixed by injecting formaldehyde (40%) into the intracranial cavity through a small hole at the frontal bone. All dissections were done under magnification; the technique used in this cadaveric study was craniotomy of the occipital squama of the occipital bone from the external occipital protuberance to the occipital condylar, laminectomy of both posterior arches of the atlas, and laminae of the

axis, respectively, and laminectomy of vertebrae from C3 to T2 to expose the dura.
The dura mater was longitudinally dissected, from the cerebellum to the T2 vertebra, followed by a reflection of the cerebellum superiorly to identify the intradural patterns of the VA parts, and the PICA origin was identified. All these procedures were followed by the removal of the brain and spinal cord from the C3 spinal segment, using the dissection protocol of Grant's dissector, 13th ed, and a detailed description of findings after dissection was done. All the procedures were conducted after ethical approval was obtained from the IRB-CMHS, University of Rwanda, with approval number CMHS/IRB/554/2023.

The size of the sample is small, and the power of the study was limited because of donation program was low in the anatomy laboratory at the University of Rwanda

RESULTS

Of the total 28 PICA studied from 14 cadavers, four types of PICA origins were found: extradural segment of VA, 25% (n=7), intradural segment of VA, 57%(n=16), PICA originated from the basilar artery were found in 3 cases 11% and 2 PICA shared a common trunk with the AICA, 7% (Table 1).
Of 28 PICAs examined, 11 cross the rootlets of the hypoglossal nerve(CN XII) and thereafter pass through the rootlets of the vagus nerve (CN X) 36%(n=11), 23%(n=7) do not cross any rootlets of lower cranial nerves, mostly of extradural origin, because they pass the posterior surface of the medulla oblongata. In 6(20%) PICAs examined their lateral medullary segment cross through the vagus and the cranial rootlets of spinal accessory nerve(CN XI) and the rest cross through the cranial roolets of CN XI, above the rootlets of the glossopharyngeal nerve(CN IX)and between the CN IX –CN X 7%(n=2) each (Table 2).

Of the 25% extradural origin, the bilateral extradural origins were found in 21% (n=6) compared with the unilateral origins, 4% (n=1). Of the 57% intradural origin, the bilateral origin was found in 14(50%), whereas the unilateral was found in 2 cases (7%). Apart from intradural and extradural, the bilateral PICA originated from the basilar artery were found in 2(7%), unilateral basilar origin 1(4%), and AICA –PICA was found on both sides of one cadaver 2(7%) (Table 1 and Figure 1).

All the extradural origins of PICA originate from the V3 segment of the vertebral arteries near the entrance to the dura mater. They then course

Table 1: Table representing the types of the PICA origin and comparison of the two side

Types of PICA origin	Number of PICA	Bilaterally	Unilaterally
Extradural origin on VA	7	6	1
Intradural origin on VA	16	14	2
Basilar origin	3	2	1
AICA-PICA trunks	2	2	0

Table 2: Representation of the relationship of PICA with the 4 lower cranial nerves

Relationship with the 4 lower cranial nerves	Relation with contralateral PICA		
	Loops overlap each other	Loop widely separated	No loop formed
Do not pass any rootlet	2	5	0
Pass above CN IX rootlets	0	0	2
Pass between CN IX and X rootlets	0	2	0
Pass through CN X rootlets and CN XII	0	7	4
Pass between CN X and XI	0	2	4
Pass through the CN XI cranial rootlets	0	2	0

