VIA MEDICA

CASE REPORT

Folia Morphol.
Vol. 82, No. 3, pp. 721–725
DOI: 10.5603/FM.a2022.0059

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Bilateral vertebral arteries entering the C4 foramen transversarium with the left vertebral artery originating from the aortic arch

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[Received: 29 March 2022; Accepted: 4 May 2022; Early publication date: 10 June 2022]

Vertebral arteries (VAs) serve as major blood vessels to the central nervous system. VAs typically arise from the subclavian arteries and ascend separately within the transverse foramina of the cervical vertebrae (C6-C1) before entering the skull at the foramen magnum and joining at the base of the pons to form the basilar artery of the vertebrobasilar circulation. Therefore, variations in the origin and anatomic course of the VAs have implications for invasive medical procedures involving the superior thoracic/cervical regions or the cervical vertebrae. The current case report describes variation in the entry point of both VAs and the site of origin of the left vertebral artery. The variation was revealed during routine dissection of a 72-year-old female cadaver. It was found that the left vertebral artery originated directly from the aortic arch to abnormally enter the transverse foramen of C4 instead of the transverse foramen of C6. The right vertebral artery arose as usual from the right subclavian artery. However, the right vertebral artery also directly entered the transverse foramen of C4 instead of the transverse foramen of C6.
(Folia Morphol 2023; 82, 3: 721–725)

Key words: vertebral artery, aortic arch, cervical vertebrae, transverse foramen

INTRODUCTION

The vertebral arteries (VAs) and their branches provide the blood supply to a majority of important structures of the central nervous system, including the brainstem, spinal cord, cerebellum, and cranial meninges. The VAs typically originate in the root of the neck, branching from the first part of the right and left subclavian arteries. The VAs have an extracranial and intracranial course. For the extracranial course, the VAs pass superiorly to enter the transverse foramina of the C6 vertebra and continue to run through the transverse foramina of each superior cervical vertebra before passing through the foramen magnum to enter the skull. For the intracranial course, the right and left VAs run on the posterior surface of the medulla oblongata and join at the base of the pons to form the basilar artery. The basilar artery then branches into posterior cerebral arteries. This forms the posterior part of the circle of Willis — the arterial circle that provides blood supply to the brain.

Variations in vertebral artery (VA) origin, branching pattern, and course have been seen in both cadaveric [3, 5, 11] and patient populations [1, 4, 6–12]. A study examining existing variations of VA

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origin in both cadavers and living patients found that unilateral abnormalities are most common and was seen in greater than 95% of cases. Of the cases with a unilateral aberrant origin, the left vertebral artery (LVA) was found to be the affected vessel 85.6% of the time. The site of aberrant origin of the LVA was most commonly at the aortic arch, occurring in 97.4% of cases [11]. Another study reported on variations in the entry point of VAs into the transverse foramina of the cervical vertebrae. The study findings showed that the incidence of abnormal entry of VAs into the transverse foramina is as high as 7%. The same study reported on the laterality of the abnormally entering VAs. Investigators found that the majority of VAs that entered the transverse process of the cervical vertebrae at an abnormal level were unilateral (31/33 individuals with an abnormality; 31/250 individuals studied) with only minimal incidence of a bilateral abnormality (2/33 individuals with an abnormality; 2/250 individuals studied) [1].

Knowledge of abnormal origins and unique courses of the VA is crucial for ensuring patient safety during invasive procedures near the thoracic outlet or involving an anterior or lateral approach to the cervical spine. This case report documents cadaveric findings of a LVA originating from the aortic arch and bilateral VAs with abnormal entry points into the transverse foramina of the cervical vertebrae at the level of C4.

CASE REPORT

The superior mediastinum of a 72-year-old female cadaver was dissected by faculty members during the preparation of prosected cadavers for a first-year anatomy course. While utilising Grant's Dissector [2], the sternum and anterior rib cage were reflected inferiorly to gain access to the thoracic cavity. The heart and lungs were carefully dissected and removed to fully expose the ascending aorta, aortic arch, and all relevant vascular branches. The bodies of the left and right clavicles were removed for adequate visualisation of the subclavian arteries. It was noted that the LVA arose directly from the aortic arch and the right vertebral artery arose appropriately from the right subclavian artery. The anterior and lateral neck were then dissected to visualise the courses of the VAs. It was found that both VAs did not enter the transverse foramina of C6. As a result, the anterior and lateral neck were further dissected. The deep muscles of the neck close to the transverse and spinous processes of the cervical vertebrae were reflected to better visualise the abnormal entry and courses of the VAs. It was found that the VAs entered the transverse foramina of the C4 vertebra instead of the C6 vertebra. The VAs continued to travel through the cervical transverse foramina before entering the skull via the foramen magnum. It was found that the VAs then followed a normal intracranial course.

