The lateral spinal artery of the upper cervical spinal cord

Anatomy, normal variations, and angiographic aspects

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The lateral spinal artery corresponds to the most rostral extent of the posterolateral arterial axis of the spinal cord. It supplies the posterior and lateral aspects of the spinal cord, and courses anterior to the posterior roots of the upper cervical spinal nerves (C-1 to C-4), and posterior to the dentate ligament. The lateral spinal artery anastomoses rostrally with the branches of the posterior inferior cerebellar artery (PICA) at the restiform body and laterally with the extraspinal arteries at the emergence of each nerve. It may originate either from the vertebral artery or from the PICA lateral to the medulla. Certain variations will cause an unusual but normal enlargement of the vessel in a specific portion of its course; these variations include vertebral artery duplication, a C-1 or C-2 vertebral origin of the PICA, a C-1 or C-2 occipital origin of the PICA, and an intradural course of the vertebral artery at C-2. Knowledge of these variations in the arterial supply to the area allows for an understanding of the different anatomic peculiarities present and their angiographic importance.

KEY WORDS: spinal cord artery, vertebral artery, lateral spinal artery, anatomical study, posterior inferior cerebellar artery, angiography

For more than 10 years, superselective angiography has allowed the development of an intraarterial route for the treatment of arteriovenous malformations in general. This is particularly true of the upper cervical level. Obviously, knowledge of the normal location and variations of the spinal arteries is mandatory in order to establish a proper treatment strategy and to achieve safe embolization.

The purpose of this study is to provide additional data concerning the arterial variations of the upper cervical spinal cord arterial supply. The anterior spinal artery is not included in this discussion as it has generated minimal anatomic or angiographic problems in the literature and in our own practical experience. On the other hand, the posterolateral artery of the spinal cord, which was believed to remain in the same anatomic position from the medulla to the conus, in fact presents some specific anatomic variations at the upper cervical level (Fig. 1).

During the past 10 years, we have recorded variations of the head and neck arteries. Most of these variations

FIG. 1. Posterior view of the medullospinal junction. Note the absence of an artery posterior to the dorsal root of C-1 and C-2. The lateral spinal artery arises from the posterior inferior cerebellar artery (PICA) bilaterally, courses anterior to the dorsal root of the C-1 and C-2 nerves, and supplies the posterior aspect of the cord. Both PICA's arise from the extradural vertebral artery at the first cervical space.
FIG. 2. Schematic representation of 14 different arrangements of the vertebrobasilar system between C-3 and the origin of the anterior inferior cerebellar artery (AICA) in the frontal view involving, among others, the lateral spinal artery system. (Reprinted in part from Lasjaunias P: Craniofacial and Upper Cervical Arteries. Collateral Circulation and Angiographic Protocols. Baltimore: Williams & Wilkins, 1983, with permission.)

Abbreviations: 1 = basilar artery; 2 = intradural intersegmental anastomosis (lateral spinal artery system); 3 = extradural intersegmental anastomosis (vertebral artery); 4 = AICA territory; 5 = posterior inferior cerebellar artery (PICA) territory; 6 = C-1 vertebral level; 7 = C-2 vertebral level; 8 = C-3 vertebral level; ICP = intracranial portion. Configurations are as follows. A: Classical aspect. B: An AICA dominance of the lower cerebellar supply (AICA-PICA trunk). C: Origin of the PICA at C-1. D: Duplication of the vertebral artery at C1-2. E: Origin of the PICA at C-2. F: Intraventricular course of the vertebral artery at C-2. G: Premedullary duplication of the vertebral artery. H: Double origin of the PICA at C1-2. I: Persistence of the embryonic hypoglossal artery. J: Ascending pharyngeal origin of the PICA. K: Persistence of the embryonic proatlantal artery, Type I. L: Occipital origin of the PICA via the C-1 vertebral space. M: Persistence of the embryonic proatlantal artery, Type II. N: Occipital origin of the PICA via the C-2 vertebral space.
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and an analysis of their embryological basis have already been published. However, the upper cervical spinal area has not been fully studied, although several different arterial deviations have been recognized and described in the literature as separate case reports (Fig. 2). Our goal is not to describe all of the different variations, but to point out the ones that obviously present a potential danger to surgery. We have developed a general schema, from which every variation can be derived and understood. When the specific vascular anatomy is established for each patient, the best therapeutic approach can then be selected.

