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ORIGINAL ARTICLE

The anterior spinal artery origin: a microanatomical study

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Backround: Detailed knowledge of the pattern of origin of the anterior spinal artery is critical as surgical and endovascular procedures involving the area of the ventral medulla and the vertebrobasilar junction are commonplace. We conducted a detailed microanatomical study to elucidate the site and pattern of origin of this critically important artery.
Method: Nine adult cadaveric heads (18 sides) were examined after injection of colored silicon. In every specimen, the site of origin of the rami of the anterior spinal artery, their course, branching pattern and anastomoses, external diameters, and the distance from neighbor critical vessels were recorded. The dissections were performed with the aid of both the surgical microscope and a 0 degree endoscope.
Findings: The pattern and site of origin of the anterior spinal artery show great variability. Also the distance of the origin of the two rami (right and left) forming the anterior spinal artery from the vertex of the vertebrobasilar junction and from the origin of the posterior inferior cerebellar artery is highly variable.
Conclusions: Knowledge of the different pattern of origin and course of the proximal portion of the anterior spinal artery is critically important when planning and executing endovascular and surgical procedures involving the distal vertebral artery, the vertebrobasilar junction and the ventral medulla. On the basis of our and other authors' findings, we propose an overall classification of the pattern of origin and distribution of the proximal anterior spinal artery, which has clinical repercussions.
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Keywords: anterior spinal artery; endovascular obliteration; medulla oblongata; microsurgical anatomy; microsurgery; vertebral artery

Introduction

With advances in microneurosurgical and endovascular techniques, surgical and endovascular procedures involving the ventral medulla and the distal portion of the vertebral artery are commonplace. In particular, endovascular iatrogenic vertebral artery occlusion (uni- or bilateral) for treatment of large and giant aneurysms of the vertebrobasilar system is a well established procedure for treatment of these challenging lesions. Unfortunately, ischemic complications arising from either direct occlusion or thrombus extension into the anterior spinal artery (ASA) origin can occur with devastating clinical sequelae.[1] Little information is available regarding the pattern of origin of this critically important artery.[2,3] We conducted the present microanatomical study to elucidate the site and pattern of origin and division of the ASA as well as its variability.

Materials and methods

Nine adult cadaveric heads (18 sides) were examined after injection of colored silicon. All dissections were performed with microsurgical instruments using a surgical microscope (Leica, Wild M 695, Leica Microsystems Inc., Switzerland; magnification $\times 40$) and a 0° endoscope (Karl Storz Endoskope, Tuttlingen, Germany). Measurements were taken with an electronic digital caliber with a precision of 0.01 mm In every specimen, the place and site of origin of the left and right rami of the ASA, their course, branching pattern and anastomoses, external diameters, and the distance of the fusion point from the vertebral artery (VA) were recorded. The ratio between the diameter of the ASA and the diameter of the VAs as well as the ratio between the diameter of the posterior inferior cerebellar arteries (PICAs) and the diameter of the VAs and ASA were calculated.

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Results

Site of origins
The ASA originated from the vertebral artery as a paired right and left rami in all but one specimen in which only the left ASA was present. The ASA originated from either the medial, anteromedial or posteromedial surface of the V4 portion of the VA. The ASA originated from the medial surface of the VA in nine out of 17 cases (52.9%). In four (23.5%), the ASA emerged from the anteromedial surface and in the remaining four (23.5%) from the posteromedial surface of the VA (Table 1).

Patterns and course
The emerging right and left rami had a downward direction and met to fuse and form the ASA main trunk in four specimens. In two specimens, the two rami remained separate as two different ASA trunks. There was only one ASA in one specimen; while in another, the very short left ramus provided blood supply only to the pyramid and did not join the contralateral one. In one specimen, the two rami joined together to form a vascular arch from which two separate ASAs originated.

In two of the four specimens in which the two rami fuse to form a single ASA, the left ramus joined the right dominant one and the ASA continued the course of the dominant right ramus. In the other two, the ASA after forming a single trunk bifurcated into two separate ASA branches. We did not encounter any ASA defined as a ‘textbook’ ASA arising from the fusion of two paired and symmetric left and right rami originating from the V4 portion of the VA.

