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Anatomical variations of the pre-transverse segment of the vertebral artery in Indian cadavers

Raveendranath Veeramani[1] and Nachiket Shankar*,[2]

[1]*Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Dhanvantri Nagar, Puducherry, India and* [2]*Department of Anatomy, St. John's Medical College, Bangalore, Karnataka, India*

SUMMARY

Variations of the first segment (V1) of the vertebral artery (VA) are important to spine surgeons and radiologists. The present study was conducted to document the anatomical variations of the V1 segment and estimate side and gender differences, if any. The study was a cross-sectional analytical study performed on 33 adult cadavers (24 male and 9 female) of Indian origin. The V1 segment of 67 VA was dissected and the following parameters were noted: site of origin, level of entry into cervical spine, presence of tortuosity, length, external diameter and presence of hypoplasia. Side differences were estimated using the paired sample T test and Wilcoxon signed rank test. The independent sample T test and Chi square test were used to estimate gender differences. An unusual origin of the right VA from the thyrocervical trunk, in addition to the origin of the left VA from the arch of the aorta, was noted. Stenotic segments were observed in 4.5% of the VA. Rare levels of entry into the cervical column of the V1 segment of the VA included the foramen transversarium of C5 (4.5%) and C7 vertebra (2.5%). Nine per cent of V1 segments showed a high degree of tortuosity. The mean length and diameter of the V1 segments were 3.7±1.5 cm and 4.2±0.9 mm respectively. Hypoplasia was observed in 18% of the V1 segments. The mean length of the V1 was found to be significantly greater on the left side. Male cadavers had a significantly greater external diameter of V1. The knowledge of these variations of the V1 segment of the VA is imperative for the safe performance of anterior spine procedures.

Key Words: Vertebral artery – Pre-transverse segment – Anatomical variations

INTRODUCTION

The vertebral artery (VA) is clinically important for the diagnostic interpretation of angiograms, sonograms, neurovascular interventions, and during surgery of the cranio-vertebral region. An injury to the VA can cause brain stem ischemia and cerebellar infarction (Strub et al., 2006). It is usually described as a branch from the posterior-superior aspect of the subclavian artery (SA) and is divided into four segments (V1 to V4). Segments V1 to V3 represent the extra-cranial VA. The V1 segment or pre-transverse segment extends from the origin of the VA to its entry into the foramen transversarium (FT) of the sixth cervical vertebra (C6). The V2 segment extends from the transverse process of C6 to where the VA exits the axis vertebra. The V3 segment extends from the point of exit from the axis to its entry into the cranium. The V4 segment is intracranial and joins with its fellow at the lower pontine border to form the basilar artery (Buckenham and Wright, 2004).

The V1 segment is more prone for atherosclerotic change, particularly at its origin (Robert and Demetrides, 2004). Additionally, the risk of VA injury during anterior surgical decompression is greatly increased when the anatomy is atypical

*** Corresponding author:** Nachiket Shankar. Department of Anatomy, St. John's Medical College, Sarjapur Road, Bangalore – 560034, India. Tel: +91-9980.3359.95
E-mail: nachiket76@gmail.com

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(Eskander et al., 2010). Anomalies of the extra-cranial branches of the VA are rare (Chiras et al., 1982). Numerous individual case reports have documented anatomical variations of the VA found incidentally on angiograms (Lemke et al., 1999; Kubikova et al., 2008). Though studies describing the anatomical variations of the V1 segment of the VA have been conducted earlier, data from India is scarce (Matula et al., 1997; Ranganath and Manjunath, 2006; Wang et al., 2009; Dodevski et al., 2011). In view of the above reasons, the present study was carried out. The objectives of the present study were the following: 1) To document the anatomical variations of the V1 segment of the VA in Indian cadavers in terms of origin, tortuosity, and level of entry into the cervical column; 2) To estimate the length and external diameter of the V1 segment of the VA; 3) To estimate side and gender differences if any in the above parameters.