Review of the Literature

In 1867, Cruveilhier described an artery anterior to the posterior cervical root, and Somemmering (cited by Cruveilhier) identified an artery entering the dural space with the C-1 spinal nerve. In 1876, Sappey reported a branch to the restiform body arising rostrally from the artery of the 11th nerve. In 1951, Libersa mentioned a lateral spinal artery in his study on the arterial supply of cranial nerves. More recently, the relationship of the upper cervical roots with the 11th nerve has been investigated in detail, but with no emphasis placed on the feeding arteries. Turnbull, et al., in 1966 and Maillot and Koritkó in 1970 described an unusual lateral course of the posterior spinal artery, and the contribution of an artery at C-2 to the spinal cord blood supply. They considered that it was an accessory arterial source; although some of their documentation indicated that it might constitute the dominant arterial supply to the lateral and posterior spinal cord territory. Both reports insisted that there was anastomosis of the arteries on the lateral and posterior surface of the cord, and that the classical posterolateral spinal cord arterial axis was only discernible caudal to the C-4 root. Most of the subsequent anatomic studies paid little attention to this arterial pattern of the upper cervical region. However, in 1981, Lang demonstrated on several dissections a spinal artery that he named the “lateral spinal artery.” Surprisingly, early angiographic descriptions of the arteries of the cervical spinal region, and of variations of the posterior inferior cerebellar artery (PICA) ignore this unusual arterial configuration.

Most of the arterial variations in this region were presented as anatomical curiosities, and no real
FIG. 3. Anatomic specimens (upper) and descriptive drawings (lower).  
Left: Posterior view of the left half of the medulla (M)-spinal junction. Note the position of the lateral spinal artery (LSA) ventral to the posterior root of the first (C₁) and second (C₂) cervical nerves. The LSA is arising from the vertebral artery and follows retrogradely the accessory nerve (XI). The posterior inferior cerebellar artery (PICA) originates from the intradural vertebral artery distal to the origin of the LSA.

Center: Posterior view of the left half of the medulla (M)-spinal junction. The lateral spinal artery (LSA) courses ventral to the posterior root of the first (C₁) and second (C₂) cervical nerves. It follows the recurrent direction of the accessory nerve (XI) dorsal to the dentate ligament (DL). In this case, the LSA is arising from the posterior inferior cerebellar artery (PICA). The latter is originating from the extradural vertebral artery at the occipitocervical junction.

Right: Close-up posterior view of the intradural foramen magnum on the right side. Note that the lateral spinal artery (LSA) close to the medulla (M) is originating from an anastomotic artery (AA) which accompanies the first cervical nerve (C₁). XI = the 11th accessory nerve; PICA = posterior inferior cerebellar artery; C₂ = second cervical nerve; and DL = dentate ligament.
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FIG. 4. Vertebral angiograms, lateral views, showing two distinct variations. (Reprinted from Lasjaunias P: Craniofacial and Upper Cervical Arteries. Collateral Circulation and Angiographic Protocols. Baltimore: Williams & Wilkins, 1983, with permission.) Left: Double origin of the posterior inferior cerebellar artery from the vertebral artery collateral at C-2 (double arrow) and C-1 (solid arrow). Note the projection of the distal vertebral artery at C1-2 onto the artery of the odontoid process (open arrows). The long arrow points to the transdural course of the artery. Right: Intradural course of the vertebral artery at C-2 (long arrow). In this variation, the channel used by the vertebral flow corresponds to the C-2 vertebral artery collateral (double arrow). The vertebral artery does not take its usual course at C-1 and C-2, but is seen dorsal to the odontoid process artery (open arrows). In both anatomical variations the intradural vessel is associated with two possible courses of the lateral spinal artery at C-1 and C-2, that supply the spinal cord territory.