During dissection of the superior mediastinum, an abnormal origin of the LVA was noted. Rather than originating from the first part of the left subclavian artery, it originated directly from the aortic arch. Specifically, its origin was located distal to the origin of the left common carotid artery and proximal to the origin of the left subclavian artery (Fig. 1).

Anterior and lateral neck dissections revealed that the LVA travelled superiorly but did not enter the transverse foramen of C6 as would be expected. Instead, it continued superiorly outside of the transverse foramina of C6 and C5 before entering the transverse foramen of the C4 vertebra (Fig. 2).

Of note, the right vertebral artery was found to have an anatomically normal origin at the first part of the right subclavian artery (Fig. 3). However, it also appears to follow an atypical anatomic course, ascending outside of the transverse foramina of C6 and C5 before entering the transverse foramen of the C4 vertebra (Fig. 2).

After entering the transverse foramina of C4, both VAs were found to ascend normally through the cervical transverse foramina before entering the skull via the foramen magnum. It was noted that the VAs then followed a normal intracranial course.

DISCUSSION AND CONCLUSIONS

This case report involves two different variations of the LVA and one variation of the right vertebral artery found within a single cadaveric donor. In this unique case, the LVA originated as the third direct branch of the aortic arch distal to the origin of the left common carotid artery and proximal to the origin of the left subclavian artery. Furthermore, both VAs followed an abnormal ascending course outside of the transverse foramina of C6 and C5 until entering the transverse foramina at the level of C4 and continuing to ascend normally. Within the existing literature, a LVA originating directly from the aortic arch has been a commonly observed anatomic variant [3, 6, 11]. One study involving analysis of 955 cases of the LVA originating from the aortic arch found that the location of origin seen in this case report — between the left common carotid and left subclavian arter-

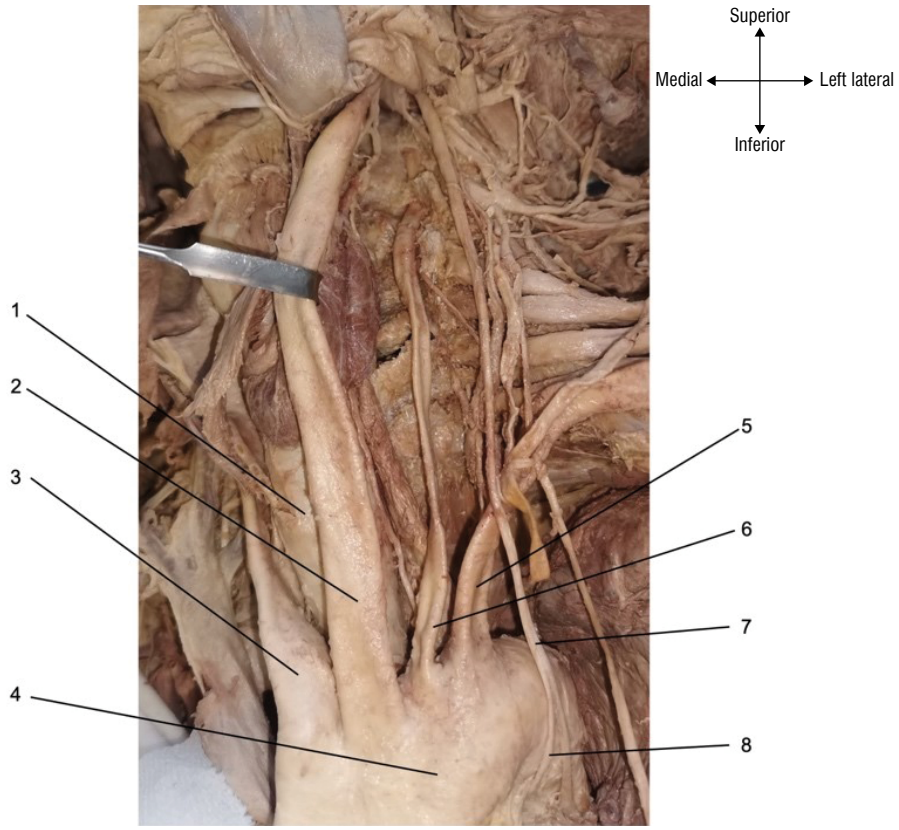

Figure 1. Aortic arch and direct arterial branches. Left vertebral artery originates between left common carotid and left subclavian arteries; 1 — trachea; 2 — left common carotid artery; 3 — brachiocephalic artery; 4 — aortic arch; 5 — left subclavian artery; 6 — left vertebral artery; 7 — left vagus nerve; 8 — left recurrent laryngeal nerve.