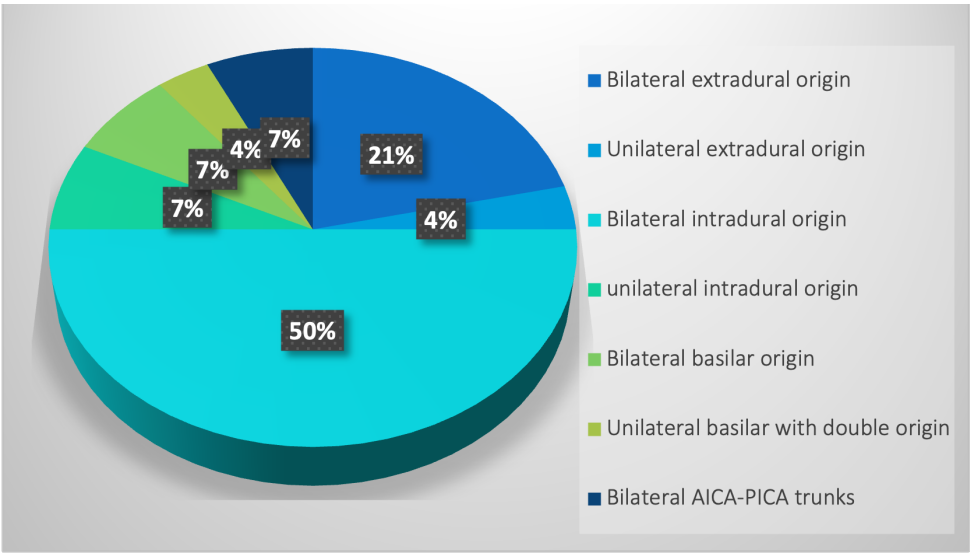

Table 1: Comparison of the right and left of posterior inferior cerebellar artery

posteriorly to the medullospinal junction before reaching the posterior lobe of the cerebellum, where they form a caudal loop near the cerebellar tonsil (Figure 2A). In contrast, the intradural origins come from the V4 segment of the vertebral artery between the dura and the vertebrobasilar junction. These PICAs curve around the medulla, forming loops that alternate in direction. The number of loops varies between three and two some PICA continue straight without forming a loop (Table 1,