Perforators
The right and left rami gave rise to a mean of 3.6 perforating branches each before forming the ASA. The ASA itself in its proximal portion gave rise to a mean of 2.5 perforating branches (Table 1).

Calibers and proportions of diameters
The outer diameter of the ASA ranged from 0.34 to 1.02 mm (mean 0.59 mm). In each specimen, the diameter of the ASA was larger than the diameter of the rami from the union of which it arose. The ASA was always smaller than either (right or left) PICAs. The caliber of the distal VA (at the level of the origin of the ASA rami) ranged from 2.76 to 4.37 mm (mean 3.45 mm). The proportion of the mean diameter of the ASA

Table 1 Types of arteries, place of origins, number of perforators and sexes of the cadaveric heads

	H-1	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-7*	*H-8*	*H-9*
Sex	f	f	m	m	m	f	m	m	m
L Ram origin	M	PM	AM	M	AM	AM	M	M	M
R Ram origin	PM	PM	M	PM	M	M	—	AM	M
Type	III	Ic	Ib	IIc	Ib	III	IIa	IIb	Ic
P from L ram	2	0	5	4	1	2	3	2	0
P from R ram	0	8	8	3	5	7	—	1	1
P from ASA	—	1	4	2	0	—	0	0	7
P from L VA	0	2	2	2	1	2	0	2	0
P from R VA	1	2	3	5	6	1	0	0	0
Total P	3	13	22	16	13	12	3	5	8

Abbreviations: AM, anteromedial; ASA, anterior spinal artery; f, female; H, head; L, left; M, medial; m, male; P, perforator; PM, posteromedial; R, right; ram, ramus; VA, vertebral artery.

Table 2 The outer diameters of the arteries

	H-1	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-7*	*H-8*	*H-9*	*Mean*
BA	4.83	4.56	4.52	5.31	4.99	4.28	5.69	4.60	4.71	4.83
L VA	2.92	3.54	3.81	2.69	4.37	2.95	4.18	3.68	3.66	3.53
R VA	2.98	2.76	3.70	4.14	3.60	2.98	3.12	3.35	3.65	3.36
L PICA	1.14	1.11	1.43	1.86	1.10	0.61	0.90	1.31	2.38	1.32
R PICA	1.21	1.16	1.12	2.01	1.34	0.50	0.91	1.12	1.80	1.24
L ram	0.50	0.51	0.60	0.61	0.40	0.61	0.34	0.34	0.40	0.48
R ram	0.34	0.51	0.58	0.79	0.34	0.50	—	0.33	0.75	0.46
ASA	0.54	0.52	0.62	1.02	0.45	0.64	0.34	0.40	0.91	0.60
L ram/L VA	0.17	0.14	0.16	0.23	0.09	0.21	0.08	0.09	0.11	0.14
R ram/R VA	0.11	0.18	0.16	0.19	0.09	0.17	—	0.10	0.21	0.14
ASA/VA mean	0.18	0.17	0.17	0.30	0.11	0.22	0.09	0.11	0.25	0.18
L ram/L PICA	0.44	0.46	0.42	0.33	0.36	1.00	0.38	0.26	0.17	0.36
R ram/R PICA	0.28	0.44	0.52	0.39	0.25	1.00	—	0.29	0.42	0.37
L PICA/L VA	0.39	0.31	0.38	0.69	0.25	0.21	0.22	0.36	0.65	0.37
R PICA/R VA	0.41	0.42	0.30	0.49	0.37	0.17	0.29	0.33	0.49	0.37

Abbreviations: ASA, anterior spinal artery; BA, basilar artery; H, head; L, left; PICA, posterior inferior cerebellar artery; R, right; ram, ramus; VA, vertebral artery. Measurements are given in mm.