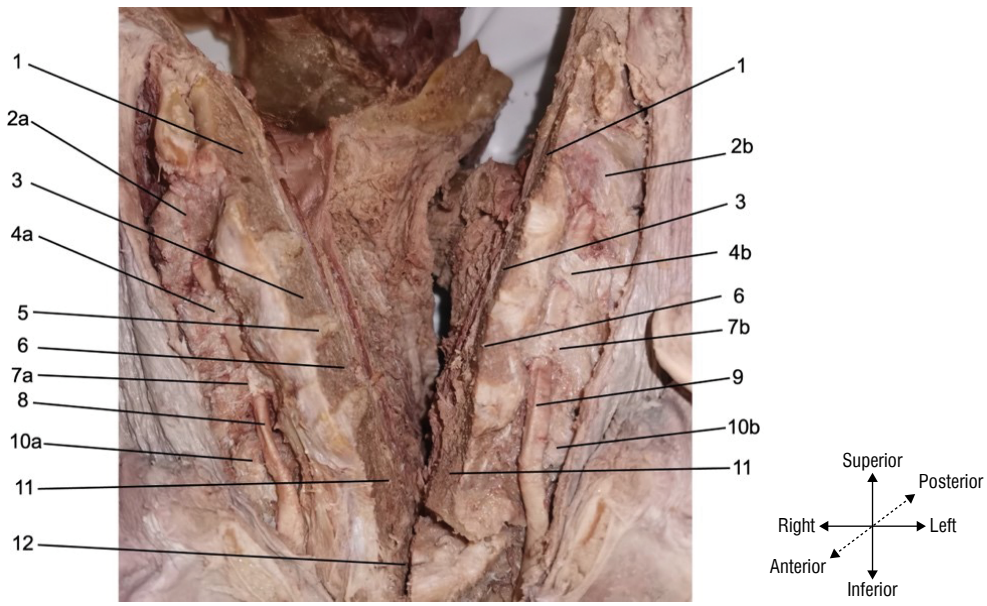

Figure 2. Anterior view of bisected cervical vertebral column. Right and left vertebral arteries directly enter C4 transverse foramen and continue to pass through C3-C1 transverse foramina; 1 — C2 vertebral body; 2a — C2 transverse process (right); 2b — C2 transverse process (left); 3 — C3 vertebral body; 4a — C3 transverse process (right); 4b — C3 transverse process (left); 5 — intervertebral disc; 6 — C4 vertebral body; 7a — C4 transverse process (right); 7b — C4 transverse process (left); 8 — right vertebral artery; 9 — left vertebral artery; 10a — C5 transverse process (right); 10b — C5 transverse process (left); 11 — C5 vertebral body; 12 — C6 vertebral body.