MATERIALS AND METHODS

The study was a cross sectional analytical study. Sixty six sides (33 left and 33 right) from 33 embalmed adult cadavers (24 male and 9 female) of Indian origin, available at the Department of Anatomy in St. Johns Medical College, Bangalore, India, were studied. Deep dissection of the neck was conducted to expose the V1 segments on both sides. The V1 segment was traced from its origin to its entry into the FT of the cervical vertebrae. The following categorical variables were recorded: 1) origin; 2) termination; 3) tortuosity. The aspect of the SA from where the VA arose was noted as cranial, caudal, ventral or dorsal. The level at which the VA entered the FT of the cervical vertebrae was noted. The tortuosity was graded as absent, low, moderate or high based on the degree of deviation the artery exhibited from a straight line path. This was decided based on a consensus between the investigators.

The total length and external diameter of the V1 segment were measured using digital Vernier callipers to the nearest hundredth of a millimetre. The proportion of VA with an external diameter less than or equal to 3.5 mm was noted and categorized as hypoplastic (Matula et al., 1997). When the V1 segment was tortuous, it was stretched just enough to straighten it, after which the length was measured. The external diameter was measured at the origin of the VA. Side differences were estimated using the paired sample T test for numerical variables and Wilcoxon signed rank test for categorical variables. The independent sample T test for numerical variables and Chi square test for categorical variables were used to estimate gender differences. A p value less than or equal to 0.05 was considered statistically significant.

RESULTS

In one of the necks, the VA was duplicated on the left side. Thus in all, 67 VA were studied, 33 from the right side and 34 from the left side. For estimating side and gender differences, the cadaver with a duplicated VA was excluded from the analysis.

Origin

The origin of the VA was from the first part of the SA in 96 % (64 of 67) of the arteries. The most common site of origin of the VA among these was from the cranial aspect of the SA (Table 1). Much less common were origins from the dorsal aspect of the SA (Table 1). The other unusual sites of origin were the arch of the aorta (two cases) on the left side and the thyrocervical trunk (one case) on the right side (Fig. 1). The two arteries from the arch of the aorta had an origin between the left common carotid artery and left SA. In one cadaver a duplication of the VA artery was noted on the