Table 3 Distances of emerging points of the arteries

	H-1	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-7*	*H-8*	*H-9*	*Mean*
L ram-BA	2.86	5.72	4.22	8.07	10.52	5.50	6.30	6.53	7.48	6.36
R ram-BA	7.05	5.90	8.58	6.94	12.38	5.51	—	8.24	4.89	6.61
L ram-L PICA	11.26	10.91	8.49	14.56	3.65	9.78	11.02	8.88	4.93	9.28
R ram-R PICA	8.92	9.40	4.48	12.34	3.60	10.00	—	8.93	12.12	7.75
L Ram-FP	—	4.07	6.42	3.70	4.38	—	—	—	5.31	2.65
R Ram-FP	—	4.00	3.47	8.89	2.54	—	—	—	6.75	2.85

Abbreviations: ASA, anterior spinal artery; BA, basilar artery; FP, fusion; H, head; L, left; PICA, posterior inferior cerebellar artery; R, right; ram, ramus; VA, vertebral artery.
Measurements are given in mm.

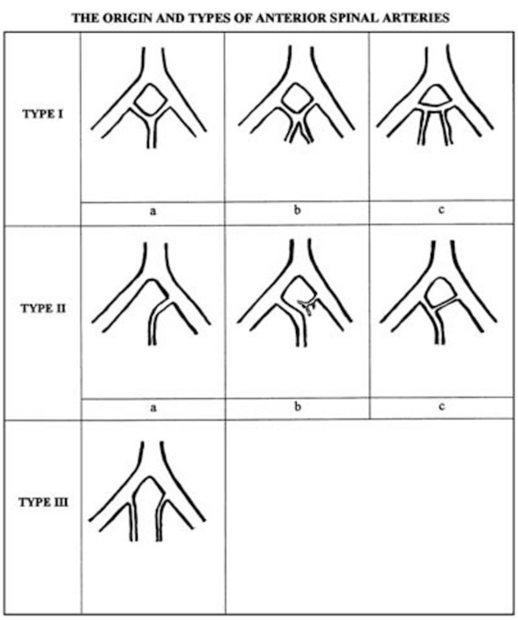

Figure 1 Schematic drawing of the pattern of origin and types of ASA found in the present study.

to the VA is 0.17. On the basis of this proportion, the flow in the ASA is approximately 1/1000 the flow in the VA, since according to Poiseuille's equation, the flow is inversely proportional to the fourth power of the radius.[4] The mean diameter of the PICA at its origin ranged from 0.50 to 2.38 mm (mean 1.31 mm). The proportion of the diameter of the ASA to the diameter of the PICA is 0.45 and the proportion of flow (ASA/PICA) is approximately 4% (Table 2).

Distances

In each specimen, the ASA originated from the VA distal to the PICA origin. The point of origin of the ASA in relation to the apex of the vertebrobasilar junction shows great variability ranging from 2.86 to 12.38 mm with an average of 6.86 mm The distance from the origin of the rami to their fusion also shows great variability ranging from 2.54 to 8.89 mm (mean 4.95 mm). The distance between the origin of the ASA rami and the origin of the PICA ranged from 3.60 to 12.34 mm (mean 9.02 mm) (Table 3).

