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Evaluation of vertebral artery variations and arterial dominance in cervical CT angiographic images in Iranian population

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Keywords
vertebral artery, anatomical variation, CT angiography

ABSTRACT

Purpose: The aim of the present study was to determine the characteristics and variations in the origin of vertebral arteries (VA), its level of entry into the transverse foramen, VA diameter, Length of VA, and VA dominance.

Methods: A total of 250 adult patients (143 males and 107 females) were enrolled (Mean age: 60.92±13.44) and scanned with Computerized Tomography angiography (CTA).

Results: The VA entered the C6 transverse foramen in 97.8% of specimens. Abnormal entrance of VA was observed in 4.4% of specimens. The mean length of prevertebral (V1) right and left VA was 81.38±14.38 mm and 82.49±14.16 mm. The mean length of the intraforaminal segment (V2) of the right and left VA was 81.38±14.375mm and 82.49±14.162mm and showed sexual dimorphism. The mean diameter of the right and left VA was 3.297±0.85 and 3.676±0.88, respectively. We found 1(0.4%) left and 1(0.4%) right VA emerging from the aortic arch. The mean right and left VA diameters were 3.28 ± 0.83 mm and 3.6±0.88mm, respectively. A total of 90(0.36) patients were right dominant and 160(0.64) patients were left-dominant. The right VA of aortic arch origin entered the 4th cervical transverse foramina, whereas the left VA entered the 7th cervical transverse foramina. We found that 22(8.8%) of the right and 1 (0.4%) of the left vertebral arteries had distal origin. The results did not show any relationship between gender and origin of VA, diameter of VA, and level of entry. A significant relationship was observed between gender and VA length (P=0.0001).

Discussion: The present study confirms the presence of anomalous in the VA route. Knowledge of such anatomical variations is important in interpreting CTA and may reduce the risk of intraoperative VA injury.

INTRODUCTION

Because of nervous tissue demands, the blood supply of the central nervous system is of special interest. The brain, one of the most metabolically active organs, is reliant on glucose's aerobic metabolism.

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The brain, which accounts for only 2% of body weight, receives 17% of the cardiac output and utilizes 20% of the body's oxygen supply (1). The cessation of cerebral circulation can cause unconsciousness in about 10 seconds. The possibility of vascular origin lesions causing neurological disorders is stronger than any other kind of disease (1). The role of VAs in brain's blood supply is well known. VA injury is rare but any change in VA haemodynamics may cause permanent neurologic deficit, important disorders in cerebellum, brain stem, inner ear and spinal cord (2-5) The VA is a branch of the subclavian artery. It ascends toward the transverse foramen of C6 vertebrae (V1) and then passes vertically through the transverse foramina of C6 to C2 (V2). After leaving the transverse foramen of C2, it runs over the axis and atlas (V3) and enters the cranial cavity (V4). Eventually, the right and left VAs join to form the basilar artery (6, 7).

VA typically originates (50.6–99.9%) from the supero-posterior aspect of the 1st part of the subclavian artery, 0.5–2 cm medial to the thyrocervical trunk origin (6, 8). The right VA (RVA) may be found displaced more than 2 cm medial to the right thyrocervical trunk (RTCT) in 1.4% (17 out of 1228 cases), while the left VA (LVA) may originate from the left thyrocervical trunk (LTCT) in 0.58 % (6, 8). Several congenital anomalies regarding VA have been described (9). Variations of the VA origin usually occur on the left side. The commonest reported atypical VA origin is from the aortic arch with an incidence rate of 5.5%(10-12). Other VA origins include the common carotid artery (CCA), the carotid bulb, external carotid artery (ECA), internal carotid artery (ICA), occipital artery, thyrocervical and costocervical trunk, inferior thyroid artery and the ascending aorta. VAs may also have a dual origin (13-17). The level of entry into the transverse foramen of the left vertebral artery of aortic arch origin was frequently higher than the sixth cervical vertebra (8, 17, 18).

The prevertebral part of the vertebral artery of aortic arch origin was less protected by bone and thus may be accidentally lacerated during surgery. On the other hand, the endovascular approach for supra-aortic lesions has been successful and is now a widely accepted alternative to surgery. Particularly during stenting of subclavian arteries and aortic arch, it might be important to know the dominant VA in decision of which one of the vertebral or subclavian arteries could be sacrificed in case of proximity to the lesion (19).