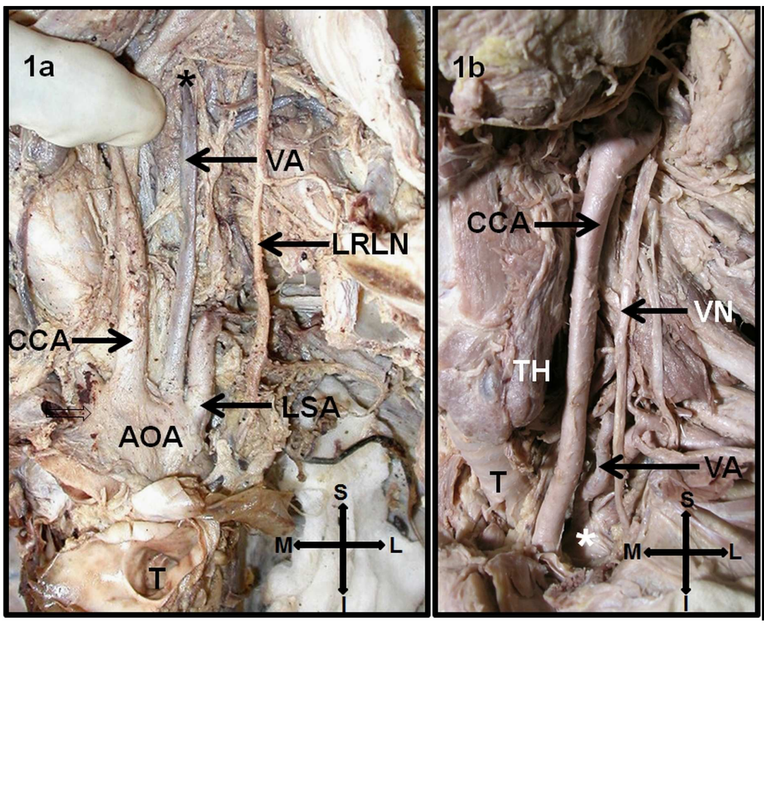

Fig. 1 (a). An anomalous origin of the left vertebral artery (VA) from the arch of the aorta (AOA). The origin is between the left subclavian artery (LSA) and left common carotid artery (CCA). LRLN - left recurrent laryngeal nerve; T - trachea; * - point of entry into foramen transversarium; L - lateral; M - medial; S - superior; I - inferior. **(b)** Another VA with an anomalous origin from the arch of the aorta. The VA has a highly tortuous course. CCA - common carotid artery; T - trachea; TH - thyroid gland; VN - Vagus nerve; * - point of origin of VA from the arch of aorta. L - lateral; M - medial; S - superior; I - inferior.

left side, as has already been mentioned. Both the arteries arose from the cranial aspect of the SA. Three (4.5%) of the arteries had a stenotic segment within a centimetre of their origins, while one artery (1.5%) had a dilatation close to its origin. No significant side or gender differences were noted in the site of origin of the VA (Table 1).

Tortuosity

The V1 segment was tortuous in a little more than half of the necks. Of these, this was in most of the instances mild in nature (Table 1). However, on the right side, a moderate degree of tortuosity was noted more commonly (Table 1). A high degree of tortuosity (Fig. 1) was observed much less often (Table 1). No significant side or gender differences were found.

Level of entry into the cervical column

The pre-vertebral segment of the VA entered the FT of C6 in a large majority of the cases. The other levels of entry noted were the FT of C5 or C7 (Table 1). In the cadaver with the duplicated VA on the left side, one of the arteries entered the FT of C6 while the other artery on the same side entered the FT of C7. In the same cadaver, the VA entered the FT of C7 on the right side. Entry into the FT of C5 was only noted on the right side (Table 1). One of these VA arteries arose from the thyrocervical trunk. Though anomalous entries were noted more frequently in females (2 of 18, 11%), this was not significantly different from males (1 of 46, 2%).

Length and external diameter

The mean length of the V1 segments was significantly greater on the left side (Table 1). The length of V1 was greater on the left side in 24 of 32 (75%) necks. Though the mean length of V1 in males was greater (3.9 ± 1.5 cm) than females (3.3 ± 1.2 cm), this was not significant. The mean external diameters of the V1 segments were greater on the left side but not significantly so (Table 1). In 20 of 32 (62%) cadavers, the diameters were greater on the left side. Males had a significantly greater (p=0.05) external diameter (4.4 ± 0.8 mm) as compared to females (3.9 ± 1 mm). A slightly higher but not significant proportion of hypoplastic arteries were noted on the right side (Table 1). Females had a greater proportion of hypoplastic V1 segments (5 of 18, 28%) compared to males (6 of 46, 13%), though this was not significant. Hypoplastic arteries were noted bilaterally in only one cadaver. In the cadaver with a duplication of the VA on the left side, one of the arteries was observed to be hypoplastic.

DISCUSSION

Origin

An anomalous origin of the left VA is more common than that of the right VA (Cavdar and Arisan, 1989). The prevalence of an anomalous origin is 1 to 3% on the right side and 5% on the left side (Cavdar and Arisan, 1989; Yamazaki et al., 2004). In the present study an anomalous origin was noted in 3% of the VA on the right side and 6% on the left side with an overall prevalence of 4.5%. In a previous large study, the VA was found to arise from the cranial and dorsal aspects of the SA in almost equal proportion (Matula et al., 1997).

However in the present study, most of the VA (88%) arose from the cranial aspect of the SA. Of the anomalous origins of the left VA, an origin from the aortic arch is by far the most common,

Table 1. Descriptive statistics and side differences in the vertebral artery between the categorical and numerical variables.

