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Anatomico-radiologic study of the distribution of the suboccipital artery of Salmon

Veronica Macchi[a], Andrea Porzionato[a], Aldo Morra[b], Anthony V. D'Antoni[c], R. Shane Tubbs[d], Raffaele De Caro[a,*]

[a] Institute of Human Anatomy, Department of Molecular Medicine, University of Padova, Via A. Gabelli 65, 35127 Padova, Italy
[b] Section of Radiology, Euganea Medica Center, Via Colombo 3, Sant'Agostino Di Albignasego, Padova, Italy
[c] Division of Pre-clinical Sciences and Department of Surgery, New York College of Podiatric Medicine, New York 10035, USA
[d] Children's Hospital, 1600 7th Avenue South, Birmingham 35233, USA

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ABSTRACT

Objectives: The frequency of suboccipital injections to treat headaches has increased. The third segment of the vertebral artery is located in the suboccipital triangle and its main muscular branch, the suboccipital artery of Salmon (SAS), supplies blood to the suboccipital muscles. The purpose of this study was to radiographically investigate the morphology and territory of distribution of SAS.
Patients and methods: Computed tomography angiographs of brains of 50 subjects (25 female, 25 men, mean age 70.2 years) were analyzed.
Results: SAS was present in 48% of subjects. The vessel was present bilaterally in 37.1%, and had a mean (SD) luminal diameter of 1.71 (0.34) mm and mean (SD) length of 36.42 (17.1) mm. SAS was found to have two morphologic patterns: (1) a single main trunk with collateral branches (52.6%) and (2) a short common trunk that divided into two branches (48.4%). The SAS supplied the obliquus capitis inferior, semispinalis capitis, and splenius capitis muscles. When the SAS was absent, the suboccipital muscles were supplied by a branch of the occipital artery. No anastomoses were found between the SAS and occipital artery.
Conclusion: The suboccipital muscles are vascularized by the SAS and occipital artery. The detailed course of the SAS is important for clinicians and surgeons who perform procedures in the suboccipital region.

1. Introduction

The vertebral artery (VA) commonly arises from the first part of the subclavian artery, passes through the foramina in the transverse processes of the first six cervical vertebrae, and then curves medially behind the lateral mass of the atlas to enter the cranium via the foramen magnum [1]. The vessel can be regionally divided into 4 segments [2,3]. The first segment (V1) is from the vessel's origin from the subclavian artery to its entrance into the transverse foramen of the C6 vertebra [4–6]. The second intraosseous segment (V2) ascends through the transverse foramina of the cervical vertebrae [7]. The third segment (V3) begins as the artery exits the transverse foramen of the C1 vertebra [4,8]. It courses medially, just superoposteriorly to C1, and then courses superoanteriorly to penetrate the posterior atlanto-occipital membrane and dura mater [9]. The fourth segment (V4) of the VA is the intracranial portion.

The VA gives rise to various branches that supply muscular, osteoarticular, meningeal, medullary, and radicular structures. In particular, the V3 segment gives rise to muscular or radiculo-muscular and meningeal branches [4,10]. The muscular branches supply the deep muscles of the suboccipital region and they may anastomose with the occipital, ascending and deep cervical arteries [1]. The artery that branches from the V3 segment to supply these muscles is called the suboccipital artery of Salmon (SAS) [2,4,5,11]. The SAS is not always present and in cadaveric studies its frequency has been reported to be from 20% to 67% [4,5] and in radiologic studies 9.8% [12].

From a clinical perspective, suboccipital steroid injections that target the greater occipital nerve have been used as an alternative to oral steroids in the treatment of cluster headaches [13,14]. Suboccipital nerve blocks have been used to treat chronic migraine headaches because they are an attractive alternative to orally administered prophylactic therapy [15], which further emphasizes the clinical relevance of the SAS.

* Corresponding author at: Institute of Human Anatomy, Department of Molecular Medicine, University of Padova, Via A. Gabelli 65, 35127 Padova, Italy. Tel.: +39 049 8272327; fax: +39 049 8272319.
E-mail address: rdecaro@unipd.it (R. De Caro).

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The purpose of this study was to radiographically analyze the morphology and branching patterns of the SAS, and to document which muscles these branches perfuse.

2. Material and methods

Our institutional review board approved the study, and we did not obtain informed consent because the study was retrospective.

Fifty subjects ($N = 50$) were randomly selected (25 females and 25 males with a mean age of 70.2 years) from the archives of a radiology center (Euganea Medica, Padova). The subjects had undergone computed tomography angiography (CTA) of the brain for suspected atherosclerosis.

CTA scans were obtained with a Philips Brillance iCT (Philips Medical Systems; Best, The Netherlands), obtained during administration of intravenous contrast medium (Omnipaque 350 mg/ml, GE Healthcare Ireland, Cork, Ireland, 50 ml). Analysis and post-processing of the CTA scans were carried out on an Aquarius Workstation (version 3.6.2.3; TeraRecon, San Mateo, California). Source images and 2D–3D reconstructions were reviewed at the workstation (Fig. 1a and b). The following characteristics were recorded: (1) presence and number of SASs, identified as vessels that supplied blood to the suboccipital muscles and related tissues according to George and Laurian [2,11]; (2) site of origin of the SAS; (3) caliber of SAS at the level of origin including its length, course, number of branches and pattern of distribution; (4) territory of vascularization; and (5) analysis of vascularization of suboccipital muscles. During the analysis the intraluminal area of the vessel with contrast medium was measured without including wall thickness. Therefore, it is more accurate to describe lumen diameter rather than the caliber of the vessel. Analyses were independently conducted by two radiologists, who were blinded to subject identification. In cases of disagreement, the two radiologist collegially rectified the disagreement. To measure the luminal diameter at a right angle to the long axis of the vessel, multiplanar reformatting following curvilinear planes were realized in all subjects. In this type of images, measurements are always made in the transverse plane (Fig. 1c and d). Results are reported as mean (SD) values and ranges. Statistical analyses were performed using a Student *t*-test. A $p < 0.05$ was considered significant (GraphPad Software Inc., San Diego, CA, USA).

