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The vascular layers on the rostral ventrolateral medulla

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Abstract

There has been a keen interest in assessing the neurovascular anatomy of the rostral ventrolateral medulla oblongata (RVLM). The present study was aimed at documenting the complete neurovascular anatomy of the RVLM, in order to offer a general picture of the possible offending vessels of this area, which seems to be involved in the pathogeny of the essential hypertension. Noteworthy, syndromes of the last cranial nerves could be due to vascular contacts or compressions. The present study was performed on 20 human adult brainstem-cerebellum blocks, dissected out of the posterior cerebral fossa at autopsies. The origins of the inferior cerebellar arteries (anterior – AICA and posterior – PICA) were traced bilaterally (*n*=40 sides). When present (26/40) AICA most frequently left the basilar artery and PICA (28/40) most frequently left the vertebral artery. At the level of the RVLM, a quadrilateral space delimited by the vertebral artery (VA) and the vertebrobasilar junction, the AICA and the PICA, was defined. Within that space, three vascular layers were identified: a superficial one, formed by the inferior cerebellar arteries, a middle one, consisting of perforating arteries, and a deep, venous one. The RVLM perforating arteries left the VA (31/40), basilar artery (BA) (3/40), anterior spinal artery (ASA) (34/40), PICA (28/40) and AICA (24/40). These perforators had a transverse or oblique course if given off by the VA, BA or ASA, were descendant if given off by the AICA or BA, and were ascending if given off by the VA or PICA. Microanatomical studies of the vascular relations of the RVLM are able to complete the somewhat limited findings of studies based on imaging techniques. The offending vessels of the RVLM could be any of the vessels inside the quadrilateral space. Major vessels, such as the VA, AICA or PICA should not be viewed as the only possible offending vessels at this level. The perforators and the venous layers in the quadrilateral space should also be better evaluated from this perspective.

Keywords: cerebellar arteries, perforating arteries, RVLM, PICA, AICA, vertebral artery, olive, anatomy.

Introduction

There has been a keen interest of researchers in evaluating the neurovascular anatomy of the retroolivary root entry zone of medulla oblongata.

This is mostly because various observations support the assumption that neurovascular compression of the left ventrolateral medulla oblongata may determine neurogenic hypertension [1–3].

Nevertheless, various syndromes involving cranial nerves V–XI are determined by neurovascular compressions and can benefit from neurosurgical decompression [1, 4–21].

Actually, most of the existing data on the neurovascular anatomy of the rostral ventrolateral medulla (RVLM) in humans resulted from imaging (MRI) studies on various groups of patients. Usually, and undoubtedly justified by the methods used, only larger arteries were involved as offending vessels of the RVLM, such as the antero-inferior cerebellar artery (AICA), the postero-inferior cerebellar artery (PICA), or the vertebral artery (VA) [3, 22].

The medullary perforators, the anastomoses at this level and the veins are usually omitted when neurovascular compressions of the RVLM are approached. Thus, we aimed at documenting the complete neurovascular anatomy of the RVLM, in order to offer a general picture of the possible offending vessels of this area playing a role in the pathogeny of the essential hypertension.

Materials and Methods

The present study was performed on 20 human adult (aged 44 to 64 years, with a sex ratio of 1:1) blocks of brainstem and cerebellum dissected out of the posterior cerebral fossa at autopsies. The cause of death was traumatic, the patients were negative for neurodegenerative disorders, and the bodies were refrigerated before necropsies. Sampling was conducted in accordance with the Romanian law regarding procedural norms for medical legal expertises No. 1134/C/25/05.2000 (Ministry of Justice), and 255/4.4.2000 of the Health Ministry, Art. 42, regarding the ethics of autopsy practice, and the Ethical Code of the Romanian College Board regarding the scientific use of medical cases. Microdissections were performed with surgical magnifying glasses (4.5× magnification). The results were documented by digital photographs.

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Results

The origin of the cerebellar arteries was documented bilaterally (*n*=40 sides): AICA left the vertebral artery in four sides, the basilar artery in 17 sides, in five sides there was a common trunk of PICA and AICA leaving the vertebral artery. In the remaining 14 sides, AICA was absent, its cerebellar territory being supplied either by the superior cerebellar artery, or by the PICA, or by both arteries. PICA left the vertebral artery in 19 sides; it left the vertebral artery in a common trunk with AICA in five sides, it originated from the basilar artery in four sides and in 12 sides it was absent, its territory being supplied by other cerebellar arteries.