Parameter	Combined n=67	Right n= 32c	Left n = 32c	p value*
Origin	**CS DS A TC** 57 7 2 1 (85%) (10.5%) (3%) (1.5%)	**CS DS A TC** 25 6 0 1 (78%) (19%) (3%)	**CS DS A TC** 29 1 2 0 (91%) (3%) (6%)	0.380^{a}
Level of entry into FT	**C5 C6 C7** 3 62 2 (4.5%) (93%) (2.5%)	**C5 C6** 3 29 (9%) (91%)	**C5 C6** 0 32 (100%)	0.083^{a}
Tortuosity	**No Mild Mod Highly** 30 19 12 6 (45%) (28%) (18%) (9%)	**No Mild Mod Highly** 15 6 8 3 (47%) (19%) (25%) (9%)	**No Mild Mod Highly** 13 12 4 3 (41%) (37.5%) (12.5%) (9%)	0.637^{a}
Length (cm) Mean ± SD (Range)	3.7 ± 1.5 (1.7 – 10.12)	3.4 ± 1.2 (1.92 – 8.21)	4.1 ± 1.7 (1.7 – 10.12)	0.002^{b}
Diameter (mm) Mean ± SD (Range)	4.2 ± 0.9 (1.8 – 6.44)	4 ± 0.8 (1.8 – 5.67)	4.3 ± 1.6 (2.32 – 6.44)	0.169^{b}
Hypoplasia	**Present Absent** 12 55 (18%) (72%)	**Present Absent** 6 26 (19%) (81%)	**Present Absent** 5 27 (18.5%) (81.5%)	0.739^{a}

A – arch of aorta; CS – cranial aspect of subclavian artery; DS – dorsal aspect of subclavian artery; TC – thyrocervical trunk; C5, C6, C7 – foramen transversaria of the 5th, 6th and 7th cervical vertebrae; Mod – moderate; cm – centimeters; mm – millimeters; SD – standard deviation; * - p value ≤ 0.05 is considered significant; a – Wilcoxon signed rank test; b – Paired t test; c – The cadaver with a duplicated VA on the left side was excluded for estimating side differences.

as noted in the present study. The anomalous origin of the right VA from the thyrocervical trunk does not fall under any of the categories previously described (Lemke et al., 2009). This variant has been described in detail by the present authors as a case report (Veeramani and Shankar, 2011).

Duplication of the VA on either side has been described in the literature (Bergman et al., 1988). A duplicate origin of the left VA has been described from the arch of the aorta and the left SA (Cheng et al., 2009). If a duplicated VA is seen on the right side, both commonly arise from the SA (Lie, 1972; Cavdar and Arisan, 1989). Double origins from the SA and the brachiocephalic trunk or thyrocervical trunk have also been described (Kiss, 1968; Lippert and Pabst, 1985). In the present study, a double origin of the VA from the SA was noted on the left side. In the present study, 4.5% of the arteries showed stenotic segments near their origins, which is similar to a previous study which showed a prevalence of 5.4% (Kumar Dundamadappa and Cauley, 2013).

Tortuosity

Tortuosity of the V1 segment is not uncommon, with previous large studies showing prevalence varying from 27% to 47.5% (Tschabitscher et al., 1991; Matula et al., 1997; Curylo et al., 2000). The proportion of V1 segments showing tortuosity in the present study was 55%, though in a majority of these the tortuosity was of a mild degree. In a previous study, tortuosity was classified according to the geometric plane as horizontal, sagittal and transverse (Matula et al., 1997). However, in the present study tortuosity was classified as mild, moderate or high, as it was often difficult to define the plane of tortuosity. Another possibility to be considered is that the tortuosity might have been due to problems with either fixation or conservation.

Level of entry into cervical column

The VA may enter the FT of the second to the seventh cervical vertebra (Fazan et al., 2004). Previous large studies have shown that the VA enters the FT of C6 vertebra in over 90% of individuals, which is similar to the present study (Adachi, 1928; Eskander et al., 2010). In the remaining individuals, the point of entry is usually at the level of C5. Some authors have reported that entry into C4 vertebra as being more frequent than C7 (Adachi, 1928; Eskander et al., 2010), while others have observed the converse (Cavdar and Arisan, 1989). The present study found an equal prevalence of entry into C5 and C7 vertebra at 3%. There are also few reports in the literature in which the VA does not pass through the FT of the cervical vertebrae (Vincentelli et al., 1991).

