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The Arterial Supply of the Human Spinal Cord: A New Approach to the Arteria radicularis magna of Adamkiewicz

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Summary

The arteria radicularis magna (Adamkiewicz's artery) was studied in 30 human spinal cords after arterial injection. The artery was present in all cases, between T 8 and L 2, and was identified by its diameter and position. The arteria radicularis magna was the main blood supply to the lowest region of the spinal cord. In one out of three cases it accompanied the ventral root at T 9, and in 80% of the cases studied it was found on the left side. The arteria radicularis magna had a posterior component in 63% of the cases. We did not observe specific radiculo-medullary arteries in the conus medullaris region.

Keywords: Arteria radicularis magna; Adamkiewicz's artery; thoraco-lumbar region; spinal cord; vascular anatomy.

Introduction

The arteria radicularis magna (A. magna spinalis, Adamkiewicz 1882[1]; A. du renflement lombaire, Lazorthes *et al.* 1957[22]) is the only radiculo-medullary supply to the thoraco-lumbar region of the human spinal cord[23, 34]. Its importance is demonstrated from different points of view: the clinical one: syndrome of the intumescentia lumbalis[4, 7]; the surgical one: postoperative paraplegia[2, 12] and the diagnostic one: angiographic technique[11, 19].

The arteria radicularis magna has the greatest diameter and is the most consistently present of the radiculo-medullary arteries[1]. However, the fact that it arises from a rachideal vessel at variable levels, has led several authors to consider high and low configuration patterns[6, 23].

In spite of these facts there are still some aspects in the literature open to discussion: such as, the position level, the presence of an homonymous posterior artery[25] and the presence of supplementary arteries in its distribution area[6, 9, 32]. All these have been a source of motivation for the present research carried out on 30 human spinal cords, normal with respect to the anatomy of the arteria radicularis magna, in terms of both their origin and distribution pattern.

Material and Methods

We studied 30 human spinal cords from adult cadavers of both sexes supplied by the Institute of Forensic Pathology of Barcelona and the Department of Human Anatomy (Autonomous University of Barcelona). The ages of the corpses varied between 15 and 47 years (average 27 years) (Table 1). The cause of death was well established in each case and none had spinal pathology. The viscera were removed 12 to 24 hours after death and the arterial system washed out with tap water. Thereafter, natural coloured latex was injected at hand pressure into the aortae ostia of the segmental arteries (intercostal and lumbar arteries). Extensive laminectomies were performed to remove the dural sac. The specimens were immersed in a 15% formaldehyde solution for more than 15 days. Dissection was performed using a surgical microscope (OPMI-1, Zeiss). The measurement of the arteries was carried out with a palmer-type instrument.

Results

The arteries supplying the thoraco-lumbar region of the spinal cord (from the T 6 level) have their origin in the posterior intercostal and lumbar arteries. They join the vertebral canal through the intervertebral foramen passing through the spinal dura mater. Then, they reach the surface of the spinal cord at the ventral surface of the posterior and/or anterior nerve roots. One of the radiculo-medullary arteries, which has the greatest diameter, is easily recognisable as it is anterior (Table 1) and extends to the region of the conus medullaris (Fig. 1). This is the arteria radicularis magna. Ventral to the median fissure of the spinal cord it divides in two branches: the ascending branch which has

Table 1. *Distribution of the Anterior Radiculo-Medullary Arteries*

Specimen	years	T6		T7		T8		T9		T10		T11		T12		L1		L2		L3	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
20	19								0.60							**1.00**					
21	39		0.70					0.70						**0.95**							
22	19	0.70						**0.90**								0.55					
23	32			0.65						**1.10**											
24	17					0.50						**0.85**				0.30					
25	24	0.60			0.50					**0.90**											
26	19					0.50				**0.80**						0.40					
27	23					**0.90**															
28	38								**0.90**					0.40							
29	21				0.60				**0.80**			0.35									
30	25	0.45							**0.85**	0.25											
31	30					0.75						0.60						**0.85**			
32	24			0.80							**1.00**										
33	35			0.25		0.60		0.45							0.75			**0.90**			
36	36							**1.00**													
37	41							**0.90**								0.20					
38	21	0.50					0.50	0.50				**0.80**									
39	31							**1.10**													
40	15			0.50						**0.60**					0.30						
41	30																	**1.10**			
42	26					0.85											**1.10**				
43	47							**0.90**								0.50					
44	29			0.60													**1.10**				
45	22	0.70								0.75								**1.20**			
46	21							**0.95**													
47	22		0.40					**1.10**								0.20					
48	23									**0.90**											
49	34	0.55				0.60								**0.80**							
50	41					**0.95**															
52	17		0.60					0.75				**0.80**									

L left.
R right.
000 radiculo-medullary arteries (mm).
000 radicularis magna artery (mm).