Anatomical Description

Based on specimen dissections and on normal or abnormal angiographic studies, the lateral spinal artery can be described as follows. It originates lateral to the medulla, from either the PICA or the intradural vertebral artery (Figs. 1 and 3 left and center). It then courses caudally, running parallel to the spinal component of the 11th nerve, posterior to the dentate ligament, and anterior to the posterior spinal nerve roots to C-4 (Figs. 1 and 3). The collaterals of the artery supply the 11th nerve and the lateral and posterior surface of the spinal cord via the C1-4 spinal nerves. The lateral spinal artery anastomoses rostrally with the PICA branches at the level of the restiform body, with the extradural arteries arising from the vertebral or occipital arteries at each metameric level (particularly C-2), and with the contralateral system posteriorly (Fig. 3 right). The artery terminates at C-4 or C-5 in the classical posterolateral arterial axis, dorsal to the posterior root of the spinal nerves.

The normal variations of the lateral spinal artery that have been recorded are diagrammed in Fig. 2. They include enlargement of the artery associated with various normal arterial deviations, including an intraspinal course of the vertebral artery at C-2 (Fig. 4 right); a cervical vertebral origin of PICA at C-2 (Fig. 5); a double origin of PICA at C-1 and C-2 (Fig. 4 left); a cervical vertebral origin of the PICA at C-1; an occipital artery origin of the PICA at C-2; an occipital artery origin of the PICA at C-1; and a vertebral artery duplic-
FIG. 5. Vertebral angiogram, frontal view, showing a cervical origin at C-2 of the posterior inferior cerebellar artery (PICA). Note the non-pathological enlargement of the C-2 vertebral artery collateral (double arrow) and the transdural portion of this unusual PICA at the C-2 vertebral space (long arrow).

cation at C-2. Each of these deviations modifies the role of the lateral spinal artery by adding to its primary spinal cord territory. As proof of the normal nature of these congenital variations, a corresponding "hypoplastic" artery can be found for every single instance of enlargement of the lateral spinal artery mentioned above. Therefore, these variations correspond to a transfer of certain branches of the embryonic lateral spinal artery by a combination of spontaneous regression and persistence of specific arterial channels within the vascular network of the neural tube. Obviously, the metameric arteries of the region (first, second, and third segmental arteries) play an important role in the persistence of either the extradural intersegmental anastomosis (future vertebral artery) or the intradural intersegmental anastomosis (future lateral spinal artery) (Fig. 2).

It should be remembered that the vertebral artery represents the persistence of six to seven consecutive intersegmental arteries; each of which can be the site of arterial agenesis leading to a specific variation. Such variations must bypass the unformed segment to provide the necessary blood supply to the posterior fossa territory. At the upper cervical level, these deviations are usually described as an "aberrant course" of the distal vertebral artery; in fact, the so-called "aberrant segment" corresponds to the recruitment of a different channel, namely, the lateral spinal artery. At times this can involve the carotid system (proatlantal arteries). On these rare occasions, the subjacent vertebral artery is hypoplastic. It is of interest to note that none of the variations encountered were associated with parenchymal congenital anomalies at the occipitocervical junction. These variations illustrate different equilibrated hemodynamic patterns able to supply a normally developed and functioning central and peripheral nervous system.

Comment

Although it has been known for a long time, the significance of a lateral course of the posterior spinal artery at the upper cervical level has not been considered. The relationship and links between the arterial variations in this area were described a few years ago; however, the identification of the lateral spinal artery as a normal vessel was not proposed at that time. The schema that we have developed has allowed us to establish this link, and applies to all the other areas at the base of the skull. It has even permitted the first description of an arterial variant 2 years before it was demonstrated angiographically, that is, an occipital artery origin of the PICA.

It should be possible to demonstrate routinely the lateral spinal artery on high-quality angiograms, and to recognize every variation related to it (Figs. 2, 6, and 7). This is important when planning surgery or intraarterial embolization procedures in this area.
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FIG. 7. Vertebral angiogram, lateral view, in a case of von Hippel-Lindau disease. Note the dorsal situation of the posterior spinal artery (arrowheads) at the lower cervical spinal cord. At C-4, this artery courses ventrally (curved arrow) to lie lateral to the cord (double arrowhead). Double arrow points to the C-2 vertebral artery collateral.

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