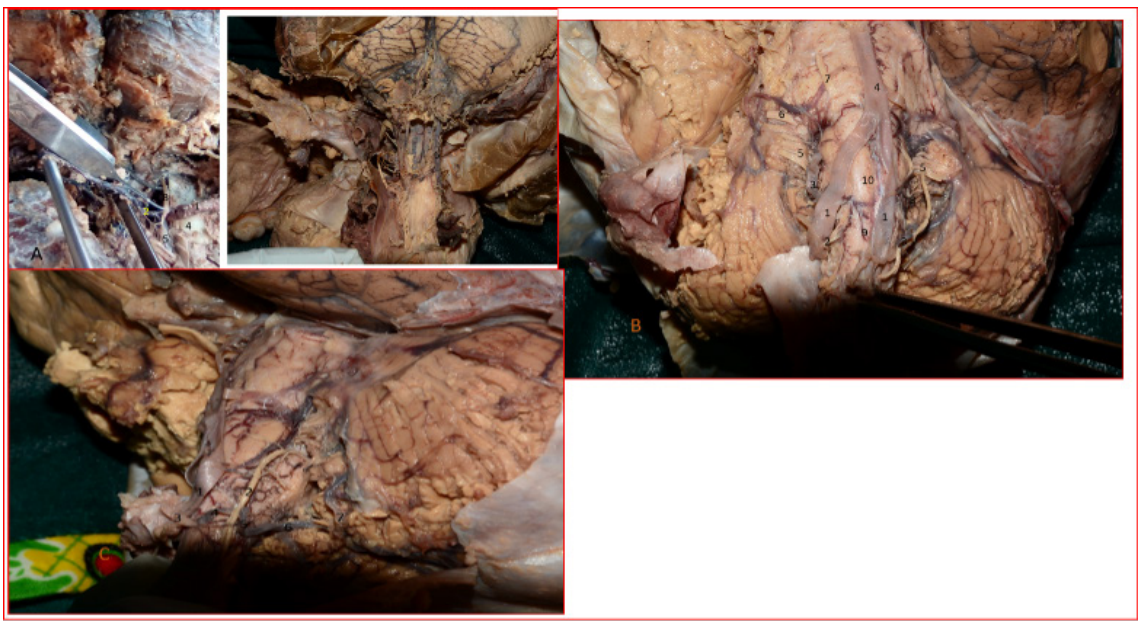

Figure 2 (A)Pictorial representation of the extradural origin of pica: *1. V3 segment of the vertebral artery in the groove of the posterior arch of the atlas, 2. Right PICA, 3. Spinal root of CN XI, 4. Posterior arch of atlas (cut), 5.Denticulate ligament 6.PICA in straight course, 7. cortical branches; (***B) Pictorial representation of intradural PICA originates from V4 of the vertebral artery:** *1. V4 of vertebral arteries (R and L), 2.Ventral root of C1 spinal nerve, 3. PICA (R and L), 4.Basilar artery, 5. Rootlets of 3 lower cranial nerves (CN IX, X, XI), 6. Cranial nerve VIII, VII, 7. Abdecent nerve, 8.Hypoglossal nerve rootlets, 9.Medulla oblongata, 10. Pons;* **(C) Pictorial representation of PCA segment:** *1 .Left vertebral artery, 2. Spinal root of CN XI, 3. Anterior medullary segment of PICA, 4.lateral medullary segment of PICA, 5. Tonsillomedullary segmentof PICA 6. Telovelotonsillar segment of PICA 7. Cortical segment of PICA*

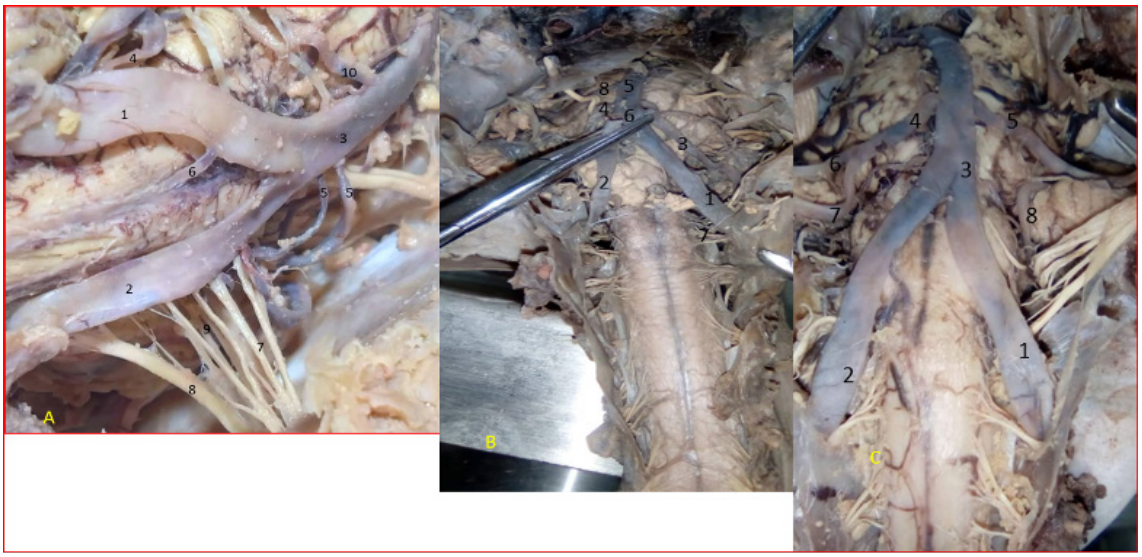

Figure 3 (A). Pictorial presentation of the double origin of PICA: *1. Right vertebral artery, 2. Left vertebral artery 3.Basilar artery, 4. Right pica with the loop, 5.Fenestrated origin of PICA, 6.Anterior spinal artery, 7.Rootlets of the hypoglossal nerve, 8.Accessory nerve, 9. Vagus nerve rootlets;* **(B). PICA originates from the basilar artery***: 1. Left vertebral artery, 2. Right vertebral artery, 3.Left PICA, 4. Right PICA, 5. Basilar artery, 6. Vertebral basilar junction, 7. Ventral rootlets of C1, 8. Right AICA;* **C. Pictorial representation of AICA –PICA trunk anterior view of medulla***: 1. Left PICA, 2.Right PICA, 3. Basilar artery, 3. Right trunk, 4. Left trunk, 5. Right AICA , 6. Right PICA 7.Left PICA 8. Right PICA*

Figures 2B and C).
In three cases, the PICA originated from the basilar artery; one of these originated from the basilar artery on the left side only and had a double origin that merges above the rootlets of CN XII, forming a loop before crossing the rootlets between CN IX and CN X (Figures 3A, B, and C).

