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The applied anatomy and clinical significance of the proximal, V1 segment of vertebral artery

Short title: The V1 segment of a sample of Chinese cadavers

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Abstract

Background: The aim of the study was to probe the morphological features of the proximal segment (V1) of vertebral artery (VA) in a sample of Chinese cadavers.

Materials and methods: The origin, course and outer diameter at origin of the prevertebral part of the VAs were evaluated in 119 adult cadavers.

Results: 94.12% of the VAs originated from the subclavian arteries, bilaterally. The variant origins were present in 5.88% of the cadavers and all originated directly from the arch of the aorta. All the variations were observed on the left side of male cadavers. The average outer diameters at origin of the normal and variation groups were 4.35 ±1.00 mm and 4.82 ±1.42 mm, respectively (P=0.035). In the normal group, no variation group, the average diameter in the males was significantly larger than
that in the females (4.50 ±0.99mm, 3.92 ±0.92mm), respectively, P=0.000. In addition, only 5 cadavers in the normal had hypoplastic VAs (4.20%, 4 males, 3 right sided). VAD was present in 91 (69 males) out of 112 cadavers and more common on the left (n=48). In addition, 3 cadavers satisfied conditions for coexistence of VAD and VAH. All 7 cadavers in the variations group exhibited VAD that was more common on the right side (n=5).

**Conclusions:** The morphologic variations and frequencies described above have implications for the early prevention, abnormal anatomy detection, accurate diagnosis, safe surgery and endovascular treatment on cardiovascular and neurological disease.

**Key words:** vertebral artery, anatomy, vertebral artery hypoplasia, vertebral artery dominance

**INTRODUCTION**

The vertebral artery (VA) takes origin from the supero-posterior subclavian arteries on each side. It is the primary blood supply for posterior circulation central nervous system structures such as the spinal cord, inner ear, the brainstem, cerebellum, midbrain, thalamus, and areas of temporal and occipital cortices [10, 32]. Therefore, any change in VA haemodynamics may cause important disorders in cerebellum, brain stem, inner ear and spinal cord. Incidentally, atherosclerosis, cardioembolism and congenital disorders are leading causes of ischemic strokes of the posterior circulation territory [3]. In addition, posterior circulation strokes represent approximately 20% of all ischemic strokes [13], thereby making the vertebral arterial tree very important clinically.

Normally, the vertebral artery is divided into four segments, namely: proximal segment (V1), transverse process segment (V2), suboccipital segment (V3), intracranial segment (V4) [47]. V1 is the most proximal segment from the VA origin to point of entry into the initial foramen transversarium, usually at the level of the sixth cervical vertebral body [24]. The tapering diameters, bilaterally, of the vertebral arteries’ V1 segments are usually unequal [42], ranging from 2mm to 7.5mm. The current study focused mainly on the V1 segment and explored its variations such as the aberrant origin, size, and presence of vertebral artery dominance (VAD) or vertebral artery hypoplasia (VAH). The V1 segment is more prone to atherosclerotic change, particularly at its origin [24]. Additionally, the risk of VA injury during
anterior surgical decompression of the cervical spine is greatly increased when the anatomy is atypical [8]. Although a few studies describing the anatomical variations of the V1 segment of the VA have been conducted earlier, data from China is scarce [22, 38].

According to Hong et al. [15], VAH is associated with pontine or posterior inferior cerebellar artery territory infarctions. In addition, the incidence of posterior circulation infarctions is higher in VAD patients, especially in the posterior inferior cerebellar and basilar artery territories [48]. However, there is no consensus among researchers and clinicians over the exact definitions of vertebral artery dominance and vertebral artery hypoplasia [7]. Discordance also exists in the literature regarding which side is dominant in several populations. Some researchers have reported left vertebral dominance [35, 51], others right [1, 7] whilst others reported no difference at all [29]. Previously, VAH was defined as a VA diameter <2.5 mm [11] and VAD was the side to side diameter difference ≥0.3mm [14]. To provide anatomical data for medical education, clinical diagnosis and treatment, 119 cadavers were evaluated for VAs’ dimensional characteristics, course and origin variations. For comparison purposes, we also examined different criteria from the literature to determine the VAD, VAH and rate of co-dominance of hypoplasia of the VA emphasizing some morphological, functional and clinical data about this rare vascular abnormality, in order to offer useful information to anatomists, radiologists, vascular and head and neck surgeons.