The advent of multidetector CT has allowed less invasive acquisition of CT angiography from the aortic arch to the intracranial regions with excellent three-dimensional (3D) spatial resolution.

The aim of present study was to determine the characteristics and variations in the origin of vertebral arteries (VA), its level of entry into transverse foramen, VA diameter, Length of VA, and VA dominance.

Materials and methods

This protocol was approved by the AJUMS Ethics Committee in Human Research (IR.AJUMS.HGOLESTAN.REC.1400.171) and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Because the retrospective nature of the study, the informed consent form was waived.

CT angiograms of 250 consecutive patients, who underwent CT angiography for reasons other than evaluation of vertebral artery disease between September 2021 and September 2022, were retrospectively reviewed. There were 143 men (52.7%) and 107 women (47.3%). The mean age of patients was 60.92±13.44 years (range from 12 to 89). The cervical spine CTs were ordered by neurosurgeons and neurologists for the evaluation of carotid artery stenosis, source of subarachnoid bleeding, or for the workup in multiple trauma patients. Patients who met the following criteria were excluded: Subjects with bony abnormalities, such as Klippel-Feil syndrome and ankylosing spondylitis, previous history of cervical spine surgery, patients with rheumatic involvement of the cervical spine, and those with VA aplasia.

All patients were scanned on a commercially available CT scanner (Siemens SOMATOM Sensation, Erlangen, München) equipped with a 64-slice multidetector array. The standard protocol consisted of a timed contrast injection, with images obtained from the aortic arch to the clinoid process.

To identify the level of entrance of the VA into the transverse foramen, both the axial cuts and the three-dimensional reconstructions were then reviewed by an attending board certified neuroradiologist.

The right and left subclavian arteries were identified and traced to their origins and entrances into the foramen transverse. The lengths of the prevertebral (V1) and intraforaminal segment (V2) of the vertebral arteries were measured. The outer diameters of the prevertebral parts of the vertebral arteries were then measured at their mid-lengths.

Results

Table 1 exhibits the detected variations in length, origin, and level of entry of VA. The left VA of 248 (99.2%) and right VA of 227 (90.8%) subjects normally originated from the subclavian arteries. The left VAs of aortic arch origin were in 1(0.4%) of cases, and 1 (0.4%) case from distal part of subclavian artery. The RVAs with aortic arch origin were not detected, and 22(8.8%) patients from distal part of subclavian artery (SA) (Table1).

The length of V1 and V2 segments was more in men than in women and showed a significant difference (P-value < 0.05). However, there was no sexual dimorphism in the right and left diameter of VA (Table 2).

The results did not show dual origin of the LVAs arising from the aortic arch and the left subclavian artery, also did not encounter any cases of the RVAs arising from another vessel. Only two male cases, 1(0.7%) patient with LVA and 1(0.7%) patient with RVA originate from aortic arch was detected.

Most of the LVA entered the transverse foramina of the sixth (98.8%), and only 1.2% entered fifth cervical vertebrae. The level of entry of RVA was 96.8% sixth, 2.4% fifth and only 0.4% (1 patient) fourth cervical vertebrae. The LVA with direct aortic origin proximal to the LSA entered the transverse foramen of the sixth vertebra.

The average length of the prevertebral part of the right and left VA was 81.38±14.38 and 82.49±14.16 mm, respectively. The length of the prevertebral part of the LVA of aortic arch origin was 88 mm.

The average outer diameters of the prevertebral part of the left and right VA were 3.676±0.88 and 3.297±0.85, respectively. No significant difference was observed between male and female groups. The outer diameters of the prevertebral part of the LVA of aortic arch origin measured at mid-length was 2.7 cm. The mean width of the corresponding parts of the LVA of aortic arch origin compared with of subclavian origin were not statistically different.

Fisher's exact test was used to compare VA dominance between both gender. No significant difference was observed between men and women (Table 3). Among 250 patients, right side was found wider in 90(36%) patients and left side was found wider in 160 (64%) patients (Table 3). There was no statistically significant relation between gender and VA dominance.

