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ORIGINAL ARTICLE

Microsurgical Perspective for Uncommon Variations Associated with the Vertebrobasilar Junction: An Anatomical and Radiologic Investigation

Ali Karadağ[1], Mehmet Şenoğlu[2], Ömer Furkan Turkis[3], Burak Kınalı[4], Mustafa Güvençer[5], Yeliz Pekçevik[6], Lela Okromelidze[7], Erik H. Middlebrooks[7,8], Mahmut Çamlar[1], Necmettin Tanrıöver[9]

[1]Department of Neurosurgery, Health Science University, Tepecik Research and Training Hospital, İzmir, Turkey
[2]Department of Neurosurgery, KTO Karatay University, Medicana International İzmir Hospital, İzmir, Turkey
[3]Department of Neurosurgery, Health Science University, Van Research and Training Hospital, Van, Turkey
[4]Department of Neurosurgery, Bahçelievler Medicana Hospital, İstanbul, Turkey
[5]Department of Anatomy, İzmir Tınaztepe University, Faculty of Medicine, İzmir, Turkey
[6]Department of Radiology, Health Science University, Tepecik Research and Training Hospital, İzmir, Turkey
[7]Department of Radiology, Mayo Clinic, Jacksonville, Fla, USA
[8]Department of Neurosurgery, Mayo Clinic, Jacksonville, Fla, USA
[9]Department of Neurosurgery, İstanbul University-Cerrahpaşa, Cerrahpaşa School of Medicine, İstanbul, Turkey

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Abstract

Objective: Anatomic variations of the vertebrobasilar junction have been described as uncommon, but may have important neurosurgical implications. The aim of this study is to emphasize the importance of the variations during the surgery and report the frequency of detected uncommon variations through cadaver dissection and computed tomography angiography.

Methods: A combined cadaveric and radiologic study was performed to assess for basilar artery fenestration, intervertebral transversal anastomosis, and persistent primitive lateral vertebrobasilar anastomosis. Thirteen formalin-fixed human cadaveric heads were perfused with red- and blue-colored silicone and dissected in a stepwise manner through an endoscopic endonasal transclival approach. Radiologic data from 887 subjects were retrospectively analyzed for the presence of intervertebral transversal anastomosis.

Results: Basilar artery fenestration was found in 7 patients (0.8%), intervertebral transversal anastomosis in 1 (0.1%), and persistent primitive lateral vertebrobasilar anastomosis in 1 (0.1%) by CTA analysis.

Conclusion: Anatomic variations of the vertebrobasilar junction are a rare, but important, finding in vascular neurosurgery practice. We also report the first case of intervertebral transversal anastomosis discovered through human brain dissection.

Keywords: Anatomy, variation, vertebral artery, basilar artery, intervertebral transversal anastomosis

Introduction

Vertebral arteries (VAs) are the supplying component of the vertebrobasilar vascular system, delivering blood to the upper spinal cord, brainstem, cerebellum, and posterior part of the brain. They most commonly originate from the subclavian artery, pass through the transverse foramen of cervical vertebrae, enter the skull through foramen magnum, and merge at the base of the pons to form the basilar artery (BA).[1-3] The VA is anatomically divided into 4 segments (V1-V4). V1, also known as the pre-foraminal segment, is a short segment originating from the subclavian artery extending to the transverse foramen of C6, which then continues as V2, known as foraminal segment. At the C2 level, the V3 segment (atlantic, extradural, extraspinal) of the VA reaches the dura mater. The V4 (intradural) segment extends from the dural penetration to the origin of the BA at the lower border of the pons.[1-4]

Due to the complex embryological development, intracranial blood vessel variations are common among the general population, with duplications, fenestrations, hypoplasia, persistent primitive fetal arteries, and aplasia of arterial segments being the most common entities.[5] Although these variations do not frequently manifest symptomatically, their detection is critical for treatment planning.[6,7] Variations of the VA can be visualized through radiological imaging or cadaver dissection. Computed tomography angiography is a common modality used for blood vessel imaging and is a useful tool for preoperative surgical planning for circulatory pathology.[8-11] In this study, we report the incidence of rare variations associated with VA and BA, as well as review their anatomical and radiological characteristics to address their importance for preoperative planning.

Methods

Anatomical Dissection

The study was approved by the Institutional Ethical Committee Health Science University İzmir Tepecik Training and Research

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Corresponding author: Ali Karadağ, Department of Neurosurgery, Health Science University, Tepecik Research and Training Hospital, İzmir, Turkey
e-mail: egealikaradag@gmail.com
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Hospital (2021/03-08). Thirteen formalin-fixed and silicone-injected adult cadaveric heads without intracranial, extracranial, or brainstem pathology were endoscopically dissected. An endoscopic endonasal transclival approach was performed to assess the vessels of the posterior circulation. Descriptive anatomy was recorded with a 0° and 30° endoscope. After dissection of the nasal passage, the lower and medial parts of the clivus, the anterior arch of C1, and the odontoid were removed. The clival dura was opened vertically to expose the cerebellomedullary cistern, posterior inferior cerebellar artery, anterior inferior cerebellar artery, anterior spinal arteries, proximal part of BA, intradural part of VA, and the vertebrobasilar junction. Also, a vernier caliper (Vernier Software and Technology, Beaverton, Ore, USA), accurate to 0.1 mm, and a goniometer was used to assess the relevant cadaveric anatomy.