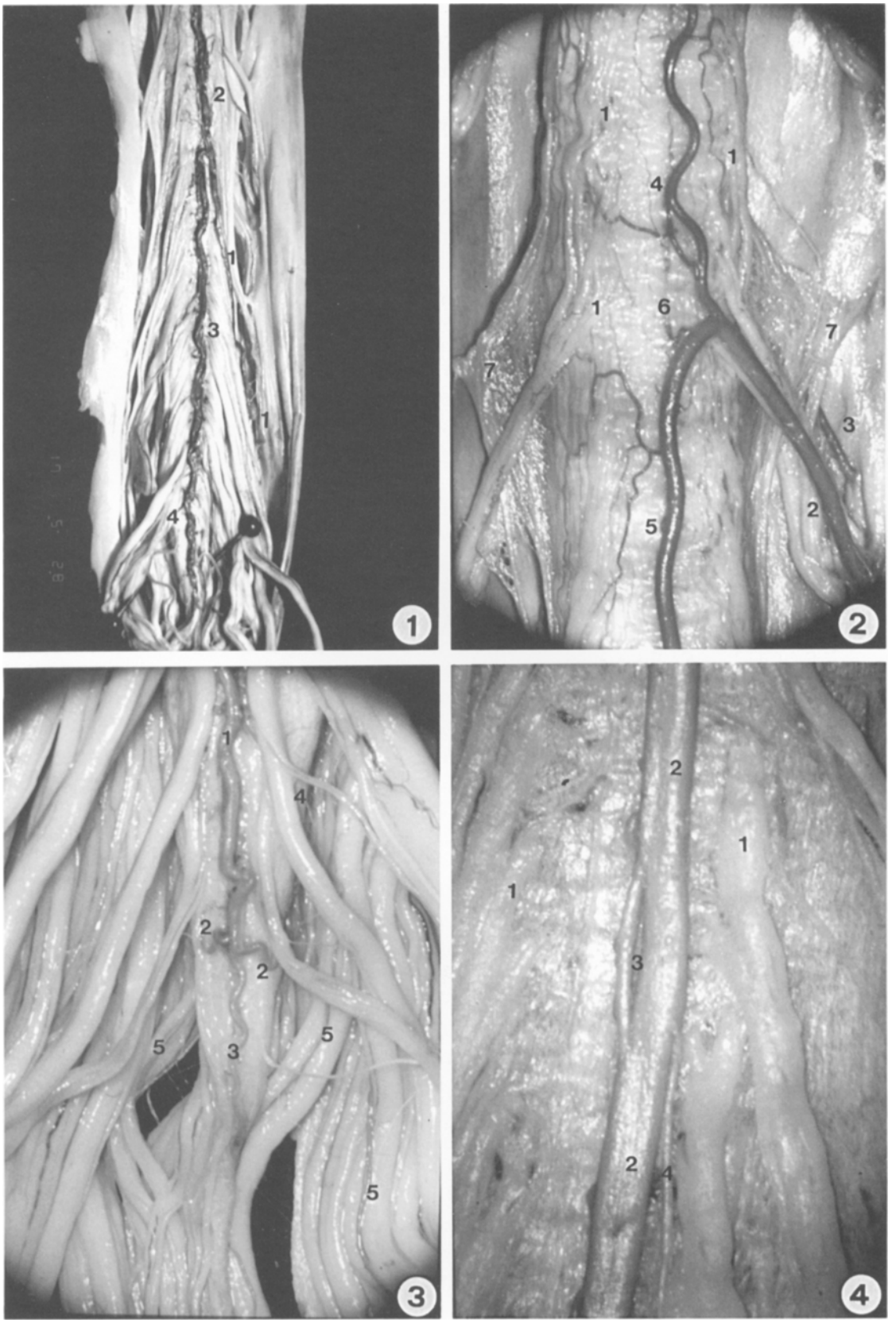
a small diameter and the descending branch which has a greater diameter (Fig. 2). The descending branch seems to be the main branch of the arteria radicularis magna; it is found in front of the median fissure, covered by an enlargement of the spinal pia mater and by the ventro-median vein. The descending branch anastomoses in the conus medullaris with the posterior longitudinal vessels giving rise to the crus vasculosa or

