Is the asymmetry between the vertebral arteries related to the cerebral dominance?

Abstract

Aim: The two vertebral arteries (VAs) are usually unequal in size, the left one being generally larger than the right one. It was hypothesized that the asymmetry results from the need of the dominant cerebral hemisphere for more glucose and oxygen, i.e. more blood supply. In this study, we aimed to test this hypothesis in patients by evaluating their arterial diameter and hand preference, as it is the most common criterion to determine the dominance of hemisphere.

Materials and methods: The study was performed with 844 participants who consented to participate in the study. We identified the dominant cerebral hemisphere by questioning their hand preference. Then we measured both the vertebral artery (VA) diameter and VA flow volume by Doppler ultrasonography. After demonstrating the asymmetry, correlation was tested.

Results: Among 844 participants included in the study, the mean diameter of the right VA was 3,14±0,35 mm, the left VA was 3,41±0,54 mm, mean flow volumes of right VA was 119,21±44,98 mL/min. and left VA was 151,45±57,26 mL/min. It is recorded that 771 (86.43%) of the participants were right-handed, 73 (8.18%) were left-handed.

Conclusion: No significant relationship was found between the increased blood demand of the dominant cerebral hemisphere and the vertebral artery dominance.

Key words: Cerebral Dominance, Vertebral Arteries, Handedness, Doppler Ultrasonography
1. Introduction

The concept of hemispheric dominance in cerebral processes was first revealed by Broca in 1860 [1]. It could be thought that the dominant cerebral hemisphere may require more blood supply due to increased demand for oxygen and nutrients [2]. However, it is unclear whether the asymmetry in the cerebral blood flow is a determinant of the cerebral dominance [3].

In pre and postmortem studies, the mean VA diameter was found to be larger on the left side than the right-side [4, 5]. Zaina et al. speculated that the vascular demands of the brain could lead to the asymmetry during embryological formation [6]. Since hand preference is one of the indicators of the cerebral hemisphere dominance, it could be expected that the left cerebral hemisphere will be dominant on the right-handed people and vice versa. Based on this hypothesis, Cagnie et al. investigated the relationship between the VA diameters and hand preference in 50 subjects, but they could not prove a statistically significant correlation [7]. This may be due to the small number subjects used in the study. Therefore, we aimed to test this hypothesis with a larger group of participants (844 subjects). We analyzed arterial diameter and blood flow volume in correlation with the right or left-handedness.

Additionally, to investigate the embryological origin differences which are another hypothesis of diameters of vertebral arteries, diameters of the right VA with right subclavian artery (SCA), and left VA with left SCA that have similar origins were compared.
2. Materials and methods

The patients who were admitted to our clinic due to various reasons were asked if they want to participate in the study \((n = 892)\). Patients with the history for significant neck pain, atherosclerosis and cardiovascular disease were excluded. Hand preference was determined by ten questions in Oldfield handedness questionnaire that is modified by Geschwind and Behan [8, 9, 10]. The required explanations about the importance of the questionnaire were given to ensure that the given questionnaire forms were answered correctly. Features required to be considered by the participants were specified. Through this survey, hand preference while performing some actions such as writing, painting, throwing ball or stone, holding a scissors, brushing teeth (hand holding the brush), holding a knife (cutting a bread), holding a fork (without blade), holding a hammer (when nailing), holding the matchstick while striking a match, the hand holding the cap while opening the bottle was questioned. “Left hand”, "both hands” and “right hand" responses were scored as -10, 0, +10 points, respectively. The total score ensuing was evaluated according to the Geschwind score proposed by Tan. The Geschwind scores ranged from -100 to +100. Negative scores showed left-handedness, and positive scores showed right-handedness. According to this scoring, those between +40 and +100 were evaluated as right-handed, between -30 and +30 as ambidextrous, between -100 and -40 were evaluated as left-handed [11, 12].

The examination of the vertebral arteries and subclavian arteries with duplex Doppler USG \((Toshiba Apio 300, Toshiba Medical Systems Corporation, USA)\) was performed by an experienced radiologist. All subjects were positioned supine with the head in neutral position. Both VA diameter and flow volume were measured with a 7.5-MHz linear probe.
between the fourth and fifth or fifth and sixth cervical vertebra transverse processes of both sides (Figure 1 and Figure 2). Similarly, in the same position, SCA diameters were measured at 1 cm distal from both sides of the VA in the supraclavicular area using the same probe.

