Abstract

Aim: The aim of this investigation was characterize morphologically the cerebellar artery and its branches in a specimen of autopsy material.

Methods: This descriptive cross-sectional study evaluated the anatomical characteristics of the cerebellar arteries and their branches in 93 brain stem and cerebellum blocks obtained from fresh cadavers. The specimens were perfused bilaterally channeling the proximal segments of the internal carotid and vertebral arteries with a semi-synthetic resin (Palatal GP40L 85%; styrene 15%) impregnated with mineral red dye. We evaluated the distribution patterns of the cerebellar artery and its branches.

Results: The calibers of the superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA) and posterior inferior cerebellar artery (PICA) were 1.46 ± 0.2 mm, 1.02 ± 0.35 mm and 1.45 ± 0.37 mm, respectively. Agenesis of the SCA was observed in six specimens (3.2%), AICA in 30 (16.1%), and PICA in 14 (7.5%) specimens. Usual irrigation was observed in 44 (47.3%) cerebellar blocks, whereas 49 (52.7%) specimens showed irrigation variants, 23 (46.9%) of which appeared bilaterally. The dominant distribution of the cerebellar arteries corresponded to SCA in 9 (12.5%) cases, AICA in 46 (63.9%) and PICA in 7 (9.7%) specimens; shared dominance was found in 10 (13.9%) specimens.

Conclusion: The high variability of the cerebellar arteries observed in the present study is consistent with previous reports. The diverse anatomic expressions of the cerebellar arteries were typified in relation to their dominance and territories irrigated, useful for the diagnosis and clinical-surgical management of the cerebellum blood supply.

Keywords
Cerebellar Arteries; Cerebellum; Agenesis; Dominance.
Introduction
The superior cerebellar artery (SCA) emerges in the frontal part of the midbrain, usually from the basilar artery, although less frequently from the proximal segment of the left posterior cerebral artery (LPCA). In its proximal trajectory it relates to the oculomotor nerve, surrounds the brain stem close to the pontomesencephalic junction, and then runs through the cerebellomesencephalic fissure giving cortical branches to the upper surface and the cerebellar vermis [5, 7, 15, 17].

The anterior inferior cerebellar artery (AICA) emerges from the proximal segment of the basilar artery (67.9%-84%) and with a lower incidence (20.9%-32%) from its upper half. The AICA runs through the central part of the cerebellopontine angle close to the facial and vestibulocochlear nerves. It is intimately related to the pons, the lateral recess, the lateral foramen of the fourth ventricle, the cerebellopontine fissure, the middle cerebellar peduncle and the petrosal cerebellar surface [3, 5, 15, 17]. The AICA has variant expressions reported in different population groups concerning duplicate uni- or bilateral presentations in 3.2%-22 % [5, 15, 17], agenesis in a range of 2%-36.1%, as well as an asymmetric origin, or emerging from a common trunk with the PICA in 16.1-20% [5, 15, 17].

The posterior inferior cerebellar artery (PICA) has the most complex, tortuous and variable course of all cerebellar arteries. It is intimately related to the cerebellomedullary fissure, the lower half of the ventricular tectum, the inferior cerebellar peduncle and the suboccipital surface [17]. The PICA emerges from the vertebral artery close to the lower edge of the olive, and then passes around the medulla oblongata [8, 17, 18]. The PICA emerges from the vertebral artery (VA) in 61%-82% of the cases, and with a lower incidence from the basilar artery (BA), the internal carotid, and the posterior meningeal artery. The presence of a main trunk has been described (84%-88%), which it bifurcates into medial or rostral, and lateral or caudal branches [12]. When the PICA is absent, the territories it irrigates are supplied by the other cerebellar arteries [12].

The territories supplied by the cerebellar arteries are in a dynamic equilibrium expressed in settings where, when the petrosal surface and part of the posterior inferior area of the cerebellum are supplied by the AICA, the territory of the PICA is smaller, or vice versa. Similarly, in the presence of an arterial hypoplasia or agenesis, the other cerebellar arteries alter their trajectory to irrigate the territory that would correspond to the varying vascular structure. However, qualitative and quantitative information on the global distribution patterns of cerebellar artery variants is scarce [3]. These morphological characteristics must be taken into account for diagnostic imaging, for surgical approaches, and for the interpretation and management of clinical events involving these structures [1, 15, 16, 17].

The clinical implications of the cerebellar arteries are related to the possibility of an embolic or thrombotic occlusion that may result in an infarction of a part of the pons, or of portions of the cerebellum, with the resulting edema, hemorrhage and death. On the other hand, these vascular structures can be the origin of neurovascular compression syndromes affecting the oculomotor, trochlear, trigeminal, abducens, facial, and vestibulocochlear nerves [15].

