Anatomy of spinal blood supply

Anatomia da circulação medular

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Abstract

The intricate three-dimensional vascular anatomy of the spinal cord is still not completely understood, and its terminology varies between studies. In view of its importance in spinal ischemia, an analysis is needed of the anatomic vocabulary used to describe the spinal cord blood supply to improve understanding of the subject. The main supply is the Adamkiewicz artery, also known as great anterior radicular artery. The literature was reviewed to equate the different nomenclatures employed and an accurate description of current knowledge on spinal cord vascularization was prepared.

Keywords: spinal cord; anatomy; spine; aorta.

Resumo

A intrincada anatomia tridimensional da irrigação medular é frequentemente explanada na literatura com diferentes nomenclaturas e devido a sua alta relevância no estudo da isquemia medular, o estudo da terminologia se faz necessário para melhor compreensão do tema. A artéria de Adamkiewicz, também chamada de artéria radicular magna, é a via principal. Foi realizada a revisão da literatura com equiparação das nomenclaturas utilizadas e elaboração de descrição acurada e sumarizada do conhecimento atual sobre a vascularização medular.

Palavras-chave: medula espinhal; anatomia; coluna vertebral; aorta.

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INTRODUCTION

Spinal blood supply was first studied by Albert Wojciech Adamkiewicz [AFI: ʔadamkiɛviʧ],[1,2] a Polish pathologist, in 1881.[3-6] The great radicular artery is also known eponymously as the Adamkiewicz artery (AKA).[4]

Knowledge of the blood supply to the spinal cord is important when planning treatment of diseases of the aorta. However, the vasculature involved is complex and difficult to study because of the small caliber of arteries, which make up an intricate three-dimensional network with a large degree of anatomic variation.[7] The lack of a gold standard imaging exam also makes it difficult to compare existing imaging methods.[8]

This study is intended to clarify the anatomic presentation of the spinal vasculature and propose a standardization of the terms for use in Portuguese.

REVIEW OF THE LITERATURE

The intricate three-dimensional anatomy of the spinal blood supply is often explained in the literature using different terminology[9] and merits review in order to clarify the standard that should be used (Table 1).

The intercostal and lumbar arteries that supply the spinal marrow originate in the aorta, as do the subclavian and hypogastric branches. The intercostal and lumbar arteries divide three times before reaching the spinal cord. The first branch is the spinal branch, which divides into the anterior and posterior radicular arteries and, farther on, bifurcates into the dorsal and vertebral branches. The last bifurcation of the spinal branch is constant for anterior and posterior supply of the vertebral canal, of the nerve roots and of the dura mater, at some levels only, and the anterior and posterior radicular arteries pass through the dura mater and reach the marrow. Only some (2-14, a mean of 6) of these segmental branches remain into adulthood. The anterior spinal artery (ASA) is crucial to vascularization of the marrow and anterior and lateral funiculi and is basically an anastomotic channel between the ascending and descending branches of the adjacent anterior radicular arteries (Figure 1).

Generally, one of the anterior radicular arteries is dominant in terms of caliber and is known as the great anterior radicular artery or Adamkiewicz artery (Figure 2). The posterior radicular artery follows a

Table 1. Terms found in the literature and Portuguese terms proposed.

Most frequent	Synonyms	Portuguese term adopted
Aorta	Aorta	Aorta
Segmental Arteries	Segmental a.,[10] segmental posterior intercostal a.,[9,11] radicular a.[12] aa. intercostales, intercostal a.[13] aa. lumbales	Artérias segmentares AA. intercostais posteriores (TA) lombares
Vertebral branch	vertebral branch,[9] ventral branch,[11] dural a.,[12] anterior branch,[13,14] anterior ramus, muscular branch[15]	Ramo vertebral
Dorsal branch	dorsal branch,[11] muscular branch,[14,16] branches to erector spinae and intercostal muscle,[17] dorsal somatic branch[15]	Ramo dorsal (TA)
Radiculomedullary artery	Dorsal ramus intercostal a.,[12] nervomedullary a.,[7,9,11] spinal branch,[11] radicular a.,[12] radicular medullary dural a.,[18] radiculomedullary a.,[13,14,16] ramo espinhal,[19] posterior ramus	Ramo espinhal (TA)
anterior radicular artery	anterior radicular a.,[9,10,20] medullary a.,[12] anterior medullary a.,[18] anterior radiculomedullary aa.,[16,17] a. radicular anterior,[19] anterior spinal canal a., segmental a.[21]	Ramo radicular anterior (TA)
Posterior branch of the radicular artery	posterior radicular a.,[9,10,20] medullary a.,[12] posterior medullary a.,[18] posterior radiculomedullary aa.,[16] a. radicular posterior,[19] posterior segmental medullary a.[22]	Ramo radicular posterior (TA)
Posterolateral spinal artery	posterolateral spinal aa.,[9,18] posterior spinal aa.,[12,16] posterior pial arterilar plexus,[10] aa. espinhais posteriores[19]	Artéria espinhal posterolateral
Anterior spinal artery	a. spinalis anterior;[5,6] anterior spinal a.,[12-14,18] anterior median spinal a.,[10] anterior long spinal a.	Artéria espinhal anterior (TA)
Artery of Adamkiewicz	a. radicularis magna, great(er) radicular a., anterior great(er) radicular a., lumbar enlargement a., anterior radiculomedullary a., major radicular a., dominant radiculomedullary a., e outros.[9,11,23]	Artéria de Adamkiewicz*
Lumbar arteries	aa. lumbales	Artérias lombares (TA)
Intercostal arteries	aa. intercostales, intercostal a.[13]	Artérias intercostais posteriores (TA)
Sulcal arteries	a. sulci,[5,6] sulcal a.,[10,11] aa. sulcais,[19] medial medullary branch,[22] sulco-commissural a.[21]	Artérias sulcais
Pial plexus	pial plexus[18]	Plexo pial**