**Figure 1.** Normal vertebral artery of 38-year-old man. Grey-scale sonograms show vertebral artery below vertebral vein, both visualized between shadows from transverse processes of spine (arrows).
Figure 2. The left vertebral artery with normal flow parameters, flow volume and diameter is observed with Doppler ultrasonography exam.

The study was approved (permit no: 13/2017) by the institutional research ethics committee for human clinical investigations which conforms to protocols in accordance with the Declaration of Helsinki. Written informed consents were obtained from all patients enrolled in the study.

2.1. Statistical Analysis

When evaluating the findings obtained in this study, IBM SPSS Statistics 22 for statistical analysis (SPSS IBM, Turkey) program is used. The availability of the parameters to normal distribution was evaluated by the Shapiro Wilks test and the parameters were detected to be available for normal distribution. In the evaluation of the study data, besides descriptive
statistical methods (mean, standard deviation, frequency), Student t test was used on comparison of the quantitative data parameters of two groups, and paired samples t test was used for intergroup comparisons. Pearson Correlation Analysis was used to examine the correlation between the parameters. Significance was evaluated at p <0.05.

3. Results

In our study, it is recorded that 771 (86.4%) of the participants (n = 892) were right-handed, 73 (8.2%) were left-handed, and 48 (5.4%) were using both hands. Forty-eight participants who use both hands were excluded from the study. The final evaluation was done in 844 cases (after excluding ambidextrous ones). Two hundred and ninety (34.4%) were male and 554 (65.6%) were female. The mean age of the patients was 52.24±12.64 years. The age range of the participants varied between 20 to 78. It was determined that 771 (91.4%) of the participants were right-handed and 73 (8.6%) were left-handed.

In right-handed subjects; the mean left VA diameter was statistically significantly larger than the right VA diameter (p:0.000; p<0.05).

In left-handed subjects; the mean left VA diameter was statistically significantly larger than the right VA diameter (p:0.000; p<0.05).

There was no statistically significant difference with regards to right and left VA diameter between right-handedness and left-handedness (p>0.05) (Table 1).

Location for Table 1

There was no statistically significant difference between right and left VA flow volume averages in right dominant hand and left dominant hand (p>0.05).
In right-handed subjects; the mean left VA flow volume was significantly higher than the mean right VA flow volume (p=0.001).

In left-handed subjects; although the mean left VA flow was higher, there was no statistically significant difference between the right and left VA flow volume averages (p=0.06).

There was a statistically significant difference between the mean right VA diameter and the mean left VA diameter (p<0.05).

The difference between the mean right VA flow volume and the mean left VA flow volume was statistically significant (p<0.05) (Table 2).

**Location for Table 2**

The mean diameter of the right SCA was measured 9.28±0.48 mm, and the mean diameter of the left SCA was measured 9.16±0.53 mm.

There was no statistically significant correlation between the right VA diameter and the right SCA diameter (p>0.05).

There was no statistically significant correlation between the left VA diameter and the left SCA diameter (p>0.05) (Table 3).

**Location for Table 3**
4. Discussion

In this study, we investigated whether the right-handed people have a dominant left VA, or on the contrary, whether the left-handed people have a dominant right VA.

It was previously stated that the individuals who use their left hand or both hands constitute approximately 2 to 30% of the human population [13]. Depending on the criteria used to determine the hand preference, there may be a difference of around 10%. Some studies report that the use of right-hand increases with the age [14]. In our study, it is reported that 86.43% of the participants were right-handed, 8.18% were left-handed, and 5.38% were ambidextrous. As a cultural habit, families in Turkey tend to discourage their children to use their left hands [15]. Hence, the effects of such environmental factors are unknown [16].

There are different methods to determine the dominant VA in the literature, but there is no consensus. Jeng et al. stated that there should be at least 0.3 mm diameter difference between vertebral arteries to confirm an asymmetry [17]. However, Smith and Bellon stated that a minimum of 30% difference should be between the arteries [18]. In our study, when the difference of 0.3 mm in diameter (as accepted by Jeng and et al.) were taken as the criteria for dominance; the diameter of the left VA was more dominant in 58% of the cases while right vertebral diameter was dominant for the 19%. In 23% of the cases, no dominance between right and left was detected. These percentages we observed is different than the percentages reported in the literature; where left VA is dominant in 35.5-46.5% of
individuals and the right VA dominant in 22.4-35.7% [16, 19, 20, 21, 22]. In our study, left VA dominance was more prominent with the prevalence of 58%.