MATERIALS AND METHODS

The present study was based on a sample of 119 formalin fixed adult cadavers which were offered by the Department of Human Anatomy, Sun Yat-sen Zhongshan School of Medicine (90 males, 29 females). Their ages ranged from 55 to 85 years old. All cadavers were inspected for any evidence of surgery performed on the cervical and axillary regions and none of the them had any apparent history of surgery. Information available on each cadaver does not include cause of death or medical/surgical history. The vertebral arteries of both sides of 119 cadavers were dissected and evaluated for dimension, length, origin (normal or aberrant), course (tortuosity) and level of entry into respective foramen transversarium.

Morphometry
The external diameters at the beginning of each vertebral artery were measured using a Vernier calipers with an accuracy of 0.02 mm.

**Statistical analysis**

We used SPSS 20.0 for statistical analysis. Descriptive statistics (mean, minimum, maximum, range, standard deviation, and variance) were computed using SPSS. Comparability between groups was tested using the independent two-sample t-test for continuous variables and the Chi-square test for categorical variables. Continuous variables were represented as mean ± standard deviation, and categorical data were represented by number (N) and percentage. The t-tests were performed to compare the data between different side and gender in normal origin group and anomalous group. Chi-square tests were performed to analyze the relationship between sex, origin and the incidence of VAD and VAH. P-values less than 0.05 were considered statistically significant.

**RESULTS**

**Origin of vertebral artery**

Of the 119 cadavers, 75.63% (90/119) were male and 24.37% (29/119) were female. In 112 (94.12%) cadavers, the VA originated from the usual first part of the subclavian artery, bilaterally, while variations were present in the remaining cadavers (n=7, 5.89%). In the variations group, the left vertebral artery originated directly from the arch of the aorta of all the 7 male cadavers. There were no other associated anomalies on the V1 segment.

**Morphometries of the vertebral arteries**

The detailed presentation of the morphometries of the vertebral arteries (V1) in normal and variation groups are summarized in Table 1. The average V1 VA diameter in the normal group was 4.35 ±1.00mm, which was significantly smaller than that in the variation group (4.82 ±1.42 mm, P=0.035). In addition, average male cadavers’ VA diameter was found to be significantly wider (4.50 ±0.99mm) than that of females (3.92 ±0.92mm; P= 0.000). The difference between the diameters of the left and right VAs in the normal group were not statistically significant, although the right side was generally wider.

All the cadavers with aberrant, aortic origin (variation group) of VAs were male.
Although the cadavers’ right VAs were generally larger (5.06±0.96mm) than those on the left (4.82±1.42mm), the difference was not statistically significant (p=0.717) (Table 1). In addition, table 1 shows that the recorded minimum diameters of both left and right VA (3.27mm) in this group were way above the set criteria for VAH (diameter <2.5mm). As also shown in table 1, the average difference between the thinnest and the thickest vertebral arteries was greater in males (5.31mm) than that of females (3.88mm).

**Sex and incidence of VAH and VAD**

Results in Table 2 show the incidence of VAH and VAD among the males and females in the normal and variation groups. In the normal group, there were only 5 cadavers with VAH according to the criteria of Gaigalaite et al. [11] giving an incidence of 4.20%. In 3 cadavers there was left VAH while the remaining 2 exhibited right sided VAH. Four of the cadavers with VAH were male. As noted earlier, the VA diameter in the variation group were all larger than the set criterion for VAH.

As shown in table 2, occurrence of VAD in the normal group was observed in 91 cadavers out of 112. Figure 1 shows a typical case of right sided vertebral dominance in which the left vertebral artery (2.18mm, labeled 2) was thinner than the right vertebral counterpart (5.24mm, labeled 7). Results from our normal group also showed that VAD was more common on the left (n=48) then on the right (n=43). More males had VAD (n=69) then females (n=22). The differences between sexes and sidedness of the dominance were, however, not statistically significant.