TA: Term adapted from the Brazilian Anatomic Society's reference work Anatomic Terminology.[24] *Eponym adopted in view of frequent use in the literature.[23] **Term not included in Anatomic Terminology.

similar pattern, but gives rise to two longitudinal anastomotic channels: the posterolateral spinal arteries. Arteries that supply the spine are divided between a central system, fed by the sulcal arteries, and a peripheral system, the pial plexus, which gives origin to perforant branches (Figure 2).[7,25-27]

Spinal drainage is no less controversial, and its principal characteristics are the posterior great radicular vein, in the shape of a "coat-hook", the posterior spinal vein and the anterior spinal vein.[15] The anatomic importance of venous drainage with relation to this article, dedicated to the spinal arteries, lies in anatomic differentiation of the arterial system (Figure 3) and the subject will not be dealt with in depth. Posteriorly, there is just one posterior spinal vein, rather than two smaller posterolateral veins, and this is frequently of smaller caliber than the anterior median vein.[28]

Although there is a single identifiable artery supplying the spine at the thoracic height, this is not the only source of medullary blood supply. Griepp et al. recently refined the conceptualization of the collateral circulation network for spinal blood supply,[29] providing details of its vascular redundancy, but the importance of the AKA has not yet been sufficiently elucidated. There is an axial network of small arteries in the spinal canal, in paravertebral tissues and in paraspinal muscles that anastomose with each other and with the arteries supplying the spinal marrow; the entry to this network includes segmental vessels (intercostal and lumbar arteries), subclavian arteries, hypogastric arteries and their branches (Figure 4).[30,31] In addition to these multiple entry routes, there is also an extensive network of epidural arterial and small vessels that supply the paraspinal musculature. All of these vessels are interconnected and anastomose with the subclavian arteries cranially and the hypogastric arteries caudally.[31]

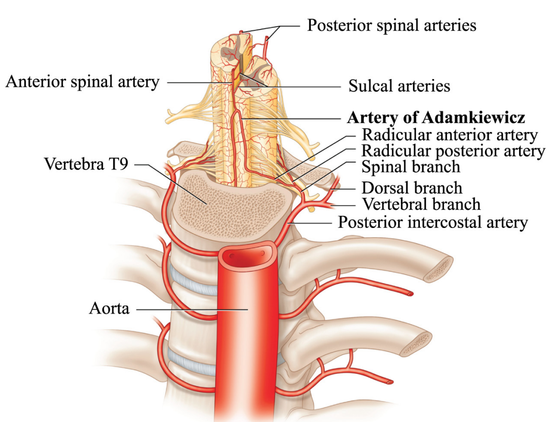

Figure 1. Schematic drawing of the blood supply of the spinal marrow.

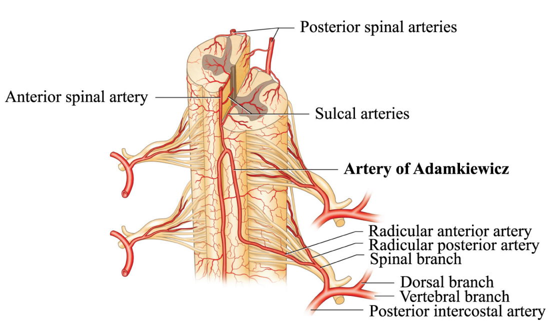

Figure 2. Anatomy of the spinal arterial supply, showing the Adamkiewicz artery.