When present, AICA coursed at the level of the pontomedullary junction, and it divided after a variable length of its main trunk into the rostral and caudal branches; variations were encountered (such as lack of a secondary trunk, variable cerebellar distribution). When it left the vertebral artery, PICA had a lateral medullary rostral loop in 18/24 sides. The height of the rostral loop seemed to be related to the passage of PICA between the cranial nerve rootlets: a higher passage was related with a higher rostral loop. PICA had a lateral medullary course above the glossopharyngeal nerve in 5/28 sides, between the glossopharyngeal and vagus nerves in 4/28 sides, between the vagal rootlets in 6/28 sides, caudal to the vagus nerve in 6/28 sides, and between the medullary and spinal roots of the accessory nerve in 7/28 sides.

The perforating arteries were evaluated at medullary level. Those of the foramen caecum of Vicq d'Azyr were leaving the vertebral, basilar and anterior spinal arteries. Those of the medullary pyramid left the basilar, vertebral or the anterior spinal arteries. The perforators of the medullary olive were found leaving the basilar artery (3/40), AICA (24/40), the vertebral artery (31/40), PICA (28/40), or the anterior spinal artery (34/40).

Attention was paid to make a coherent and complete evaluation of the vascular anatomical relations at the level of the RVLM. After observing all specimens, the following topography was concluded.

The superficial vascular layer at the level of the RVLM may include any of the following arteries: the VA, AICA and PICA, depending upon their presence, the geometry of the intracranial VA, and the presence or absence of the AICAs caudal loops or the PICAs rostral loops (Figures 1 and 2).

If the angle of the VAs is larger, the anterior spinal artery could be added to this layer as a direct relation of the caudal pyramid (Figure 1).

Especially when the loops of the inferior cerebellar arteries are absent, a quadrilateral space encloses the RVLM and is limited superiorly by the AICA, caudally by the PICA and medially by the VA and the vertebrobasilar junction (Figures 2–5).

The upper border of this quadrilateral space, represented by the AICA, seems mostly subjected to variations as to the absence (complete absence, or absence of the AICA cerebellar branches), course (paralleling or crossing the pontomedullary junction) or morphology. For example, instead of the AICA, the labyrinthine artery could be the rostral border of the quadrangular space (Figure 6).

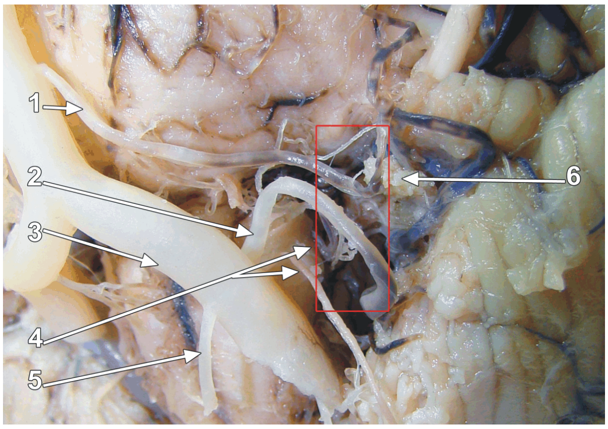

Figure 1 – *The left ponto-cerebello-medullary junction complex vascular anatomy (inset). 1. Antero-inferior cerebellar artery; 2. Postero-inferior cerebellar artery; 3. Left vertebral artery; 4. Olive, hypoglossal nerve rootlet; 5. Anterior spinal artery; 6. Choroid plexus of fourth ventricle.*