Fig. 1. Specimen 17. Ventral surface of the spinal cord (Lumbo-sacral region). The arteria radicularis magna is the only feeder artery in the anterior thoraco-lumbar region. *1* Arteria radicularis magna, *2* ascending branch, *3* descending branch, *4* conus medullaris

Fig. 2. Specimen 25. Ventral surface of the spinal cord. T 10 level. × 7.5. The arteria radicularis magna is accompanied by a posterior radiculo-medullary artery. *1* Ventral root of the spinal nerve (T 10), *2* arteria radicularis magna, *3* posterior radiculo-medullary artery, *4* ascending branch, *5* descending branch, *6* central arteries, *7* ligamentum denticulatum

Fig. 3. Specimen 36. Ventral surface of the conus medullaris. × 7.5. The caudal part of the descending branch of the arteria radicularis magna at conus medullaris. *1* Descending branch, *2* left and right branches of the anastomotic formation of the conus medullaris, *3* filum terminale artery, *4* posterior longitudinal anastomotic pathway, *5* radicular artery

Fig. 4. Specimen 47. Ventral surface of the spinal cord. L 1–L 2 level. × 20. Split in the descending branch of the arteria radicularis magna. *1* Fila radicularia, *2* descending branch, *3* split, *4* supplementary artery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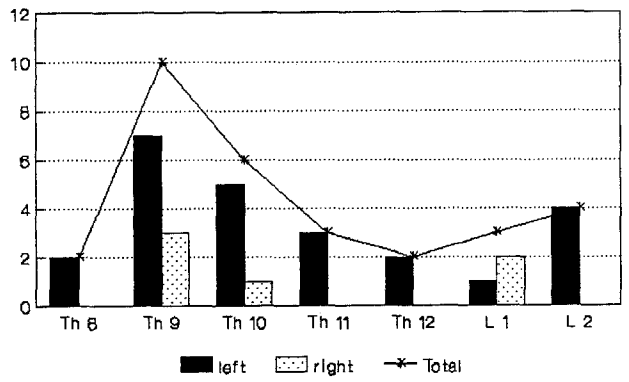

Fig. 5. Adamkiewicz artery. Distribution

ansa anastomotica of the conus medullaris, where the filum terminale artery emerges (Fig. 3). Several arterioles, smaller than 0.2 mm in diameter, join the loops of this anastomotic formation accompanying the lumbo-sacral nerves. The ascending branch of the arteria radicularis magna anastomoses termino-terminally with the descending branch of the radiculo-medullary artery immediately above. The arteria radicularis magna reaches the spinal cord at the level shown in Fig. 5. In the corpses studied it was always between T 8 and L 2, with the highest frequency at T 9 (33%). In 80% of the cases it was located on the left side (Table 1). The diameter ranged from 0.6 to 1.2 mm (mean 0.9 mm) (Table 1). In two thirds of the cases the arteria radicularis magna was the last radiculo-medullary supply (Table 1), while in the remaining third there was a supplementary artery immediately below, which anastomoses termino-laterally with the descending branch of the arteria radicularis magna. It is also worth mentioning that in 7 cases (23%) the arteria radicularis magna was the only anterior supply to the thoraco-lumbar region below T 6 (Table 1). We did not observe bilateral anterior radiculo-medullary arteries at the same segment of the region studied in any case. However, in 63% of the cases the arteria radicularis magna was accompanied by a posterior radiculo-medullary artery (Fig. 2). This artery did not show any special distinguishing features with respect to other posterior supplies. The division of the arteria radicularis magna always gave rise to central arteries which entered through the median fissure (Fig. 2) and to superficial arterioles supplying the funiculus anterior. On three occasions we observed that the downward path of the arteria radicularis magna split in the fashion of a vascular ring (Fig. 4).