On the other hand, in the variations group, all the 7 cadavers exhibited VAD according to the criterion of Han et al. [14]. Table 2 also shows that right sided VAD was present in 5 cadavers while left sided VAD occurred twice. We also noted that 3 cadavers exhibited co-existence of VAD and VAH in three cadavers. This scenario is also depicted in Figure 1. This figure is an example of situation where the difference in the sizes of the two arteries satisfied the criteria for VAD (difference between the left and right vertebral arteries was above 0.3mm) as well as that of VAH in which one of the vertebral arteries has a diameter under 2.5mm.

**Course of Vertebral arteries**

Upon close examination, we observed that there was nothing usual about the course of the V1 segments of the vertebral arteries in all the 112 cadavers in the
normal group with respect to origin, course, branches, tortuosity and entry into the foramen transversarium of the sixth cervical vertebra. However, in 4 of the 7 cadavers in the variations groups we observed that the right V1 segments had some sinuous course which were not very prominent and appeared to be molded around the convexities formed by the seventh cervical vertebral transverse process. The left side V1 had a fairly straighter upward course. In 4 of the cadavers in the variations group we observed that the entry level of the left V1 segment occurred at the 5th cervical transverse foramina instead of the 6th, thus taking a longer upward course. There were no other abnormalities such as dual arteries, duplication, fenestration, tortuosity, kinking, arachnoid cysts, aneurysmal formation which were apparently observed in this region.

DISCUSSION
The two vertebral arteries (VA), which usually arise from the ipsilateral subclavian arteries, converge into the basilar artery as an important blood supply of the CNS structures such as brainstem and cerebellum. It is not uncommon to find variations in the prevertebral segment of the vertebral artery because the region is devoid of bony structures [40]. Although the aberrant anatomic origins of the VA are rare and usually is asymptomatic [24], it is critical to identify them before performing open surgery of the supra-aortic vessels or endovascular interventions [34, 43], among other interventions. In addition, direct aortic origin of the left VA is the most frequent anatomic variant of the VA, which predisposes to arterial dissection [43]. In the present study, all the origin variations occurred on the left side and the left vertebral artery originated directly from the arch of the aorta.

Attempts to set a universally agreed upon criterion for diagnosing VAH have not yielded consensus as yet and operational definitions of VAH vary between diameters of less than 2 to less than 3 mm [17]. Numerous studies use different subjects often made up of small samples leading to the discordance. Park et al. [25] defined VAH as VA diameter less than 2mm on MRI and found an incidence of 35.2% in a Korean sample (3.4% of the sample had VAH bilaterally). Earlier on Touboul et al. [33] defined VAH as lumen diameter <3 mm and reported an incidence of 6% in 50 healthy subjects while a little later Delcker et al. [6] reported 1.9% VAH (<2 mm) in 451 subjects who underwent ultrasonography. In our cadaveric study we report a VAH incidence of 4.20% which is within range of previously reported incidences although
there is a wide variance of sample and methods of assessment.

However, there have been extremes of incidences reported previously in the literature. For instance, Zhang et al. [46] reported that 64 of 245 patients (26%) had VAH as defined by the lumenal diameter of a vertebral artery ≤2 mm. Ideally normative data and diagnostic criteria must be population specific and sometimes patient specific because VA diameter showed a significant dependence on sex as well as anthropometric parameters (height) [11]. In addition, accompanying data from modern radiological tools such as colour-coded duplex ultrasonography must be employed in each study or clinical population [17] in order to augment diagnosis. VAH is not rare in the normal population [25], and is frequent in patients with non-cardioembolic posterior circulation ischemic events rather than in asymptomatic patients [11]. As a consequence, researchers have provided evidence which suggest that people with VAH may have a high probability of posterior circulation strokes [46], with atherosclerotic susceptibility and ipsilateral lesions in the vertebral artery territory partly because the smaller of paired arteries are more vulnerable to occlusion [20, 25].