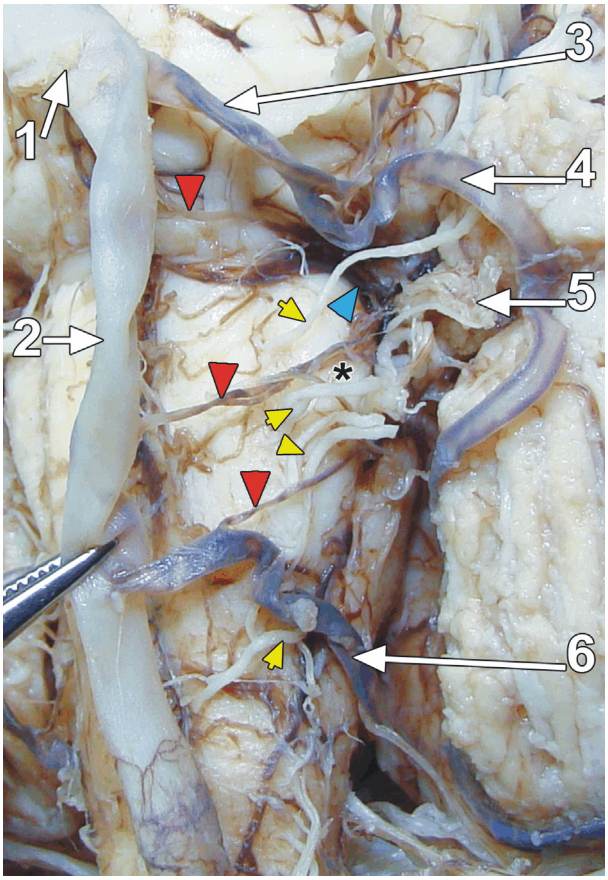

Figure 2 – *Ventral view of brainstem and cerebellum (left side). 1. Vertebrobasilar junction: 2. Vertebral artery; 3. Antero-inferior cerebellar artery (AICA); 4. Caudal trunk of AICA, describing a caudal loop; 5. Glossopharyngeal nerve; 6. Postero-inferior cerebellar artery. There are indicated: the olive (*), the perforating branches of the retroolivary sulcus (red arrowheads), the rootlets of the hypoglossal nerve (yellow arrowheads) and the lateral medullary vein that drains into the pontomedullary vein (blue arrowhead).*

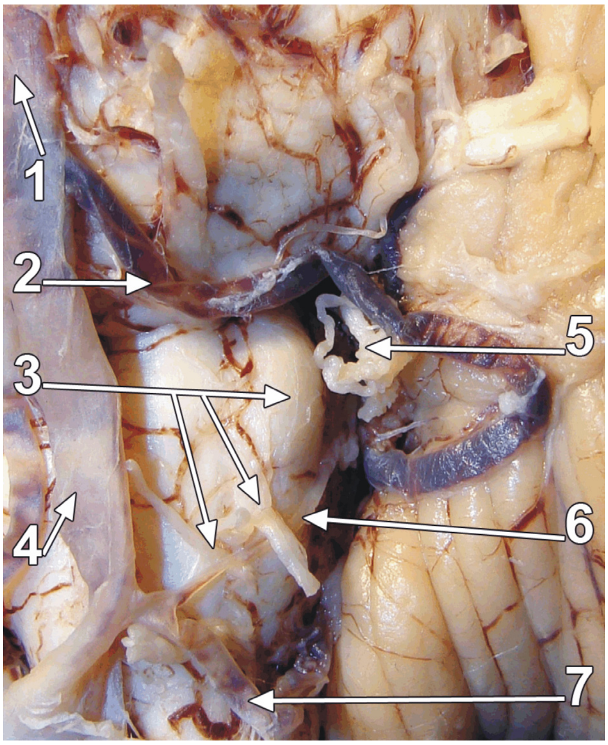

Figure 3 – *Ventral view of the left rostral ventrolateral medulla. 1. Basilar artery; 2. Antero-inferior cerebellar artery; 3. Olive, hypoglossal nerve rootlets; 4. Vertebral artery; 5. Glossopharyngeal and vagus nerves; 6. Retroolivary perforating artery; 7. Postero-inferior cerebellar artery.*