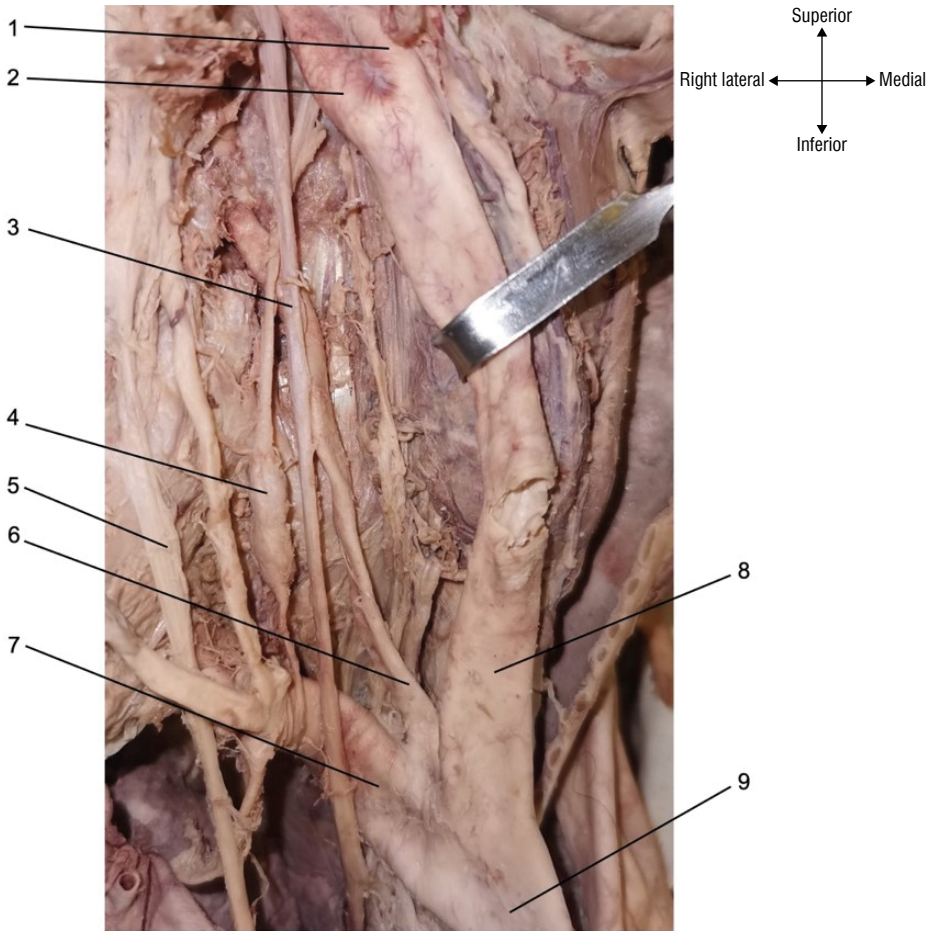

Figure 3. Right vertebral artery originates from right subclavian artery; 1 — right internal carotid artery; 2 — right external carotid artery; 3 — right vagus nerve; 4 — inferior cervical sympathetic ganglion; 5 — right phrenic nerve; 6 — right vertebral artery; 7 — right subclavian artery; 8 — right common carotid artery; 9 — brachiocephalic artery.

ies — was the most common variant, occurring in 782 (81.9%) cases [11]. The same study noted other abnormal sites of origin for the LVA, including 71 (7.4%) cases originating between the right common carotid and left common carotid arteries, 37 (3.9%) cases originating distal to the left subclavian artery, and 46 (4.8%) cases originating at the root of the left subclavian artery [11]. Additional case reports have also noted the LVA originating both completely and partially (i.e. having multiple origins) as the third direct branch of the aortic arch [3, 8]. Right and LVAs that enter the cervical transverse foramina above the level of C6 are a significantly less common variation. A study utilising magnetic resonance imaging of 500 VAs in living individuals cited the incidence of VAs entering the transverse cervical foramina at the level of C6 as being greater than 90% [1]. Entrance at more superior levels was cited as being significantly less common, with the incidence of entrance at the level of C4 being as little as 1% [1]. Furthermore, the same study found most cases of abnormal VA courses to be unilateral, occurring in 31/33 individuals with noted abnormalities, while bilaterally abnormal courses were significantly less common, occurring in only 2/33 individuals noted to have abnormal anatomy [1]. These findings are corroborated in other studies that have examined the anatomy of VAs in living patients via a variety of imaging modalities, including multi-detector computed tomography [9], magnetic resonance imaging [4], and computed tomography angiography [7, 12]. Similar findings have also been noted via direct observation in cadaveric specimens [5]. While each of the individual VA abnormalities exhibited in this report has been documented, the unique combination found here with the LVA originating from the aortic arch and both left and right VAs entering the transverse foramina of the C4 vertebra appears to be exceedingly rare. No known cases that

match the precise anatomy of this cadaveric donor were found within the available literature.

There are many clinical implications that warrant a more widespread awareness of such VA variants among physicians. For example, a case report of a 16-year-old male with a LVA that ascended outside of the transverse foramina of C6-C3 with entrance into the transverse foramen of C2 documented that this individual experienced dizziness and syncope as a result of arterial folding with neck flexion [10]. This case highlights the possibility of abnormal VA anatomy predisposing patients to cerebral ischaemia likely involving the posterior circulation. Such ischaemic changes may have dangerous and potentially life-threatening implications for patients with such anatomy, which warrants clinical consideration. Perhaps a more important application of the knowledge of VA variations is surgical. Iatrogenic injury of the VA is a potentially disastrous complication of surgeries involving the anterolateral neck and cervical vertebrae or injections of the cervical epidural space in patients with cervical radiculopathies. Potential complications include arterial dissection, vasospasm, fistula formation, pseudoaneurysm formation, cerebral ischaemia, or even patient death. This case report highlights the possibility of a VA that ascends outside of the transverse foramina of the cervical vertebrae and therefore without the protection offered by the bony transverse processes. Thus, an awareness of the anatomy of the VAs prior to initiation of surgical procedures that risk injury to these vessels is of paramount importance for patient safety. Preoperative mapping of the VAs may be accomplished via commonly utilised imaging studies such as colour doppler ultrasonography, computed tomographic angiography, or magnetic resonance angiography and may therefore be both widely available and clinically useful in avoiding injury to these vessels. The possible clinical utility of such imaging practices warrants further studies to better characterise the prevalence of anatomic variants of the VAs in specific patient populations as well as the impact on patient outcomes in those who undergo preoperative mapping of the vertebral vasculature.

The findings of this report may therefore be of particular interest to clinicians, as similar unidentified variations of the VAs may increase the potential for complications during invasive procedures in the superior thoracic or cervical regions. The use of preoperative imaging in order to determine the course of the VAs may thus be warranted to avoid such complications and enhance patient safety.

Acknowledgements

The authors acknowledge and thank the donor whose body and tissues were used for this study and for the advancement of medical student and physician education.

Conflict of interest: None declared

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