Vertebral artery dominance (VAD) is a common congenital variation of vertebral artery. Several researchers have reported equal sizes of vertebral arteries only in 6 to 26% of patients in different settings and populations [17]. Therefore, vertebral arteries are either of equal size (vertebral artery codominance) or one side is significantly wider (vertebral artery dominance) [18]. The left side is most commonly found to be dominant in vertebral artery origin and co-dominance is the second most common form in vertebral arteries [15, 17, 18]. Just like VAH, there is no consensus on the definition of VAD. In the present study, we adopted Hong et al. [15] standard that VAD is present when both sides of the VA diameters differed by ≥0.3 mm. This is however a very sensitive definition that give little room for codominance and therefore incidence of VAD is inherently high (82.35%). In our present study, there was a tendency towards right hand dominance, although this difference was not statistically significant. Previously, other researchers reported right vertebral dominance in their samples [1, 7]. Interestingly, other researchers have used a wider vertebral artery diameter difference of more than 1.2mm. According to Zhu et al. [49], VAD was present when the difference in diameters of two vertebral arteries was greater than 1.2 mm. They found that the left VA was larger (dominant) as was reported previously using the same criteria [17, 23]. Using this criterion on our data
only reduces the prevalence of VAD, as expected. However, in the clinical practice and research settings, there is need to balance sensitivity of tests and also integration of clinical data and that of other modalities where present in order to make a diagnosis of VAD or associate it with cerebrovascular events. Table 3 summarizes the salient features and different criteria used by various researchers and clinicians in previous publications. This table shows widespread discordance in the criteria used and, therefore, calls for modality-based criterion that would be valid, reliable and sensitive to detect both VAD and VAH where present in clinical practice. Such data would be useful to make diagnosis accurate and endovascular as well as surgery safer.

Previously ignored as an embryological vestige, accumulating evidence now supports the notion that VAD has significant connections with the angulation and elongation of basilar artery as well as being a risk factor for posterior circulation cerebral events [23, 25, 49]. Therefore, it is being consistently shown that VAD increases the risk of posterior circulation infarction [49]. It is thought that the unequal mechanical force of vascular wall in the bilateral vertebral arteries and the high vascular resistance of the side opposite to the of VAD leads to a high probability of atherosclerosis lesions. These, coupled with the bending of BA, changes the blood flow pattern of the posterior circulation [15]. Consequently, the occurrence of the common cardiovascular disease like atherosclerotic disease and transient ischemic attack (TIA) in the territory becomes commonplace [22]. Some scholars have suggested that VAD contributes to the vertebrobasilar dolichoectasia, a condition in which the vertebral/basilar artery is elongated, distended and tortuous leading to diminished blood supply and hemodynamic changes manifest clinically by compression of the cranial nerves, ischemic symptoms or intracranial bleeding [19, 44]. As a result, VAD has been posited as an independent risk factor of vertigo and also related to the severity of this condition [5, 45]. However, in the present study we only observed a slight tendency towards tortuosity of the right vertebral artery in 4 cases that exhibited VAD. Tortuosity was not very apparent, although the left vertebral artery of our samples took a longer course owing to aortic origin inferiorly and foramen transversarium entry above the usual C6 level.

There is no general agreement on the underlying mechanism of asymmetry in the vertebral artery diameter. Ren et al. [28] suggested that most people prefer to use right hand, resulting in more exercise in the left cerebrum. The more the exercise the left cerebrum obtain, the more blood it needs, causing the enlarged aortic origin of the left
vertebral artery or the left VAD. However, Cagnie et al. [2] had earlier on found that no correlation between differences in vertebral artery diameter and hand dominance existed, thus there is no significant connection between VAD and hand preference. As we noted previously [27], the embryologic origin of the present variation (left VA arising aortic arch), arises when the anastomosis between the 6th and 7th intersegmental arteries does not develop on the left side. In this scenario, the 6th intersegmental artery remains, leading to the left vertebral artery arising from the aortic arch between the left common carotid and subclavian arteries. It is, thus, possible that such a direct origin of the left vertebral artery from the high-pressure aortic arch would result in a wider artery consistent with our present observation that all the cadavers in this group had no VAH but wide bore left VAs. However, further research is required on this matter. Lastly, since some scholars also used VAD and VAH interchangeably, there is an urgent need for clearer definition between them. There is also apparent overlap in discussing their clinical significance [48, 49, 50]. As observed in our sample, some 3 cadavers had both VAD and VAH present and whether that adds to the burden and heightened risk of stroke remains to be elucidated. We, therefore, also suggest further study on this matter.