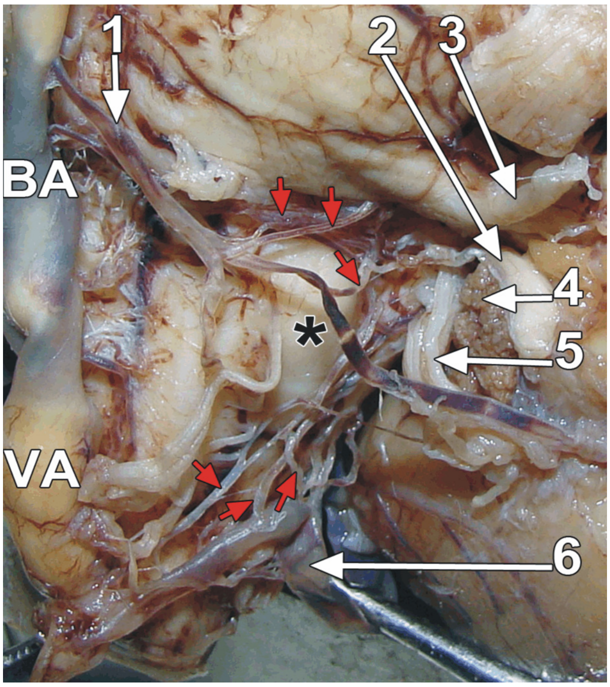

Figure 5 – *Ventral view of the left rostral ventrolateral medulla. 1. Antero-inferior cerebellar artery; 2. Vestibulocochlear nerve; 3. Facial nerve; 4. Choroid plexus of the fourth ventricle; 5. Glossopharyngeal nerve; 6. Postero-inferior cerebellar artery. BA: Basilary artery; VA: Vertebral artery. The olive is indicated (*). Red arrows indicate perforating arteries of the retroolivary sulcus.*

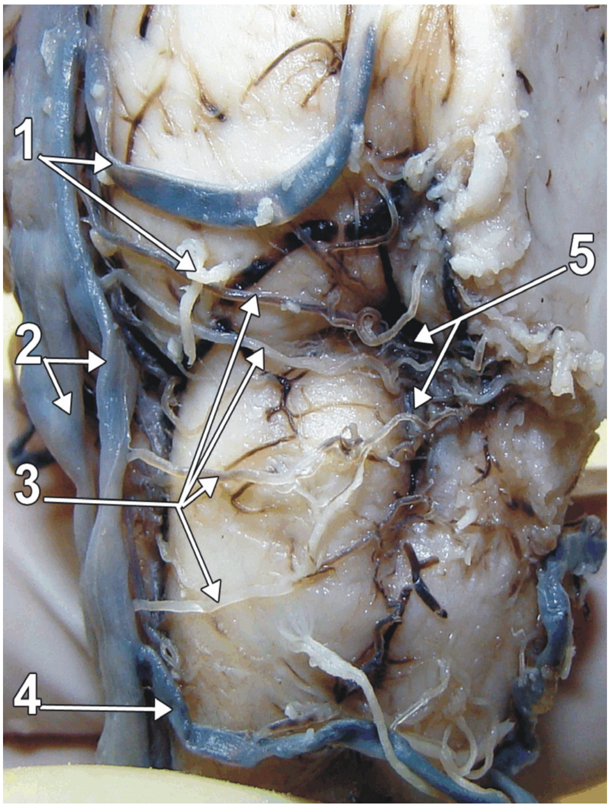

Figure 4 – *Ventro-lateral view of the left olive and pyramid. 1. Antero-inferior cerebellar artery, abducent nerve; 2. Vertebral arteries; 3. Perforating arteries of the retroolivary sulcus; 4. Postero-inferior cerebellar artery; 5. The lateral medullary vein is deeply located to the retroolivary perforating arteries.*