Radiological Evaluation

Retrospective analysis of CTAs (including 3D images) of 877 adult human subjects obtained by a 64-slice CT scanner (Aquilion 64, Toshiba Medical Systems, Tochigi, Japan) was performed. The patient cohort was selected from a convenience sample of neurosurgical outpatient clinic patients at our tertiary university medical center imaged in the timeframe of January 2012-2020. Exclusion criteria were as follows: history of posterior fossa surgery, occlusion, tumor, infection, craniovertebral junction anomaly, occipital bone deformity, and/or obvious brainstem pathology. An upper limb vein was used for iodine contrast administration. Images of the CTAs were acquired with the following parameters: 120 kV, 225 mA, slice thickness of 0.5 mm, and reconstruction interval of 0.3 mm. The evaluation of the CTAs was performed by 3 experienced physicians (2 neurosurgeons and 1 radiologist) for the existence of basilar artery fenestration, intervertebral transversal anastomosis (IVTA), or persistent primitive lateral vertebrobasilar anastomosis (PPLVBA) using 3D reconstruction software (AquariusNET, Tera-Recon).

Statistical Analysis

Statistical analysis was performed by Statistical Package for Social Science (SPSS Inc., Chicago, IL, USA) version 16.0. Anatomic and radiologic data were expressed as mean, SD, and range.

Results

Radiological Evaluation

Retrospective analysis of the 887 healthy patients who have undergone CT angiography consisted of 451 men and 426 women with an average age of 56.2 (range 17-82). Imaging revealed IVTA in one patient (0.1%) located in the V4 segment (Figure 1). A proximal BA fenestration located at the proximal segment with a small slit-like configuration was observed in 7 patients (0.8%) with the length of the BA fenestration measuring 5.61 (±3.06) mm (Figure 2a-g). An incidental unruptured aneurysm located at the proximal part of the vertebrobasilar junction was observed in 1 patient with BA fenestration (Figure 2e). Persistent primitive lateral vertebrobasilar anastomosis was found in 1 patient (0.1%), with a length of 21.7 mm (Figure 2h). Additionally, the IVTA was visualized inferiorly to the vertebrobasilar junction, and the distance between the vertebrobasilar junction and IVTA was 13.9 mm in the midline.

Anatomical Dissection

Following the endoscopic dissection of the endonasal passage, removal of the clivus, and opening of the dura, the neurovascular structures of the posterior circulation and ventral brainstem

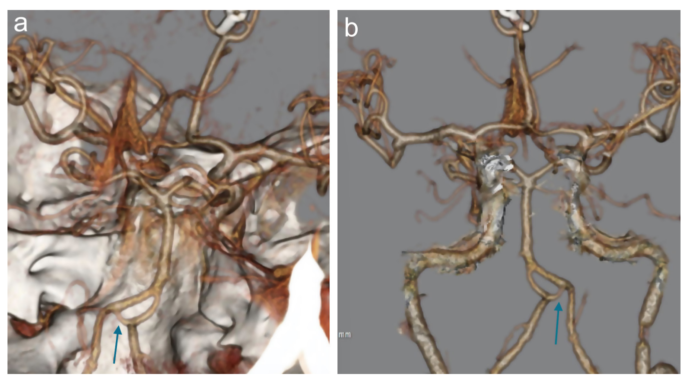

Figure 1. (a, b) Intervertebral transversal anastomosis is shown on 3D–CT angiogram (blue arrow). CT, computed tomography.

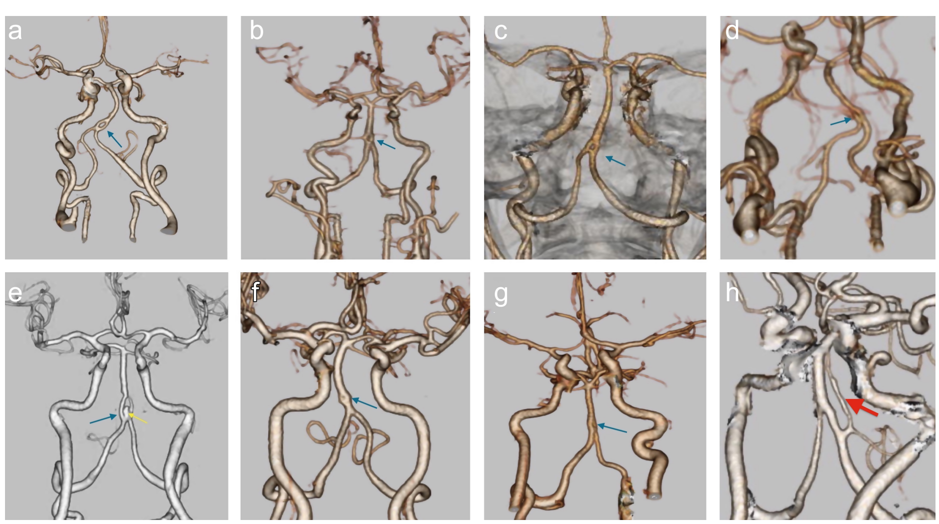

Figure 2. (a-g) 3D–CT angiogram renderings of the basilar artery fenestrations (blue arrows). An aneurysm associated with fenestration is also present (yellow arrow in E). (H) Persistent primitive lateral vertebrobasilar anastomosis, which is a longitudinal connection between the V4 portion of the vertebral artery and proximal basilar artery, is shown (red arrow). CT, computed tomography.