**CONCLUSIONS**

In summary, we have described the VA morphologic variations and their frequencies. The study provides basic information about the relative frequency and potential clinical importance of vertebral artery hypoplasia and dominance. Results from this study suggest that vertebral artery hypoplasia is less common while vertebral artery dominance is very common. Such implications should be considered in patients requiring thoracocervical and cranial care, especially those with subclavian artery stenosis, and patients in whom the left subclavian artery is to be covered by a thoracic endograft. Our study has emphasized some morphological, functional and clinical data about these rare vascular abnormalities, in order to offer useful information to anatomists, radiologists, vascular and head and neck surgeons. We have also attempted to summarize and highlight the width and breadth of various criteria used by different researchers, diagnosticians and clinicians in defining VAH and VAD in the hope that, in future, there would be convergence towards universal definitions.
Acknowledgements

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vertebral artery morphological variation: report of 37 cases. Journal of Third Military Medical University. 2014.


51. Zwiebel WJ. Introduction to vascular ultrasonography, second edition: Grune and Stratton Inc., Orlando, FL; 1986;37

Table 1. Descriptive summary of V1 vertebral artery measurements in normal and variation groups

<table>
<thead>
<tr>
<th></th>
<th>Normal group morphometries</th>
<th>Variation group morphometries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All sides</td>
<td>Side</td>
</tr>
<tr>
<td>Number (N)</td>
<td>both</td>
<td>Left</td>
</tr>
<tr>
<td>Mean (X)</td>
<td>4.35</td>
<td>4.44</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.07</td>
<td>2.07</td>
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<tr>
<td>Maximum</td>
<td>7.38</td>
<td>7.32</td>
</tr>
<tr>
<td>Range</td>
<td>5.31</td>
<td>5.25</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.00</td>
<td>1.01</td>
</tr>
<tr>
<td>Variance</td>
<td>1.01</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Table 2. VAH/VAD; incidences in normal and variation groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sex: all cadavers</th>
<th>Variation group</th>
<th>Normal group</th>
<th>Incidence of VAH and P</th>
</tr>
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<tr>
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<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Left</th>
<th>Right</th>
<th>Left</th>
<th>Right</th>
<th>VAD (82.35%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAD</td>
<td>76</td>
<td>22</td>
<td>2</td>
<td>5</td>
<td>48</td>
<td>43</td>
<td></td>
<td>0.557</td>
</tr>
<tr>
<td>Non-VAD</td>
<td>14</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>5 (4.20%)</td>
<td>1.000</td>
</tr>
<tr>
<td>VAH</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>5 (4.20%)</td>
<td>1.000</td>
</tr>
<tr>
<td>Non-VAH</td>
<td>86</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>5 (4.20%)</td>
<td>1.000</td>
</tr>
<tr>
<td>P</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.414</td>
</tr>
<tr>
<td>Authors &amp; Year</td>
<td>Sample</td>
<td>Method</td>
<td>Criterion &amp; Prevalence</td>
<td>VAH</td>
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<tr>
<td>Fisher et al., 1965 [9]</td>
<td>178 cadavers (91 males) USA</td>
<td>pathoanatomical study</td>
<td>N/A</td>
<td>&lt;2mm: right (5%), left (2%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Touboul et al., 1986 [33]</td>