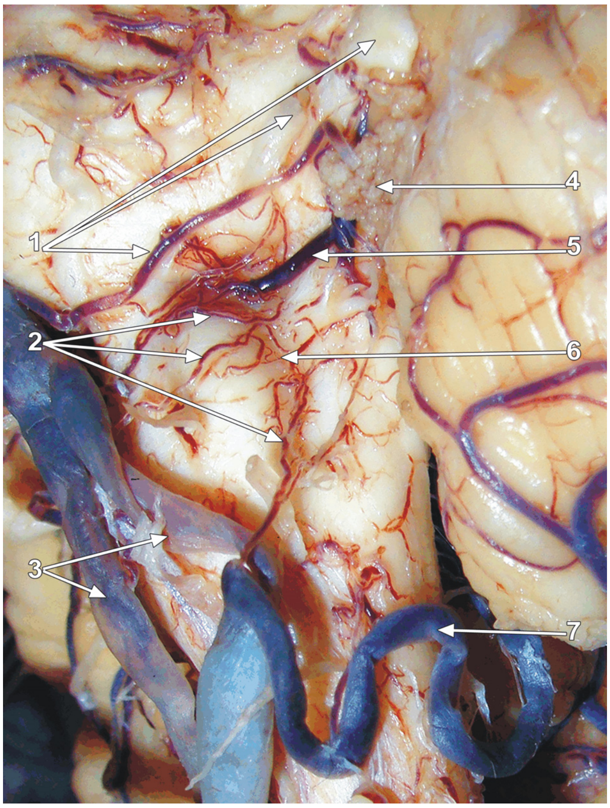

Figure 6 – *Ventrolateral view of the left RVLM. 1. Labyrinthine artery, facial and vestibulocochlear nerves; 2. Retroolivary perforating arteries; 3. Vertebral arteries; 4. Choroid plexus of fourth ventricle; 5. Vein of the pontomedullary sulcus; 6. Retroolivary sulcus.*

That quadrilateral space contains two other vascular layers closer related to the RVLM, formed by small vessels (Figures 2–7). Thus, the second vascular layer is configured by perforating arteries, eventually anastomosed (Figure 8); the anastomoses of the perforators are in fact anastomoses of their suppliers. The third, deepest vascular layer over the RVLM is represented by the veins at this level (Figures 4, 6 and 9): pontomedullary, antero-lateral medullary, retroolivary, lateral medullary and transverse veins. This venous layer is in close contact with the RVLM.

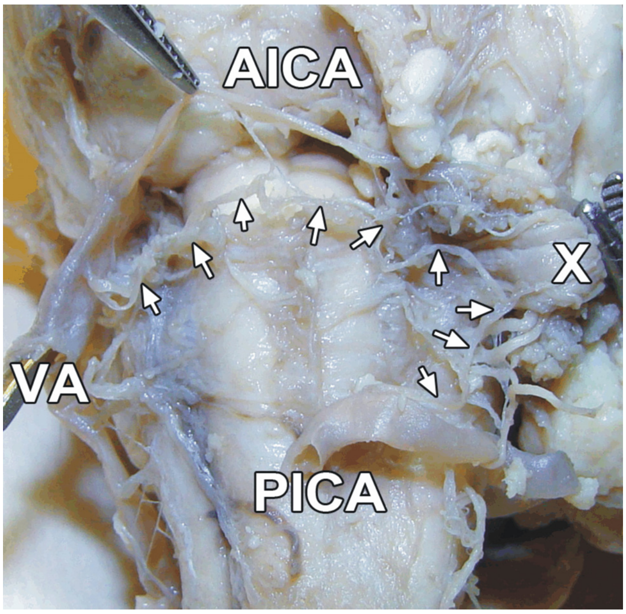

Figure 7 – ***Anastomosis of the vertebral artery (VA) and postero-inferior cerebellar artery (PICA) crosses over the rostral ventrolateral medulla. X: Vagus nerve. AICA: Antero-inferior cerebellar artery.***

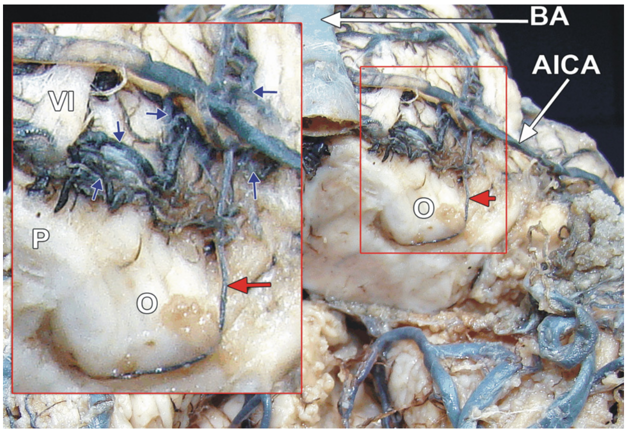

Figure 8 – ***Retroolivary perforating branch (arrow) of the antero-inferior cerebellar artery (AICA), antero-inferior view of the transverse section of medulla through the rostral olive. BA: Basilar artery; O: Olive; P: Pyramid; VI: Abducent nerve. The retroolivary perforating artery courses intra-medullary dorsally to the olivary nucleus (inset, magnified). Veins of the RVLM are indicated (blue arrows).***