Length and external diameter

In the present study, the length of the V1 segment of the VA was significantly greater on the left as compared to the right. This could possibly be attributed to the fact that the VA arises from the arch of the aorta more commonly on the left side as compared to the right, contributing to an increased mean length on that side. The asymmetric origins of the SA on the right and left sides may also be a plausible explanation for differences observed in the length of the V1 segment, though this needs further investigation.

The left V1 segment usually has a wider calibre as compared to the right (Bergman et al., 1988; Dodevski et al., 2011). In the present study, though mean diameters were greater on the left side, this was not significant. A survey of the literature shows that the mean diameter of the left VA is usually greater than the right (Dodevski et al., 2011). Another study showed that the left VA was dominant in 48% of the cases, while the right VA was larger in 14% (Touboul et al., 1986). Other studies have noted that the left VA is larger than the right in 42-51% of subjects and right larger than the left in 32-41% (Fisher et al., 1965; Thevenet and Ruotolo, 1984). The prevalence of hypoplasia was found to be between 6% to 28% in previous studies (Ranganath and Manjunath, 2006; Chuang et al., 2008; Eskander et al., 2010; Peterson et al., 2010). The prevalence in the present study falls within this range.

Limitations

The exact age of the cadavers was not known. If this information was available, it could have provided some insight into the age changes in the V1 segment. The number of female cadavers studied was low compared to the males. Thus the study may not have been adequately powered to pick up significant gender differences. In spite of this, significant gender differences were noted in the external diameters of the V1 segments.

In conclusion, the present study described the anatomical variations of the V1 segment of the VA in Indian cadavers and documented side and gender differences. These variations of the V1 segment of the VA need to be kept in mind during imaging and for the safe performance of anterior spine procedures.

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REFERENCES

ADACHI B (1928) Das Arteriensystem der Japaner: Kyoto, Verlag der Kaiserlich-Japanischen Universität zu Kyoto.

BERGMAN RA, THOMPSON SA, AWW AK, SAADEH FA (1988) Compendium of human anatomic variations: text, atlas, and world literature. Urban & Schwarzenberg, Baltimore, 71-72, 358-359.

BUCKENHAM TM, WRIGHT A (2004) Ultrasound of extracranial vertebral artery. *Br J Radiol*, 77: 15-20.

CAVDAR S, ARISAN E (1989) Variations in the extracranial origin of the human vertebral artery. *Acta Anat*, 135: 236-238.

CHENG M, XIAODONG X, WANG C, YOU C, MAO B, HE M, ZHANG C (2009) Two anatomic variations of the vertebral artery in four patients. *Ann Vasc Surg*, 23: 689.e1-5.

CHIRAS J, LAUNAY C, GASTON A, BORIES J (1982) Thoracic vertebral artery. *Neuroradiology*, 24: 67-70.

CHUANG YM, HWANG YC, LIN CP, LIU CY (2008) Toward a further elucidation: role of vertebral artery hypoplasia in migraine with aura. *Eur Neurol*, 59: 148-151.

CURYLO LJ, MASON HC, BOHLMAN HH, YOO JU (2000) Tortuous course of the vertebral artery and anterior cervical decompression: a cadaveric and clinical case study. *Spine*, 25: 2860-2864.

DODEVSKI A, LAZARESKA M, TOSOVSKA-LAZAROVA D, ZHIVADINOVIK J, ALIJI V (2011) Morphological characteristics of the first part of the vertebral artery. *Prilozi*, 32: 173-188.

ESKANDER MS, DREW JM, AUBIN ME, MARVIN J, FRANKLIN PD, ECK JC, PATEL N, BOYLE K, CONNOLLY PJ (2010) Vertebral artery anatomy: a review of two hundred fifty magnetic resonance imaging scans. *Spine,* 35: 2035-2040.