Discussion

The aortic arch and its branches develop in the early weeks of fetal life (20). The primitive third arch forms the bilateral carotid arteries; the right fourth arch forms the brachiocephalic trunk and RSA; and the left fourth arch forms the aortic arch and LSA and joins the descending aorta. The primitive third arch forms the bilateral carotid arteries; the right fourth arch forms the brachiocephalic trunk and RSA; and the left fourth arch forms the aortic arch and LSA and joins the descending aorta. Bilateral VAs are formed by anastomoses of neural axes between each upper segmental artery. Normally, only the seventh segmental artery, which arises from the SA, persists. Persistence or obliteration of these arches may lead to anatomical variations.

Vertebral arteries in the brain's blood supply has an essential place as being the second largest blood supplier. In case of failure of the carotid artery system with occlusive diseases, VA compensate the circulation by collateral pathways (21).

The entrance and origin of the VA is essential to neck tumor resection as vascular damage may occur when VA goes through the abnormal region. Additionally, the entrance of the VA is of significance to the stellate ganglion block, where the VA is vulnerable to be located in the needle path (22).

The incidence of vertebral artery injury during anterior cervical medical procedures ranges from 0.22% to 2.77% (23-25). The VA is protected by the transverse process in the V2 segment, and iatrogenic injury to the VA is low(26-28). However, if the VA is outside the bony structure, the risk of injury is greater such as at the C7 level in normal patients and in the presence of anomalous VA (27, 29). Therefore, a complete preoperative understanding of the patient's anatomy is crucial to prevent arterial injury and its complications. Various types of VA variation have been reported in the literature, including fenestration, anomalous artery entry, and tortuous

course of the VA in V2 segment with foraminal erosions (29, 30).

The VA may enter the transverse foramen at other levels than C6 (29). In the literature, the incidence of normal entrance ranges from 90% to 93% (22, 23). The prevalence of VA entry at C4 ranges from 0.5% to 1.3%, at C5 ranges from 5% to 6.6%, and at C7 ranges from 0.8% to 5.4% (22, 29, 31). The results from this research are consistent with the previous studies (31). Abnormal level of entrance was observed in 4.4% of subjects (10 VA course), with the level of entrance into the right C4 (0.4%), right C5 (2.4%), right C7 (0.4%), and left C5 (1.2%) transverse foramen. Previous studies show that there were some differences in the rate of variation of VA (22). The variability of anomalous entry level of VA is reported in different population(12, 17, 31-36), which could be explained by sample sizes and structure differences. The findings of this study fills in the gap in Korean population and sheds lights on further related research with a reliable foundation.

Studies shows the frequency of origin of the left VA from aortic arch in the range of about 1–3%(37). The results of present research indicated that the overall variability of origin of VA was 0.4%. In addition, this study found that the origin variation of VA all occurred on the left side, which is consistent with Yi et al.(22) report.

In this inquiry, VA diameter differences in right and left side had been evaluated and dominant side was explained. There are different criteria for the diagnosis of the dominant VA in literature. In a study by Zwiebel et al.(38), they found that left VA is wider than right VA in 73% of a healthy population and reported this as left VA dominance. Turan-Ozdemir et al. (39), reported similar results of left VA dominance in 64% (55/85 patients) with colour Doppler ultrasound. In contrast to earlier findings, there are also studies reporting no differences in diameter of VA, or indicating RVA is wider than LVA (40). In the present study, the right side was found wider in 36% of the patients and the left side was found wider in 64% of the subjects. In a study by Hong et al. (41), they explained the dominant VA with criterion of side to side diameter difference ≥ 0.3 mm in CTA, and found left VA was dominant with a rate of 69.2% (63/91). Songur et al. (42) measured the widths of the VA in a large series of an anatomic study with 109 cadavers, and difference of 1 mm or greater between the widths of VA was accepted as the dominancy criterion. They observed left dominancy in 21.2% and right dominancy in 17.3%. This study couldn't find the gold standard criterion statistically with just only diameter. In the study ahead, using this criterion (1mm), RVA was dominant in 35.7%% of the patients and left VA was dominant in 64.3% of the patients. It seems that diameter could give an idea in assessment of the dominance but it must be also supported by velocities and blood flow volume.

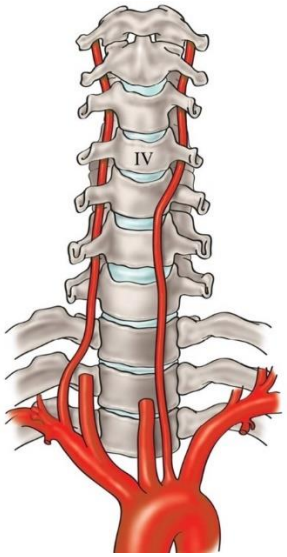

Figure 1. Schematic drawing of the VA anomaly. This picture depicts the aortic arch origin of LVA, its entrance into the transverse foramen of C4, and the entrance of the RVA into the transverse foramen of C6. With courtesy to Edwards et al (10).