<td>50 normal subjects (20 males, 30 females) France</td>
<td>ultrasonographic study extracranial continuous-wave (CW) Doppler sonography, transcranial Doppler sonography and color-coded duplex sonography</td>
<td>Difference ≥ 1 mm: left 24 (48%); right 7 (14%)</td>
<td>&lt;3 mm: 3 cases (6%): left 2, right 1</td>
<td></td>
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<tr>
<td>Delcker and Diener, 1992 [6]</td>
<td>451 patients German</td>
<td>N/A</td>
<td>revealed a decrease in blood flow velocity in VAs with diameters less than 2 mm, based on a hypoplasia rate of 1.9%</td>
<td></td>
<td></td>
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<tr>
<td>Smith and Bellon, 1995 [30]</td>
<td>15 volunteers Canadians</td>
<td>MRA</td>
<td>a dominant vertebral artery being one at least 30% greater in diameter (just for definition)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Grasso et al., 2005 [12]</td>
<td>6 formalin-fixed cadaveric heads Italians</td>
<td>Microanatomy dissection</td>
<td>Difference ≥ 0.8 mm left (4/6)</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Yokoyama et al., 2005 [41]</td>
<td>20 patients with aneurysm Japanese</td>
<td>Color Doppler Ultrasonography (CDU)</td>
<td>Diameter ratio more than 1.4: Dissecting aneurysm was observed in 5 patients (1 in dominant VA and 4 in non-differentiated VA). Aneurysmal change was absent in the patients with dissection in hypoplastic VA. The side-to-side diameter difference was greater than the standard error of measurement (0.16 mm): left (54%); right (30%); equal (16%); no correlation between differences in vertebral artery diameter and hand dominance can be found.</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Cagnie et al., 2006 [2]</td>
<td>50 subjects (29 right handers, 21 left handers) with a mean age of 21.3±2.5 years (ranging from 19 to 26 years) Belgium</td>
<td>ultrasonographic investigation</td>
<td>N/A</td>
<td></td>
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<td>Study</td>
<td>Participants</td>
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<tr>
<td>Perren et al., 2007 [26]</td>
<td>725 patients</td>
<td>Color-coded duplex flow imaging</td>
<td>European color-coded duplex flow imaging N/A</td>
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<tr>
<td>Min et al., 2007 [23]</td>
<td>410 patients</td>
<td>MRA</td>
<td>Korean MRA N/A</td>
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<tr>
<td>Songur et al., 2008 [31]</td>
<td>104 cadavers</td>
<td>Autopsy study</td>
<td>Turks Autopsy study Difference ≥ 1 mm right (17.3%) left (21.2%) two criteria:  ① Difference &gt;0.3 mm ② the VA was connected with the BA in more of a straight line ① 84 (92.3%) patients ② 7 patients left VAD (69.2%; p &lt;0.001). Difference in any diameter: co-dominance (3.1%), right (49.7%), left (47.2%). Difference ≥ 0.3 mm: co-dominance (18%), right (42.1%) left (39%). Difference ≥ 0.8 mm: co-dominance (50.8%), right (26.4%), left (22.8%). Difference ≥ 1 mm: co-dominance (62.6%) right (20.1%), left (17.3%). Diameter ratio more than 1.4: ≤2 mm: right (7.1%) left (9.4%)</td>
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<td>Hong et al., 2009 [15]</td>
<td>91 patients</td>
<td>CTA</td>
<td>South Korean CTA N/A</td>
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<tr>
<td>Ergun et al., 2016 [7]</td>
<td>254 patients</td>
<td>Digital subtraction angiography (DSA)</td>
<td>Turks Digital subtraction angiography (DSA) N/A</td>
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</table>