In the case where the PICA and AICA shared the common trunk, on the left side, the PICA arises above the vertebrobasilar junction, passes inferolaterally toward the rootlets of the lower cranial nerves, then pierces the upper rootlets of the cranial roots of CN XI and continues posteriorly under the cerebellar tonsil to the inferior lobe of the cerebellum (Figure 4A). On the right side of the same case, the PICA originates from the same contralateral level and crosses inferiorly under the cerebellar tonsil without piercing any rootlets of the lower cranial nerves, then reaches the posterior lobe of the cerebellum. Furthermore, among those with intradural origins, one cadaver had the left PICA originating from the vertebral artery just around the left anterolateral surface of the medulla, before taking a straight direction between the rootlets of the hypoglossal nerve and three other lower cranial nerves it makes the small loop then pierced the rootlets of the vagus nerve to continue to the roof of the fourth ventricle and the inferior surface of the vermis (Figure 4B).On the left side, PICA originated from the intradural segment of the vertebral artery, located lateral to the lower portion of the medulla. It then ascended upward to pass between the cranial rootlets of the spinal root of the accessory nerve and the rootlets of the hypoglossal nerve, crossing posteriorly between the cranial roots of CN XI and CN X to the inferior vermis and the inferior posterior part of the cerebellum (Figure 4C).

In all cases, the intradural segment of the vertebral artery began at the dura mater foramina just inferior to the lateral edge of the foramen magnum. In this particular anatomical location, the dura mater exhibits a notable increase in thickness compared to adjacent regions. Additionally, the commencement of the intradural trajectory of the vertebral artery transpires near the ventral roots of the first cervical nerve, anteriorly positioned relative to the dentate ligament, and the spinal segment of the accessory nerve. Subsequently, the arterial trajectory assumes an anterior course, traversing anterior to the rootlets of the hypoglossal nerve, while ascending from the lower lateral to the upper anteromedial surface of the medulla. In one case, an intradural segment of

Figure 4 (A). Pictorial representation of PICA in cranial rootlets of CNXI: *1. Left PICA, 2.cranial root of accessory nerve, 3. spinal root of accessory neve, 4. Right PICA, 5. Cerebellar tonsil, 6.Iferior lobe of cerebellum, 7. Cortical segment of left PICA;* **(B).PICA piercing the rootlets of the vagus nerve***: 1. Glossopharyngeal, 2.Vagus nerve, 3. Posterior inferior cerebellar artery, 4. Spinal root of CN XI, 5.Cranial root of CN XI, 6.Jugular foramen, 7.Cerebellar tonsil, 8. Denticulate ligament, 9. Dorsal root of C1 10. Dorsal root of C2;* **(C). Pica between the rootlets of spinal accessory nerve and vagus nerve:** *1. Right PICA, 2. Cranial root of CNXI, 3. Intradura segment of vertebral artery, 4. Dorsal root of C15, tventricle;* **D. Posterior view showing VA in CNXII:** *1. Intradural segment of vertebral artery, 2. Rootlets of hypoglossal nerve, 3. Spinal root of CNXI, 4. Rootlets of CN X*

the vertebral artery pierced the rootlets of the hypoglossal nerve to continue to the anterior surface of the medulla (Figure 4D).