Direct aortic origin of the left and right VA between the left common carotid artery and left subclavian artery was found 1.4% of cases. In a similar study by Uchino et al.(17), right VA originating from aberrant right subclavian artery prevalence was 0.4%. The findings of the current study do not support the previous research (4, 43). The study by Ergun et al.(4), showed 13 patients with the variations in the origin of the VA (5.1%). They reported the left VA with direct origin from the aortic arch in 10 (3.9%) patients, and right VA arising from aberrant right subclavian artery in 3 (1.2%) patients with no direct aortic origin.

The present study has some limitations. It is a retrospective single center analysis performed with only the data of VA diameter and without any flow parameters. Also the number of the subjects might be insufficient for such a study about anatomical arterial variations.

Table 1. The results of demographic, origin and vertebral artery level of entrance presented as average ± standard deviation (95% confidence interval). All vertebral artery measurement parameters are in millimeters.

Variable			**Measure**
Age		Mean±SD	60.916±13.44
Sex	Female	Mean±SD	107(42.8)
	Male	Number(Percent)	143(57.2)
Origin of Right vertebral artery	Proximal	Number(Percent)	227(90.8)
	Distal	Number(Percent)	22(8.8)
	Arch	Number(Percent)	0
Origin of Left vertebral artery	Proximal	Number(Percent)	248(99.2)
	Distal	Number(Percent)	1(0.4)
	Arch	Number(Percent)	1(0.4)
Level of entry of Right vertebral artery	C4	Number(Percent)	1(0.4)
	C5	Number(Percent)	6(2.4)
	C6	Number(Percent)	242(96.8)
	C7	Number(Percent)	1(0.4)
Level of entry of Left vertebral artery	C5	Number(Percent)	3(1.2)
	C6	Number(Percent)	247(98.8)

Table 2. The results of length of VA in V1 and V2 part and diameter of VA presented as average ± standard deviation (95% confidence interval). All the parameters are in millimeters. *significant at α=0.05 Level. a= T-test. B= U-Mann Withney.

Variable Name	Total Measure (Mean±SD)	Male Measure (Mean±SD)	Female Measure (Mean±SD)	P-Value
length R (V1+V2)	115.2±17.924	118.66±18.379	110.59±16.267	0.0001*[a]
Right V1 length	33.82±4.592	34.43±4.437	33.02±4.692	0.014*[b]
Right V2 length	81.38±14.375	84.23±14.667	77.57±13.101	0.0001*[a]
length L (V1+V2)	115.27±16.939	118.6±17.71	110.82±14.796	0.0001*[b]
Left V1 length	32.78±4.338	33.48±4.172	31.84±4.396	0.003*[b]
Left V2 length	82.49±14.162	85.12±14.982	78.98±12.195	0.001*[a]
diameter R	3.297±0.8528	3.357±0.9118	3.216±0.7636	0.195[a]
diameter L	3.676±0.8829	3.694±0.8786	3.651±0.8922	0.754[b]

Table 3. The results of VA dominance by digital subtraction angiography among 250 patients in both gender presented. all results are summarized with number of patients and ratio on male and female.

Dominancy		Right Dominance Number(Present)	Left Dominance Number(Present)	P-Value
Gender	Male	54(37.8)	89(62.2)	0.296
	Female	36(33.6)	71(66.4)	
Total		90(35.7)	160(64.3)	

Conclusion

In conclusion, to be aware of which VA is dominant is very important in the interventions in which one of the subclavian arteries must be sacrificed. There are different diameter criteria in the studies for the determination of VA dominance. The present study found that in most cases right VA was dominant in all the groups. Anomalous entrance of the VA into the transverse foramen has been described. This research reports the total prevalence of variations in origin of the LVA as 0.6 % and of the RVA, 8.8 %, as diagnosed by CT angiography. If entering above C6, the pre-entry course of the VA may be at risk for injury during aortic arch or lower neck surgery below

the entry level. It is also important to recognize anomalous origin of the VAs before arterial catheterization to the VAs to reduce examination time and catheterization failure.

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