were exposed. The vertebrobasilar junction was located above the pontomedullary junction in 7 cadavers (53.8%), caudally to the pontomedullary junction in 3 cadavers (23.1%), and on the pontomedullary junction in 3 cadavers (23.1%). The BA was located in the midline in 9 cadavers. It crossed the pons curvilinearly in 4 cadavers. Intervertebral transversal anastomosis was incidentally detected during the endoscopic dissection of the ventral brainstem in one cadaver, which was located within 8.6 mm of the vertebrobasilar junction (Figure 3a, b). The 3D anatomical recording of the IVTA was obtained in a stepwise manner. An anastomosis extending transversely was detected between both VAs. The IVTA has been observed as a direct close relationship with both of the anterior spinal arteries extending downward in the midline.

Discussion

In this study, we show the incidence of uncommon anatomic variations of the vertebrobasilar junction. We also report the first cadaveric dissection of an IVTA. The information gained from this study provides insights into the anatomy and frequency of these uncommon variations that can potentially impact neurosurgical procedures. Fenestrations, also known as segmental duplication or partial duplications, can be observed in all cerebral arteries. Basilar artery fenestration is an incomplete fusion defect formed by the fusion of the primitive longitudinal neural artery, usually observed at the proximal segment of the BA. Persistent primitive lateral vertebrobasilar anastomosis is a rare type of BA fenestration attributed to a fusion error of the longitudinal neural arteries during early gestation,[12-14] which was first described by De Caro et al[15] as the remnant of the primitive long tract anastomosis between the right VA and the middle BA.

Basilar artery fenestration size varies, the majority less than 5 mm in length.[16] Similar measurements of BA fenestrations were observed in the framework of our study of CTAs as well. Among 7 cases of BA fenestrations, 5 of them measured less than 2 mm, with the longest reaching 11.8 mm in a patient with a coexistent aneurysm in the fenestrated trunk of the proximal BA (Figure 2e). This finding raises a suspicion regarding the relationship between the length of fenestration and the predisposition for aneurysm formation, which could be attributable to an increased hemodynamic stress due to muscular gaps, known to be a predisposing factor for aneurysm occurrence at the BA origin.[7,17-19]

Intervertebral transversal anastomosis is a rare anatomic variation and the clinical implications are not well understood. Nevertheless, knowledge of such VA anomalies is crucial for surgical treatment planning and execution.[20] According to the literature,

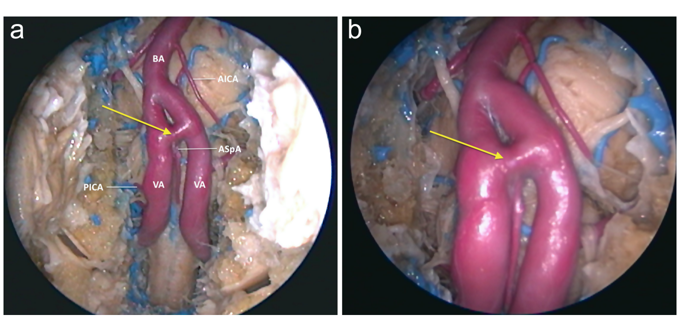

Figure 3. (a, b) Endoscopic cadaver dissection showing the posterior cerebral circulation with intervertebral transversal anastomosis (yellow arrows). AICA, anterior inferior cerebellar artery; AspA, anterior spinal artery; BA, basilar artery; PICA, posterior inferior cerebellar artery; VA, vertebral artery.

IVTA is thought to have no effect on the surgical approach when intradural in location, but it may hold importance for interventions in the adjacent region. In our study, the length of IVTA (measured as a distance between the vertebrobasilar junction and IVTA in the midline) was 13.9 mm and was located below the vertebrobasilar junction. Some studies also have shown fusion of both anterior spinal arteries in a transverse manner behind the IVTA,[21] which was supported by our dissection study. Due to the location of the IVTA between the V4 segments of VAs and the close relationship with the vertebrobasilar junction, separating this from BA fenestrations could be a challenge, while detection of an artery below the posterior inferior cerebellar artery connecting VAs to each other is definitive of IVTA.[21-23]

Intervertebral transversal anastomosis, PPLVBA, and BA fenestration are rare variations of the vertebrobasilar junction. Anatomical better knowledge of vertebrobasilar variations is critical for appropriate surgical intervention and cooperation of the neurosurgeons.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Health Science University İzmir Tepecik Training and Research Hospital (2021/03-08).

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