DISCUSSION

This study's findings offer valuable insights into the anatomical variations of the origin and course of the posterior inferior cerebellar artery. Understanding these variations is crucial for grasping cerebrovascular anatomy, relating anatomy to specific pathological processes, and guiding surgical procedures. This discussion will examine the implications of these findings for clinical practice, their relevance to neurosurgical techniques, and their potential impact on patient

outcomes. The study identified four main types of PICA origin: extradural and intradural, PICA originating from the basilar artery, and AICA –PICA trunks. These variations in PICA origin highlight the complexity of cerebrovascular anatomy and emphasize the importance of thorough preoperative imaging assessments to identify individual variations [5].The PICA accompanying neurovascular structures, including the brain stem, lower cranial nerves IX, X, XI,XII and limited working area, make microsurgical clipping of PICA aneurysms extremely tough and challenging [7]. Knowledge of the PICA pattern and its relation to the lower cranial nerves on local cadavers will help local neurosurgeons in training to navigate in this difficult working area, as PICA aneurysms are frequently located in very deep and far from the surgeon's view

Understanding the variations in PICA origin is crucial for interventional radiologists/neurologists and neurosurgeons performing procedures in the posterior fossa. Extradural origins may pose challenges during surgical approaches, especially when accessing lesions near the medullospinal junction. Intradural origins, although more common, require careful consideration to avoid injury to adjacent structures during surgical manipulation [1]. Knowledge of these variations can help with surgical planning, reducing the risk of complications and improving patient outcomes [8]. In this study, almost all cases observed to have PICA that pierced the rootlets of the lower cranial nerve, either the vagus nerve or the cranial root of the accessory nerve, were also identified, which may lead to neurovascular compression like Hemi-laryngopharyngeal spasm, a condition characterized by episodic coughing and unilateral throat contractions that may lead to severe stridor [5]. This, among other findings of diagnostic value, enhances medical decision-making during the treatment of conditions associated with the neurovascular structures transiting the medullospinal junction. Furthermore, a good knowledge of the topography and variations serves as an additional tool to conventional radiological examinations conducted for vascular conditions of the posterior fossa and cranio-vertebral junction or before surgical procedures in this region [1].
The detailed characterization of PICA origins offers valuable information for neurosurgical procedures, including tumor resections, vascular malformation treatments, decompressive surgeries and fixation procedures of the cranio-vertebral junction. Surgeons need to be aware of potential variations in PICA anatomy to adjust their surgical approach accordingly and minimize the risk of intraoperative complications. Furthermore, amidst the era of technological advancements such as intraoperative neuronavigation and imaging, it remains imperative to underscore that a profound comprehension of regional surgical anatomy remains unparalleled, indispensable for optimizing surgical outcomes.. The findings of this study have important implications for clinical practice in the field of conventional neurosurgery and interventional endovascular neurosurgery.
In this study, the AICA-PICA trunk was found in 2 cases (7.1%); conversely, the previous study reported AICA-PICA trunk in 20-24%[10]. Recognizing this variation is important because iatrogenic injury to this variant at its origin during surgery would result in strokes involving both PICA and AICA territories

This study's limitations, such as the small sample size and cadaveric nature of the investigation, need to be acknowledged.

CONCLUSION

Conclusively, the differences in PICA origin discovered in this research highlight the intricate nature of cerebrovascular anatomy and its importance for neurosurgical procedures. Having a grasp of these variations is essential for enhancing surgical preparations, minimizing potential complications, and advancing patient outcomes. Validation of these discoveries in real-life populations through further research is necessary to evaluate their influence on clinical practice. The results of this study, which demonstrate the PICA origins and its course patterns are diverse implicate that neurosurgeons operating in that area need careful and comprehensive pre-operative assessment of the medullospinal junction anatomy. We recommend future studies with larger sample sizes and in vivo imaging modalities like magnetic resonance angiography and computed tomography angiography, which could offer more insights into PICA anatomy variations in living populations. Longitudinal studies are also needed to evaluate the clinical outcomes of patients undergoing neurosurgical procedures based on preoperative

imaging assessments for validating the significance of these anatomical variations.

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