Hypoplasia (diameter less than 50% of the contralateral side): 98 (23.9%) more common on the right side (63.3%, 62/98) aplasia (non-visualization of VA): 14 (3.4%) more common on the left side (64.3%, 9/14)
<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects/Gender</th>
<th>Examinations</th>
<th>VAD Diameter</th>
<th>Findings</th>
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<tr>
<td>Gaigalaite et al., 2016 [11]</td>
<td>367 symptomatic posterior circulation stroke (PCS) or transient ischemic attack (TIA), 742 asymptomatic subjects Lithuanian</td>
<td>MRI or CT and MRA or CTA</td>
<td>N/A</td>
<td>≤2.7 mm: the optimal VA diameter to increase the risk of PCS stenosed/occluded VA; ≤2.2 mm: a risk factor of a severe distal VA stenosis or occlusion ≤2.2 mm (cut-off point through scatter plotting and receiver operation characteristic (ROC) curve analyses: difference ≥0.12 cm, side-to-side flow volume ratio ≥5 and resistance index ≥0.75): right (7.8%) left (3.8%) ≤2.5 mm (an ideal value for the discrimination of marked flow asymmetry and low flow volume of VA): left (3.3%) right (5.9%); ≤2 mm: left (0.1%) right (0.2%); ≤2.5 mm: left (25.4%) right (35.6%)</td>
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<tr>
<td>Jeng and Yip, 2004 [17]</td>
<td>447 healthy subjects (231 men, 216 women) Chinese</td>
<td>CDU</td>
<td>Difference &gt;0.3 mm: VA asymmetry (68.9%) right (22.4%), left (46.5%)</td>
<td>&lt;3 mm: 58.3 % in (PCS) or TIA; 31.3% in asymptomatic subjects, p &lt;0.01</td>
</tr>
<tr>
<td>Chen et al., 2010 [4]</td>
<td>1000 healthy subjects (582 men, 418 women) Chinese</td>
<td>CDU</td>
<td>N/A</td>
<td>≤2.5 mm (an ideal value for the discrimination of marked flow asymmetry and low flow volume of VA): left (3.3%) right (5.9%); ≤2 mm: left (0.1%) right (0.2%); ≤2.5 mm: left (25.4%) right (35.6%)</td>
</tr>
<tr>
<td>Wang, 2012 [39]</td>
<td>134 patients Chinese</td>
<td>MRA</td>
<td>Difference &gt;1.2 mm (just for definition)</td>
<td>The incidence of posterior circulation infarcts and basal artery curvature is higher in VAD patients.</td>
</tr>
<tr>
<td>Hu et al., 2013 [16]</td>
<td>841 stroke patients (264 women, 577 men) Chinese</td>
<td>MRA or CTA</td>
<td>N/A</td>
<td>(1) &lt;2 mm; (2) the whole artery was slim or absent: 10.8 % (inVAH: right (56.9 %), male (78.0 %)) VAH: an independent risk factor for PCI stroke</td>
</tr>
<tr>
<td>Study</td>
<td>Group</td>
<td>Imaging Technique</td>
<td>Results</td>
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<tr>
<td>Lu et al., 2013 [21]</td>
<td>41 vertigo patients with VAD; 36 vertigo patients without VAD Chinese</td>
<td>MRA</td>
<td>Difference &gt;0.3 mm: mild subgroup (0.04-0.70 mm); moderate subgroup (0.70-1.17 mm); severe subgroup (≥1.17 mm); The abnormal rate of basilar artery shape was higher in vertebral artery dominance vertigo; the more severe the variation, the more common of recurrent vertigo attacks and infarction in vertebral-basilar artery system. N/A</td>
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<tr>
<td>Wang et al., 2014 [36]</td>
<td>37 Wallenberg syndrome (A), 452 control cases (B) Chinese</td>
<td>DSA</td>
<td>Difference &gt;0.3 mm A (51.35%): left (63.16%) right (36.84%), B (30.75%: left (56.12%) right (43.88%) p = 0.010 1 ≤1.5 mm; 2 Diameter ratio &lt; 1/3: A (16.22%: left (33.33%) right (66.67%)) B (4.65%) p = 0.010 ≤2.5 mm: Total (n=2370): 11.9%: left 104 (4.4%), right 172 (7.3%), bilateral VAH 6 (0.3%); Normal origin (n=1985): left 71 (3.6%); right 144 (7.3%); LVA originated directly from aortic arch (n =126): left 22 (17.5%); right 5 (4.0%) (P &lt; 0.001)</td>
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<tr>
<td>Wang et al., 2016 [37]</td>
<td>2370 adults (1348 men) Chinese</td>
<td>Thoracic enhanced CT, left VA, which directly originated from the arch, was associated with right VAD and left VAH.</td>
<td>1 ≤1.3-fold of the contralateral diameter: Total (n=2370): 41.7%: left 661 (27.9%); right 328 (13.8%); Normal origin (n=1985): left 582 (29.3%); right 224 (11.3%); LVA originated directly from aortic arch (n =126): left 10 (7.9%); right 70 (55.6%) (P &lt; 0.001)</td>
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<tr>
<td>Zhang et al., 2016 [46]</td>
<td>245 patients with isolated vertigo with at least 1 vascular risk factor, Chinese</td>
<td>MRA or cervical contrastenhanced MRA (CEMRA)</td>
<td>≤2 mm, slim or absent vertebral artery to CEMRA, or a diameter ratio for the 2 vertebral arteries &gt;1:1.7: 26% (64 of 245)</td>
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</tbody>
</table>
**Figure 1.** A typical case of right VAD and left VAH

1 — left subclavian artery; 2 — left vertebral artery (2.18 mm); 3 — left common carotid artery; 4 — trachea; 5 — right common carotid artery; 6 — right subclavian artery; 7 — right vertebral artery (5.24 mm)