Discussion

The first description of the non-segmental and non-symmetrical filling of the spinal cord was recorded by von Haller (1754)[18, 27]. However, it was not until 1882 when Adamkiewicz[1] provided conclusive evidence of this fact, stating that only some of the vessels that accompany the rachideal nerves actually reach the spinal cord. Of these arteries the most important is the arteria radicularis magna, which is anterior and the most inferior[1]. Kadyi (1889)[21] confirmed these observations and found this artery mainly on the left side.

Tanon (1908)[33] suggested naming the arteries that supply the spinal cord "main arteries or radiculo-medullary arteries", these being the lumbar, 2nd sacral and occasionally the 9th and 10th thoracic arteries. Although the term radiculo-medullary arteries is widely accepted, this is not the case with the levels at which they are to be found, especially with regard to the arteria radicularis magna.

Our study in humans confirms the existence of an anterior radiculo-medullary artery, which is the main arterial supply for the lower thoraco-lumbar region of the spinal cord. We located this artery between T 8 and L 2, with the highest frequency at T 9[14]. Cranial origin at T 8[11, 12, 14, 20, 25] and caudal origin at L 2[10, 13, 16, 31, 34, 35] have been reported. However, these have not been observed in our study. In 80% of the cases the arteria radicularis magna was found on the left side[21], as described by Kadyi (1889)[21]. Lazorthes *et al.* (1963)[22] associated this location with the left side position of the abdominal aorta.

Our findings coincide with the percentages reported by Corbin (1961)[6] and Lhermitte *et al.* (1962)[26] in that in 76% of the cases the arteria radicularis magna accompanies a thoracic root and in 24% a lumbar root, but differ in the high (above T 10) and low presentation patterns (below T 10). In the high configurations (> 40%)[6] there was no other subjacent artery. However Lazorthes *et al.* (1963)[23], who also established high configuration patterns (above T 8), found that there was always a supplementary artery that accompanied the lower lumbar or sacral nerves. Our results do not allow the establishment of criteria relating the level of origin of the arteria radicularis magna with the presence of supplementary radiculo-medullary arteries (immediately above or below)[15, 36, 37]. It is important to point out that in two thirds of the cases studied the arteria radicularis magna was the lowest anterior blood supply to the spinal cord, and that in one third it was the only anterior radiculo-medullary artery below T 6.

Lazorthes *et al.* (1957)[22] described the arteria radicularis magna always associated with a posterior radiculo-medullary artery. For this reason and because of the dependent vascular region, they propose the denomination "artère du renflement lombaire". However, both Houdart *et al.* (1965)[19] and Tveten (1976)[36, 37], found these two arteries present in only one third of the cases. We observed the two arteries in 63% of cases. Therefore the posterior branch can not be considered as homologous to the arteria radicularis magna[19, 34].

The terminal end of the descending branch of the arteria radicularis magna was first reported by Mayer (1777)[27, 30]. It was described by Adamkiewicz (1882)[1] as "crus vasculosa" and by Lazorthes *et al.* (1957)[22] as "anse anastomotique du cône". Its anatomo-functional interest as a relief feeding vessel is well known[8, 17, 24]. We have verified that radicular arteries join the branches of the anastomotic loop. These radicular arteries accompany the last rachideal lumbar nerves and the sacral nerves[34]. However, no radiculo-medullary arteries were observed leading to the region of the conus medullaris[9, 32].

Further attention is drawn to the finding of splits in the descending branch of the arteria radicularis magna, as there were no previous descriptions at the thoraco-lumbar level. These splits may support the hypothesis of a double embryological source of the artery situated at the ventral mid-line[35].

Finally, we would stress the clinical importance of this anatomical study, as borne out by current studies referring to the prevention of paraplegia in aortic surgery[5], or to cases of direct compression of the arteria radicularis magna[28]. It is also relevant from a diagnostic and therapeutic point of view, in relation to selective angiography[11]. Furthermore, the distribution of the arteria radicularis magna has an anatomo-clinical correlation; the extensive ischaemic necrosis, for instance from T 8 to S 5[3], and the ischaemic graphs of the ventral horn[29] show the main supply region of the arteria radicularis magna. All these studies justify anatomical research designed to increase our knowledge of the arteria radicularis magna.

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