FAZAN VP, CAETANO AG, FILHO OA (2004) Anomalous origin and cervical course of the vertebral artery in the presence of a retroesophageal right subclavian artery. *Clin Anat*, 17: 354-357.

FISHER CM, GORE I, OKABE N (1965) Atherosclerosis of the carotid and vertebral arteries – extracranial and intracranial. *J Neuropathol Exp Neurol,* 24: 455-476.

KISS J (1968) Bifid origin of the right vertebral artery: a case report. *Radiology,* 91: 931.

KUBIKOVA E, OSVALDOVA M, MIZERAKOVA P, EL FALOUGY H, BENUSKA J (2008) A variable origin of the vertebral artery. *Bratisl Lek Listy,* 109: 28-30.

KUMAR DUNDAMADAPPA_S, CAULEY K (2013) Vertebral artery ostial stenosis: prevalence by digital subtraction angiography, MR angiography, and CT angiography. *J Neuroimaging*, 23: 360-367.

LEMKE AJ, BENNDORF G, LIEBIG T, FELIX R (1999) Anomalous origin of the right vertebral artery: review of the literature and case report of right vertebral artery origin distal to the left subclavian artery. *Am J Neuroradiol*, 20: 1318-1321.

LIE TA (1972) Congenital malformations of the carotid and vertebral arterial systems, including the persistent anastomoses. In: Vinken PJ, Bruyn GW (eds). *Handbook of Clinical Neurology.* North-Holland, Amsterdam, pp 289-339.

LIPPERT H, PABST R (1985) Arterial variations in man: classification and frequency. JF Bergmann-Verlag, München, pp 30-38.

MATULA C, TRATTING S, TSCHABITSCHER M, DAY JD, KOOS WT (1997) The course of the prevertebral segment of the vertebral artery: anatomy and clinical significance. *Surg Neurol,* 48: 125-131.

PETERSON C, PHILLIPS L, LINDEN A, HSU W (2010) Vertebral artery hypoplasia: prevalence and reliability of identifying and grading its severity on magnetic resonance imaging scans. *J Manipulative Physiol Ther*, 33: 207-211.

RANGANATHA SASTRY V, MANJUNATH KY (2006) The course of the V1 segment of the vertebral artery. *Ann Indian Acad Neuro,* 9: 223-236.

ROBERT LH, DEMETRIDES D (2001) Vertebral artery injuries. *Surg Clin North Am,* 81: 1345-1356.

STRUB WM, LEACH JL, TOMSICK TA (2006) Left vertebral artery origin from the thyrocervical trunk: a unique vascular variant. *Am J Neuroradiol,* 27: 1155-1156.

THEVENET A, RUOTOLO C (1984) Surgical repair of vertebral artery stenosis. *J Cardiovasc Surg,* 25: 101-110.

TOUBOUL PJ, BOUSSER MG, LAPLANE D, CASTAIGNE P (1986) Duplex scanning of normal vertebral arteries. *Stroke,* 17: 921-923.

TSCHABITSCHER M, FUSS FK, MATULA C, KLIMPEL S (1991) Course of the arteria vertebralis in its segment V1 from the origin to its entry into the foramen processus transversi. *Acta Anat,* 140: 373-377.

VEERAMANI R, SHANKAR N (2011) An unusual origin of the right vertebral artery from the thyrocervical trunk. *IJBMS*. http://www.ijbms.com [online]

VINCENTELLI F, CARUSO G, RABEHANTA PB, REY M (1991) Surgical treatment of a rare congenital anomaly of the vertebral artery: case report and review of the literature. *Neurosurgery,* 28: 416-420.

WANG S, WANG C, LIU Y, YAN M, ZHOU H (2009) Anomalous vertebral artery in craniovertebral junction with occipitalization of the atlas. *Spine*, 34: 2838-2842.

YAMAZAKI M, KODA M, YONEDA M, AIBA A, MORIYA H (2004) Anomalous vertebral artery at the craniovertebral junction in a patient with Down syndrome. *J Neurosurg Spine,* 3: 338-341.