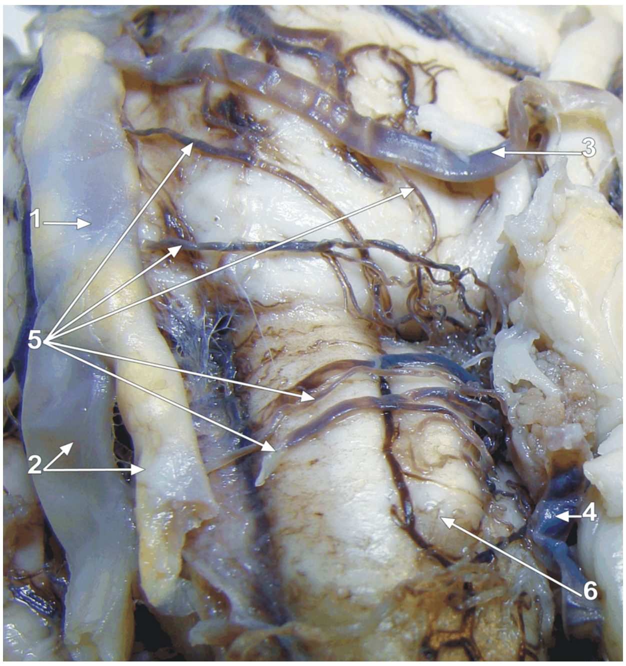

Figure 9 – ***Infero-lateral view of medulla and pons. 1. Basilar artery; 2. Vertebral arteries; 3. AICA; 4. PICA; 5. Perforating arteries of the RVLM.***

The perforating arteries located in the quadrilateral space are supplied by the arteries that border the space. The perforating arteries leaving the VA, the vertebrobasilar junction or even the basilar artery if the vertebrobasilar junction is lower than the foramen caecum of Vicq d'Azyr adopt a lateral transverse or oblique course over the pyramid; the branches of these either penetrate the medulla in the preolivary sulcus, or continue over the olive to perforate the retroolivary sulcus (Figures 2–6). AICA gives off descending perforating branches, which usually penetrate the medulla supra- or retro-olivary (Figures 1, 5, 6 and 9). At the level of the pontomedullary sulcus, the transverse or oblique perforators sent off by the basilar or vertebral arteries course and branch superficially to those perforators descending from the AICA (Figure 9). The perforating arteries can describe more or less defined loops.

Discussion

There is insufficient data in the literature related to the microanatomic features of the perforating branches of the vertebral artery [23]. It has been shown that PICA, AICA and VA occasionally compress the medulla oblongata and that patients with essential hypertension are associated with neurovascular compression of the RVLM at the root entry zone of the ninth and tenth cranial nerves, in clinical observations and magnetic resonance imaging (MRI) studies [13]. However, the microvascular layers inside the quadrilateral space we defined here at the level of the RVLM were overlooked as being possible offending vessels able to trigger the tonic sympathetic discharge from the neurons of the RVLM.

Consistent with our results, the location of the origin of the supra- and retro-olivary perforator arteries may vary: the preolivary sulcus is primarily supplied by the anterior spinal artery, the upper portion of the posterior olive is supplied with perforators by the VA, AICA and basilar artery (BA), while the middle and lower portions of the posterior aspect of olive were fed by the VA and PICA [24].

Experimental studies using rats indicated that pulsatile compression of the RVLM increases arterial pressure by enhancing sympathetic outflow [13]. These results would indicate rather the first two vascular layers over the RVLM, which are arterial and thus pulsatile, than the deep venous one, as being involved in the essential hypertension pathogeny. Noteworthy, the relation/contact of the vessels in the superficial vascular layer of the quadrilateral space (VA, AICA or PICA) with the RVLM may not be direct, but mediated by the arterial perforators and the veins inside the respective space.

Major vessels, arteries and veins, but also small-unspecified arteries, are taken into consideration as possible offending vessels of the trigeminal nerve in the cerebellopontine angle [25]. Similarly, small vessels should be taken into account when the vascular relations of the RVLM and the root entry zone of the ninth and tenth cranial nerves are considered as sites of vascular contacts or compressions.

Conclusions

Microanatomical studies of the vascular relations of the RVLM are able to complete the findings of imaging studies, which are limited by spatial and contrast resolution of imaging techniques. The offending vessels of the RVLM could be any of the vessels inside the quadrilateral space. Major vessels, such as the VA, AICA or PICA should not be viewed as the only possible offending vessels at this level. The perforators and the venous layers in the quadrilateral space should also be better evaluated.

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