An adequate knowledge of the distribution of the irrigation of the cerebellum allows us to understand the complex clinical events observed when these vascular structures are injured, and is crucial for the success of surgical approaches to the posterior cranial fossa. This work is intended to generate significant information about the distribution of the cerebellar arteries and its territories, through the perfusion of its vascular beds in fresh cadaver specimens.

Methods
This descriptive cross-sectional study evaluated the irrigation of the vermis and hemispheres of 93 cere-
bella obtained from fresh cadavers that underwent necropsy at the Institute of Legal Medicine and Forensic Sciences in Bucaramanga, Colombia. This research was approved by the Ethics Committee of Universidad Industrial de Santander.

After dissection of the neck muscles, a bilateral channeling of the proximal segments of the vertebral arteries and the internal carotid was performed with a catheter No. 14, through which it was practical to wash the vascular beds with saline and then 80 ml of polyester resin was perfused (85% palatal GP40L mixture and 15% styrene), impregnated with mineral red dye.

Subsequently, the brain was removed from the cranial vault, the brain-stem blocks including the cerebellum were resected, and the cerebellar arteries were dissected, as well as their collateral branches from their origin to their distal segments. A digital caliper (Mitutoyo®) was used to measure the external diameter of the vessels at 0.5 cm from their respective origins. The trajectories and territories irrigated by the branches of these arteries were determined.

For cases with a distribution variant, four patterns were established on the basis of the dominant cerebellar artery or branch: Type I, characterized by the SCA irrigating the upper and posterior inferior surfaces of the cerebellum; Type II, characterized by a dominant AICA that supplies the anterior and posterior inferior surfaces of the cerebellum; Type III, characterized by a PICA that irrigates the peduncle-cerebellar fissure and the petrosal and posterior inferior surfaces of the cerebellum; and Type IV, defined as a shared dominance of the SCA and the PICA due to a hypoplastic or absent AICA.

For SCA dominance three subtypes were described: Subtype Ia, characterized by dominant hemispheric lateral branch of the SCA; Subtype Ib characterized by the pontocerebellar fissure being irrigated by a marginal branch; Subtype Ic, where the flocculus and the pontocerebellar fissure are irrigated by the marginal and lateral branches respectively.

For Type II, AICA dominance, three subtypes were described: Subtype IIa, a single, non-bifurcated artery; Subtype IIb, an artery that divides into lateral and caudal branches; Subtype IIc, the AICA bifurcates in medial and lateral branches.

For Type III, PICA dominance, three subtypes were described: Subtype IIIa, when the PICA replaces completely an agenesis of the AICA; Subtype IIIb, when the lateral branch of the AICA is absent, its territory is irrigated by the PICA; Subtype IIIc, when the medial branch of AICA is absent, its territory is supplied by the PICA.

For specimens with shared dominance two subtypes were described: Subtype IVa, when the AICA is absent or hypoplastic, the cerebellar territory is irrigated by branches of the SCA and the PICA; Subtype IVb, when the PICA is hypoplastic, an AICA irrigates the petrosal surface of the cerebellum and the lateral segment of the posterior inferior surface, as well as a SCA irrigates the peduncle cerebellar fissure.

Each one of the pieces were photographed with a digital camera. The continuous variables were analyzed using Student’s t test, whereas discrete variables were analyzed using Pearson’s Chi² test. The results were evaluated using the statistical software “Epi-Info 3.5.4”. The level of significance was set at p < 0.05.

Results

The territory irrigated by each one of the cerebellar arteries was described in a paired manner in the 93 stem and cerebellum blocks. The calibers of the SCA, AICA and PICA were 1.46 ± 0.2 mm, 1.02 ± 0.35 mm and 1.45 ± 0.37 mm, respectively.

There were 180 SCA (96.8%) and 6 agenesis (3.2%), 156 AICA (83.9%) and 30 agenesis (16.1%), and 172 PICA (92.5%) with 14 agenesis (7.5%). The usual irrigation was observed in 44 (47.3%) cerebellar blocks (Figure 1), whereas 49 (52.7%) specimens showed cerebellar irrigation variants. Of the
variants, 23 (46.9%) had unilateral distribution and 26 (53.1%) bilateral distribution.

Of the 72 cerebellar hemispheres with changes in irrigation, in the right side there were 41 (56.9%) and in the left side 31 (43.1%), with no statistically significant differences (p=0.13).

The distribution patterns of cerebellar irrigation showed the presence of dominance due to ACS in 9 (12.5%) specimens, AICA in 46 (63.9%) specimens, PICA in 7 (9.7%), and shared dominance in 10 (13.9%). The greater dominance of the AICA over the other cerebellar arteries was statistically significant (p=0.001).