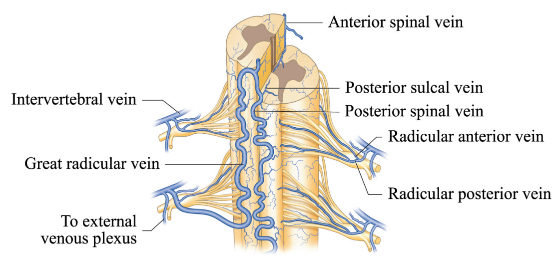

Figure 3. Spinal venous drainage.

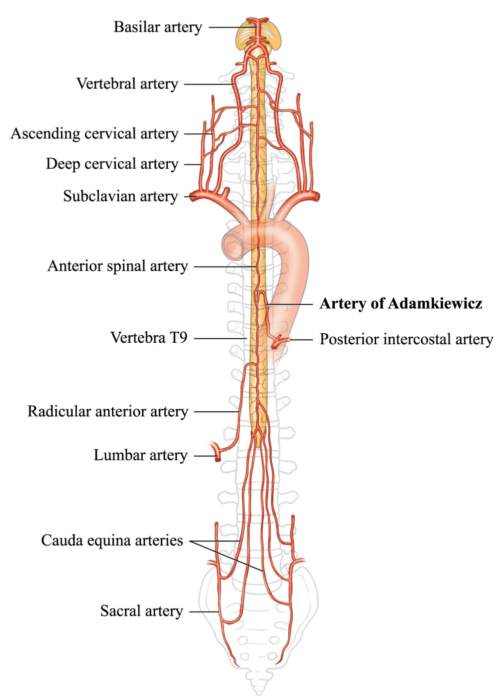

Figure 4. Collateral network: subclavian, hypogastric, intercostal and lumbar arteries.

This collateral network can provide compensatory flow to the spinal cord in the event of occlusion of the larger caliber routes,[31] and the flow from one source can increase when another is reduced; or vice versa: flow can reduce if a low resistance alternative route is opened, i.e. in cases of arterial steal.[29] According to Adamkiewicz's theory of partial flow, the flow in the anterior spinal artery originates from the radicular arteries, arriving at the spinal cord in two currents, a cranial and a caudal, and so pressure changes, or occlusion of a route in the collateral network, can invert the flow in the anterior spinal artery.[11]

INFLUENCE OF POSTOPERATIVE SPINAL CORD ISCHEMIA

A recent retrospective study using a risk model to analyze a database of results from 19 European centers with 2,235 patients registered found that 38 (1.7%) patients exhibited symptomatic spinal ischemia, providing evidence that endovascular exclusion of the intercostal arteries combined with interruption of another collateral route of spinal blood supply is a risk factor for this event. The mathematical algorithm employed identified intraoperative hypotension and simultaneous exclusion of at least two spinal supply territories as relevant to the genesis of ischemia, and it was concluded that extensive exclusion of the intercostal arteries alone was not associated with symptomatic spinal ischemia.[30] Notwithstanding, retrospective assessment of 457 patients and their intrahospital complications demonstrated that paraplegia and paraparesis had a significant relationship with endovascular exclusion of more than 20 cm of the aorta,[32] which corroborates the importance of the segmental arteries to spinal blood supply. Yingbin et al.[33] demonstrated the importance of identifying the AKA to selection of long endoprostheses for aortic dissection.

An article on interruption of the AKA during spondylectomy[34] suggests that the AKA is not the only important route of spinal blood supply.

The mechanism of spinal ischemia after endovascular repair of thoracic aorta aneurysms has not been entirely elucidated and is apparently related to an intricate mechanism of several different factors, and not exclusively to permanent interruption of supply via the segmental artery.[9,35] The collateral network concept described by Griepp et al. proposes the existence of extensive redundant spinal blood supply. However, in acute situations, such as surgical procedures, spinal perfusion is dependent on the gradient of arterial blood pressure and of cerebrospinal fluid.[35] Spinal cord ischemia is therefore correlated with perioperative episodes of hypotension and exclusion of the hypogastric artery as part of the collateral network.[28]

CONCLUSIONS

Despite the great variation in terminology found in the literature, studies are in agreement with relation to the anatomy of the spinal circulation and the existence of a large network of collateral circulation. Standardization of the terminology is necessary and the suggestions for use in Portuguese made in this study are based on current anatomic terminology.

The clinical importance of anatomic knowledge of this region lies in planning for endovascular surgery procedures on the aorta, in order to minimize the risk of ischemia, avoiding unnecessary occlusion of the spinal blood supply.

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