3. Results

We found 46 SASs (45.7%) with 26 on the left side (51.4%) and 20 on the right side (40%) in 24 subjects (48%). In all subjects with a SAS (100%), the vessel branched off the V3 segment. In 20 subjects (37.1%), the SAS was bilateral and in 4 cases (8.5%) the SAS was present only on the left side and absent on the right side. In all subjects the SAS was a single vessel except in one subject who had two on the left and one on the right (Fig. 2e). Mean (SD) luminal diameter of the SAS at its level of origin from segment V3 was 1.71 (0.34) mm, being on the left side 1.77 (0.39) mm and on the right side 1.66 (0.29) mm ($p > 0.05$). Mean length (SD) of the SAS was 36.4 (17.1) mm. On the left side it was 33.7 (19.3) mm and on the right side it was 40.3 (13.8) mm.

The SAS was found to course in two different patterns: type I: a single main trunk with collateral branches; and type II: a short common trunk that divided into two branches (Fig. 2a and b). The type I pattern was found in 24 SASs (52.6%) with a mean length of 31.3 mm. The SAS demonstrated an intramuscular course by entering the obliquus capitis inferior muscle and then ran in the interval between the latter muscle and the semispinalis capitis muscle. The SAS then entered in the semispinalis capitis muscle, emerged from it, and branched into the splenius capitis muscle.

The type II pattern was found in 22 SASs (48.4%) with a mean total length of 46.1 mm, and mean length of the common trunk at 9.26 mm. The SAS was found to be in the interval between the obliquus capitis inferior muscle and the semispinalis capitis muscle, and then divided into two branches: one for the obliquus capitis inferior muscle and the other for the semispinalis capitis muscle. This latter branch, emerging from the semispinalis capitis muscle, branched into the splenius capitis muscle.

When the SAS was present bilaterally, in 37.5% of subjects, the SAS was found to have the type II pattern bilaterally, in 25% of subjects the SAS was found to have the type I pattern bilaterally, and in 37.5% of subjects one SAS was found to have the type I and the other the type II patterns. When the SAS was present unilaterally, it was either the type I or II pattern (50%).

In subjects who did not have a SAS, the suboccipital muscles were supplied by a branch of the occipital artery, a finding that was never observed in those who had a SAS. This branch originated lateral to the splenius capitis muscle and then curved as a single vessel to supply the obliquus capitis inferior muscle and the semispinalis capitis muscle (Fig. 2c and d). No anastomoses were found between the SAS and the occipital artery.

4. Discussion

The V3 (suboccipital) segment of the VA can be subdivided into 2 parts. The horizontal part is formed by the segment of the artery that occupies the groove of the posterior arch of the atlas, and it projects supero-medially from the arch en route to the dura mater. The oblique segment of V3 forms a distal horizontal loop [16]. Alternatively, the V3 segment has been subdivided into two segments, a horizontal one (cushioned in a venous plexus) and a vertical one, which is surrounded by a venous plexus [17]. In a cadaveric study of the muscular branches of segment V3, the SAS was found to originate from the horizontal part of V3 in 70% of subjects and had the same size on both sides. In 30% of subjects, the SAS was larger on the right side (mean diameter, 0.5 mm) [17]. CT angiography has been used to evaluate the luminal diameter of muscle pedicles and perforant vessels [18–22]. With this approach we found that the mean luminal diameter of the SAS at its origin was 1.71 mm, and it was larger on the left side (1.77 mm versus 1.66 mm); this difference was not statistically significant. The major luminal diameter found in the present study can be ascribed to the different techniques since our study was conducted using in vivo CTA.

The frequency of the SAS varies based upon different research methodologies. Cadaveric studies have reported a frequency range of 20–67% [4,5,23] whereas in traditional angiographic studies the range is 50–83% [24,25]. We found the SAS to be present in 48% of subjects and it was bilateral in 37.1% and unilateral in 8.5% of subjects. A previous study used CTA to visualize the SAS and these authors reported a frequency of 9.8% (bilaterally in 4.5% and unilaterally in 5.3% of subjects) [12]. To the best of our knowledge, this present study is the first to report the detailed course and distribution of the SAS using CTA. In fact, two SAS distribution patterns were identified: type I, a main single trunk, with collateral branches (52.6%); and type II, a short common trunk that divided into two branches (48.4%), with the same territory of vascularization.

Previous studies have reported that in 80% of cases, communication exists between the SAS and the branches of the occipital artery [1,17]. This anastomotic communication is part of the suboccipital (cervical) arterial collateral network, together with the muscular branches of the occipital artery (external carotid system), and the deep cervical artery and sometimes the ascending cervical artery (branches of the subclavian). Clinically, connection between segment V3 of the VA and the occipital artery have the potential to develop and maintain adequate blood flow when occlusive