For SCA dominance, Subtype Ia was found in three (33.3%) specimens, characterized by a dominant lateral hemispheric branch emerging from the caudal branch, distributed through the superior lateral surface of the cerebellar hemisphere, and ending in the posterior inferior aspect, giving rise to

Figure 1: Frontal view of the cerebellum. Right side of the cerebellum with normal irrigation. Left side shows a Posterior inferior cerebellar artery with origin in the basilar artery.

Figure 2: Left side of the cerebellum. Superior cerebellar artery shows a dominant lateral hemispheric branch, that irrigates the posterior-inferior surface of cerebellum with hypoplasia of posterior inferior cerebellar artery.

Figure 3: Left side of the cerebellum. Superior cerebellar artery shows a dominant lateral hemispheric branch, that irrigates the posterior-inferior surface of cerebellum with hypoplasia of posterior inferior cerebellar artery.
Figure 4: Frontal view of the cerebellum. Right side of the cerebellum with a dominant posterior inferior cerebellar artery that irrigates the cerebellum-pontine fissure, petrosal and posterior-inferior surface of cerebellum. This fact is due to the agenesis of the anterior inferior cerebellar artery.

For PICA dominance, Subtype IIIa was observed in 3 (42.8%) specimens, Subtype IIIb in 2 (28.6%) cases, and Subtype IIIc in 2 (28.6%) specimens. In the absence of the lateral branch of the AICA (Subtype IIb), before entering the tonsillar medullary fissure the PICA emits a lateral cortical branch that is projected toward the pontocerebellar fissure, thus supplying the territory usually irrigated by the AICA, (Figure 4).

For shared dominance, Subtype IVa was observed in 7 (70%) specimens, and subtype IVb in 3 (30%) specimens. The hemispheric lateral branch of the SCA and small cortical branches originating from the PICA irrigate the pontocerebellar fissure and the petrosal surface of the cerebellum that are not irrigated by an absent or hypoplastic AICA; this feature is observed in subtype IVa (Figure 5).

Figure 5: Frontal view of the cerebellum. Left side of the cerebellum without anterior inferior cerebellar artery, that it has been supply by the artery posterior inferior cerebellar artery with origin in the basilar artery, and by the lateral hemispheric branch of the superior cerebellar artery.

For AICA dominance, Subtype IIa was found in 8 (17.4%) specimens; Subtype IIb in 22 (47.8%) cases, and subtype IIc in 16 (34.8%). In Subtype IIb, the AICA bifurcates at the level of the flocculus in a lateral branch that is projected onto the pontocerebellar fissure, and a voluminous caudal branch that is projected laterally onto the petrosal surface of the respective cerebellar hemisphere; then, this branch makes a loop and relates to the upper surface of the amygdala, ending up in the posterior inferior surface of the cerebellum; this subtype supplies the territory corresponding to the absent or hypoplastic PICA (Figure 3).

to cortical branches that replace the hypoplasia of the lateral branch of the PICA (Figure 2); Subtype Ib was observed in five (55.6%) cases, and Subtype Ic (11.1%) in one specimen.

For AICA dominance, Subtype IIa was found in 8 (17.4%) specimens; Subtype IIb in 22 (47.8%) cases, and subtype IIc in 16 (34.8%). In Subtype IIb, the AICA bifurcates at the level of the flocculus in a lateral branch that is projected onto the pontocerebellar fissure, and a voluminous caudal branch that is projected laterally onto the petrosal surface of the respective cerebellar hemisphere; then, this branch makes a loop and relates to the upper surface of the amygdala, ending up in the posterior inferior surface of the cerebellum; this subtype supplies the territory corresponding to the absent or hypoplastic PICA (Figure 3).
Discussion

The caliber of the SCA reported in previous studies within a range of 1.5-1.67 mm [1, 5, 7, 15] is larger than what is found in the present study (1.46 mm). In our study, the AICA had a caliber of 1.02 mm, i.e., near to the lower limit of the 1-1.37 mm range reported by other authors [1, 5, 7, 15], whereas the caliber of the PICA of 1.45 mm measured in our series is in the middle segment of the 1.2-1.84 mm range reported in previous studies [1, 7, 8, 15].

Agenesis of the AICA is an anatomical expression reported in a significant number of specimens both in our work (16.1%) and in previous studies; for the AICA a figure of 2-36.1% has been reported [1, 5, 15, 16, 17]. The agenesis of the PICA observed in the present study (7.5%) is slightly lower than what has been reported in other population groups, within a range of 9.6-38.4% [1, 5, 15, 16, 17, 20]. The variations of the cerebellar irrigation related to arterial origins, agenesis, duplication, calibers, distribution of irrigated territories, have been reported previously [1, 16] in 65.2-88.3%. In our series, this variability was observed in 52.7%. The wide variability of cerebellar irrigation can be explained by differences in the size of the specimens, methodologies used, and the biological characteristics of the population groups assessed.