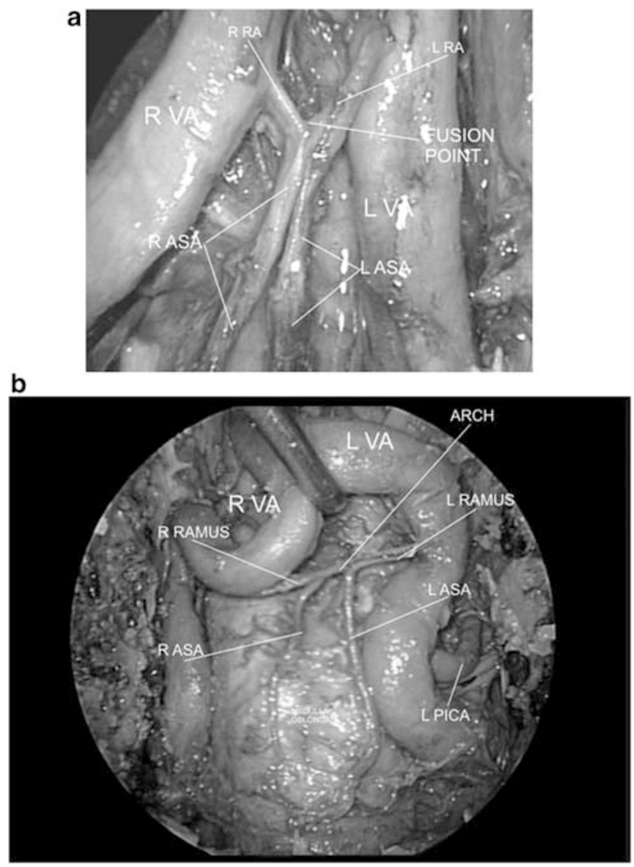

Figure 2 Type I ASA. Type Ia ('textbook' ASA) was absent in our specimens. In Type Ib, the ASA divides into two branches immediately after fusion (**a**). In Type Ic, the right and left rami originating from the VA form a vascular arch and the two ASA arise from it.

Classification

On the basis of the patterns of origin of the ASA encountered in our study and from a review of the literature we propose a classification of the ASA origin, which has clinical and radiological relevance. The pattern of origin of the ASA can be divided into three main types (Figure 1).

Type I

This type is characterized by the presence of two rami (right and left) that fuse to form the ASA. Type Ia is defined as the

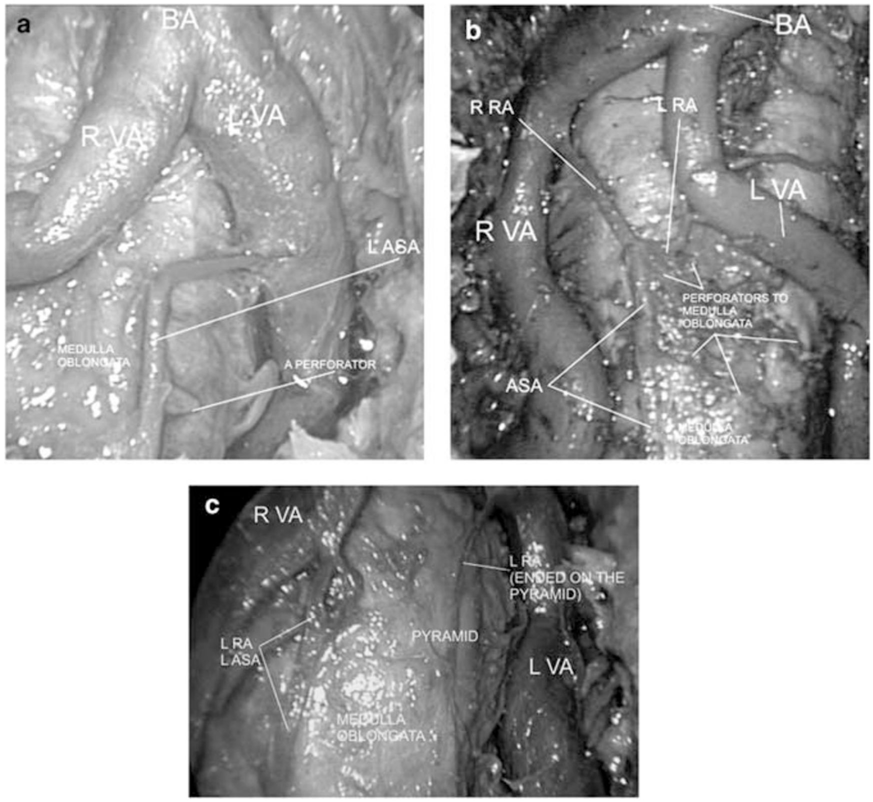

Figure 3 Type II ASA. In Type IIa, there is only one ramus forming the ASA (in this case, the left) (**a**). In Type IIb, one ramus (the left in this specimen) ends on the pyramid without joining the contralateral one, while the contralateral ramus courses downward independently (**b**). In Type IIc, one ramus (the left in this specimen) joins the dominant contralateral one in an end-to-side fashion (**c**).