We determined that the diameter of the left VA was significantly larger in the individuals preferring both right and left-handed. The left VA flow volume was found significantly higher in the right-handed group. The left VA flow volume was higher in left-handed, but it was not statistically significant. In most of the studies in the literature, although it is stated that there is a difference in favor of left between right and left vertebral arteries, neither of them showed a significant difference [6, 7, 16]. In our study, when the right and left vertebral arteries were compared in terms of the mean diameters and mean flow volumes, the dominance of the left vertebral artery was found to be statistically significant (Table 2). The large variability in the VA diameter reported in different studies in the literature could be a result of the variation in methods and protocols.

Different theories have been proposed to explain the asymmetry in VA diameters. The theory of the brain's vascular demand has been suggested, but not adequately investigated. Orlandini et al. stated that the arteries on the left side of the Circle of Willis are larger than the ones on the right, and this situation is related to the normal dominance of the left cerebral hemisphere [23]. There is a common agreement that the left and right brain hemispheres differ in anatomy and function. Hand preference in the normal population is accepted as one of the criteria for predicting cerebral dominance. It is shown that the left hemispheric dominance is more common in the right-handed individuals, while the right hemispheric dominance is more pronounced in the left-handed ones [24]. It seems tempting to relate the dominant nature of the VA to the high blood flow volume required to meet the
increased demand of cerebral hemispheres. However, our finding do not provide evidence
to support this hypothesis (Table 1).

The second hypothesis is the difference of embryological development. Although there is
no reference to this in the literature, one could assume that the diameter and flow difference
of the vertebral arteries may be due to the difference in the embryological development of
the left and right vertebral arteries. On the right side, the SCA (normally the artery where
the VA emerges) is sourced by the brachiocephalic trunk, and on the left, SCA is sourced
directly from the aorta. In this case, vertebral arteries are rooted from the left horn of the
aortic sac on the left side embryologically, while on the right side, are rooted from the right
horn of the aortic sac embryologically [25, 26, 27]. This situation may explain the diameter
and flow volume differences. In our study, we compared the diameters of right VA and
right SCA with the same embryological origin. Although the arteries rooting from the same
embryological origin are expected to show similar characteristics in terms of dominance,
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our findings have not confirmed this. In the majority of subjects with predominant right or
left VA, the right SCA diameter was larger, but no statistically significant difference was
detected between the subclavian arteries. No significant correlation between the VA
diameters and SCA diameters was detected (Table 3).

The current results should be evaluated within the limitations of our study. First, the
vertebral artery is not the sole source of blood supply to the cerebral hemisphere. A study
with internal carotid arteries can provide further evidence. Although the diameter of the
subclavian arteries were included in the study, additional investigations are required to
obtain detailed information on embryological origin.
In conclusion, our aim was to investigate the dominance of the left vertebral artery that attracted our attention in clinical practice. The first thought was to test the hypothesis that the dominant cerebral hemisphere might need more blood supply. Additionally, we wanted to evaluate the relation of the embryological development with this asymmetry. As a result, we observed prominent dominance for left vertebral artery. However, there was no significant correlation between arterial dominance and cerebral hemisphere dominance. In addition, no correlation was found based on the evaluation of the diameters of arteries based on the same embryological origin.

Declaration of Conflicting Interests: The authors declare that they have no conflict of interest.

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References


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<th>RIGHT HAND</th>
<th>LEFT HAND</th>
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<tr>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
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<tr>
<td>Right Vertebral Artery Diameter</td>
<td>3,13±0,34</td>
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<tr>
<td>(^2 p)</td>
<td>0,000*</td>
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<td>126,16±50,41</td>
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<td>Left Vertebral Artery Flow</td>
<td>151,95±57,12</td>
<td>146,16±58,82</td>
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<td>(^2 p)</td>
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\(^1\) Student t test \(^2\) Paired Samples t Test *p<0.05
Table 2: Comparison of right and left vertebral artery diameter (mm) with vertebral artery flow volumes (mL/min)

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<th>Mean±SD</th>
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<td><strong>Right Vertebral Artery Diameter</strong></td>
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<tr>
<td><strong>Left Vertebral Artery Diameter</strong></td>
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<td><strong>Right Vertebral Artery Flow Volume</strong></td>
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<td><strong>Left Vertebral Artery Flow Volume</strong></td>
<td>151.45±57.26</td>
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¹ Student t test

* p < 0.05
Table 3: Correlation analysis between vertebral artery diameter and subclavian artery diameter

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*Pearson correlations*