The various works that have reported variations in the cerebellar arteries have pointed out those expressions in a particular manner for each artery, but have not typified or grouped the different variants in an overall cerebellar irrigation spectrum. Atkinson [1] reported variations of the AICA and the PICA in a paired manner, but failed to typify or report them in a quantitative manner. This paper showed the variability of the cerebellar irrigation, and carried out a systematic and comprehensive classification, which enriches the anatomical concept and is very useful for the diagnosis and clinical-surgical management of events involving these structures.

The location and extent of the infarctions caused by occlusion of the cerebellar arteries are given mainly by the nature of the cause (embolism vs thrombosis), anatomical variations of these vessels, characteristics of inter-arterial anastomoses, and hemodynamic factors. Anatomical variations observed in our series in 52.7%, primarily include the origin and dominance of a cerebellar vessel that determines the size, branching, and cerebellar territory irrigated [13, 17, 19].

The occlusion of the AICA results in a syndrome that impacts primarily the brainstem and the middle cerebellar peduncle, which includes paralysis of the facial and vestibulocochlear nerves caused by the involvement of these nerves and their nuclei; vertigo, nausea, vomiting, and nystagmus caused by lesions of the vestibular nuclei and their connections with the nuclei of the vagus nerve [3, 14, 17].

The occlusion of the PICA, named lateral medullary syndrome, includes ipsilateral hypoesthesia of the face caused by the involvement of the trigeminal tract, dysphagia, dysarthria, and dysphonia as a result of an injury in the nucleus ambiguous; ataxia, dizziness, vertigo, nystagmus and homolateral cerebellar signs caused by an injury of the vestibular nuclei and of the archicerebellum and paleocerebellum [9, 17, 19].

The occlusion of the SCA, albeit rare, produces a characteristic clinical picture that results from the infarction of the superior cerebellar cortex, the dentate nucleus and sensory tracts located in the tegmentum of the rostral pons [6, 17, 19]. Patients with an injury of the SCA have dysarthria, which may be associated with mild ataxia, ipsilateral dis symmetry, and axial lateropulsion [2, 10, 11]. However, this cerebellar involvement spectrum that emerges from the injury of each one of the cerebellar arteries changes either little or substantially in the presence of some of the variant expressions reported in the present study, a first order circumstance for the diagnosis and management of clinical or surgical events that impair the blood supply to the cerebellum.

The recovery and survival of many patients after the occlusion of one of the arteries of the cerebe-
llum are attributed to the adequacy of the collateral circulation of the other cerebellar arteries. The size of the infarct zone after occlusion of the AICA, for example, is inversely related to the size of the PICA and the SCA, and to the size and number of anastomoses with these arteries. In the event of an occlusion of the AICA, if this artery is of a good caliber and concomitantly the PICA is small, the collateral circulation is likely to be poor, thus creating an unfavorable situation of morbidity and even mortality [17].

The SCA can establish points of contact or compression with the oculomotor, trochlear, or even trigeminal nerves; the AICA may affect the facial and vestibulocochlear nerves, whereas, the PICA can impact the nerves that emerge from the retro-olive sulcus. This vascular compression may increase after the fifth decade of life, when arterial tortuosity increases due to the atherosclerotic process. However, the anatomical variations associated to the origin and course of the cerebellar artery facilitate the contact with and compression of the related nerves [4, 17].

Revascularization surgery of the posterior circulation involving some of the cerebellar arteries relies on the presence of collateral flow abundantly supplied by the dominant cerebellar artery. These are bypass procedures of relatively small but important areas of the brainstem and the cerebellum [5, 7]. Although bypass procedures can reduce morbidity and mortality, the knowledge of the anatomical characteristics of the cerebellar vasculature plays an important role in preoperative planning and in the proper location for the anastomosis. For these procedures it must be taken into account that variations in the origins, diameters, territories irrigated, and arterial anastomoses can give rise to various clinical outcomes. For clinical and surgical activities, unfamiliarity with the common variations of the cerebellar circulation can lead to mediocre [1].

The high variability observed in the present study is consistent with previous reports. The diverse anatomical expressions of the cerebellar arteries were typified in relation to their dominance and territories irrigated, useful for the diagnosis and clinical-surgical management of the cerebellum blood supply.

Conclusion
The high variability of the cerebellar arteries observed in the present study is consistent with previous reports. The diverse anatomical expressions of the cerebellar arteries were typified in relation to their dominance and territories irrigated, useful for the diagnosis and clinical-surgical management of the cerebellum blood supply.

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References