ASA where two symmetric rami emerge from the VAs and fuse to form one ASA which courses downward. In our study, we did not encounter any Type Ia ASA. Type Ib is defined as the ASA which arises from the union of two paired rami and which divides into two separate ASA trunks after their union (Figure 2a). There were two Type Ib ASA in our specimens (22.2%). Type Ic characterized by the presence of a vascular arch formed by the left and right rami arising from each VA, two separate ASA trunks emerge from this vascular arch (Figure 2b). There was one Type Ic in our samples (11.1%).

Type II

Type II is characterized by the presence of one ASA arising either from the right or left ramus alone. In Type IIa there is only one ASA emerging from the left or right VA (Figure 3a). In our specimens there was only one Type IIa (11.1%). In Type IIb, there are two rami arising from each VAs. However, one of them, which is very short, supplies the ventral surface of the medulla and the other one actually forms a single ASA (Figure 3b). There was one Type IIb in our specimens. Type IIc is characterized by one dominant ramus, which courses downward as the main trunk of the ASA and is joined by the contralateral smaller one in an end-to-side anastomotic fashion (Figure 3c). There were two Type IIc in our specimens (22.2%).

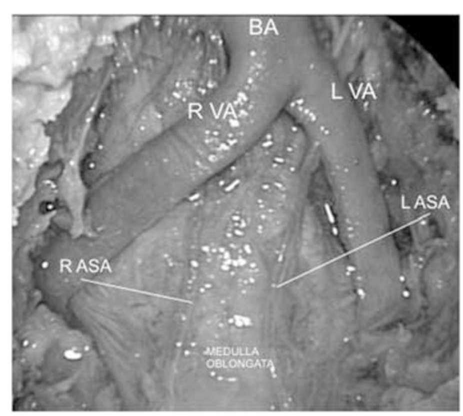

Figure 4 Type III ASA. In Type III, two separate ASA course downward independently from each other.

Type III

Type III is characterized by the presence of two separate, independent ASAs (Figure 4). There were two Type III in our samples (22.2%) (Table 1).

Discussion

The region of the ventral medulla and the vertebrobasilar junction is the site of a variety of extra- and intra-axial tumors and vascular lesions. Knowledge of the pattern of origin and division of the critical arteries in this region is key to minimize disastrous ischemic complications during surgical and endovascular procedures.[5–7] The arteries in the posterior circulation show greater anatomical variations than cerebral arteries in other locations.[1,5,8–12] The ASA is no exception. In our study, we did not find any ASA defined in textbooks as the ASA that arises from the fusion of two paired and symmetric left and right rami originating from the V4 portion of the VA. Moreover, we found a great degree of variability in the pattern of distribution and course of the two rami forming the origin of the ASA.

Knowledge of these anatomical variations in the course of the ASA has critical clinical importance during surgery and endovascular procedures involving this area. In particular, endovascular iatrogenic occlusion of the distal portion of the VA is commonly employed as a therapy for large and giant aneurysms of the proximal vertebrobasilar system. Unfortunately, with this modality, devastating complications can occur.[4,6,13,14] These are often related to direct obliteration of the ASA at its origin or to secondary thrombus extension involving the ASA origin.[1,6,14] As endovascular procedures become more sophisticated and with improved diagnostic techniques (i.e., microangiography), it will become commonplace to visualize smaller vessels and hopefully the variable pattern of origin of the ASA will be better appreciated on diagnostic studies.

Some classification systems of the origin of the ASA have been proposed in the literature. However, these classifications are based purely on anatomical grounds.[7,9,15] On the basis of our findings, we propose a new classification system. The main advantage of this classification system is that it has clinical, as well as surgical and endovascular relevance. The system we are proposing stresses the supply of the ventral medulla and can be helpful in predicting tolerance to occlusion of one ramus of the ASA. In case of occlusion of the VA in Type I (where there is bilateral participation to the main ASA trunk), the medulla might still receive adequate blood supply from the opposite ramus via collateral branches. In Type II (where there is asymmetric contribution to the ASA primarily from one side), if the occluded side is the site of origin of the single ASA trunk, there could be disastrous ischemic complications after VA occlusion. Bilateral medial and lateral medullary syndrome, including quadriplegia, complete loss of touch, position, vibration sensation and paralysis of the tongue may occur. In Type III (where two separate ASA trunks are present), occlusion of the distal portion of the VA could result in ischemia only on the ipsilateral side, and the opposite side could be spared. Medial medullary syndrome or medial inferior pontine syndrome may occur.[6]

Conclusions

The ASA has a highly variable pattern of origin and distribution. Knowledge of this anatomical variability is helpful in planning surgical and endovascular procedures involving this area.

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References

1 Akar ZC, Dujovny M, Slavin KV, Tortosa EG, Ausman JI. Microsurgical anatomy of the intracranial part of the vertebral artery. *Neurol Res* 1994; **16**: 171–180.
2 Baeza AR, Lara AM, Pazos MR, Mateu JMD. Anterior spinal arteries. Origin and distribution in man. *Acta Anat* 1989; **136**: 217–221.
3 Marinkovic S, Milisavljevic M, Gibo H, Malikovic A, Djulejic V. Microsurgical anatomy of the perforating branches of the vertebral artery. *Surg Neurol* 2004; **61**: 190–197.
4 Zhang T, Harstad L, Parisi JE, Murray MJ. The size of the anterior spinal artery in relation to the arteria medullaris magna anterior in humans. *Clin Anat* 1995; **8**: 347–351.
5 Akar ZC, Dujovny M, Tortosa EG, Slavin KV, Ausman JI. Microvascular anatomy of the anterior surface of the medulla oblongata and olive. *J Neurosurg* 1995; **82**: 97–105.
6 Mahmood A, Dujovny M, Torche M, Dragovic L, Ausman JI. Microvascular anatomy of foramen caecum medullae oblongatae. *J Neurosurg* 1991; **75**: 299–304.
7 Özgen S, Pait G, ağlar Y. The V_2 segment of the vertebral artery and its branches. *J Neurosurg (Spine 1)* ; **3**: 299–305.
8 Duvernoy HM (ed). Superficial path and internal territories of arteries and veins of medulla, pons and mesencephalon. In: *Human Brain Stem Vessels* 1999, 2nd ed. Springer-Verlag: Berlin, Heidelberg, pp 32–38.
9 Gövsa F, Aktan ZA, Arŷsoy Y, Varol T, zgür T. Ogigin of the anterior spinal artery. *Surg Radiol Anat* 1996; **18**: 189–193.
10 Grand W, Hopkins LN (eds). Vertebral and basilar arteries. In: *Vasculature of the Brain and Cranial Base. Variations in Clinical Anatomy* 1999. Thieme: New York., pp 161–179.
11 Swatko A, Matusewicz M. Variation of the place of origin and course of posterior and anterior spinal arteries in men. *Folia Morphol (Warsz)* 1979; **38**: 77–84.
12 Thron AK (ed). Postmortem angiography and microangiography of spinal cord vessels. In: *Vascular Anatomy of the Spinal Cord. Neuroradiological Investigations and Clinical Syndromes* 1998. Springer-Verlag: Wien, New York., pp 13–64.
13 Biglioli P, Spirito R, Roberto M, Grillo F, Cannata A, Parolari A, *et al*. The anterior spinal artery: The main arterial supply of the human spinal cord-a preliminary anatomic study. *J Thorac Cardiovasc Surg Feb* 2000; **119**: 376–379.
14 Kado K, Hirai S, Kobayashi S, Kobayashi E, Yamakami I, Uchino Y, *et al*. Potential role of the anterior spinal artery in preventing propagation of thrombus in a therapeutically occluded vertebral artery: angiographic studies before and after endovascular treatment. *Neuroradiology* 2002; **44**: 347–354.
15 Hott JS, Vishteh G, Wallace R, Dean BL, Spetzler RF. Anterior spinal artery supplying posterior circulation. *Neurology* 2004; **10**: 468.