

## Research Article

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## Vertebral Artery Asymmetry: Frequency, Degree, and Clinical Significance

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**ABSTRACT**

**Background:** Vertebral Artery (VA) asymmetry is a common anatomical variant associated with altered hemodynamics and increased risk of posterior circulation ischemia. Despite its clinical relevance, population-specific data on VA asymmetry remain limited, particularly in Eastern European cohorts.

**Objective:** To assess the frequency and degree of VA asymmetry using Magnetic Resonance Imaging (MRI) and to evaluate its potential clinical significance in a hospital-based patient population.

**Materials and Methods:** Fifty patients (22 men, 28 women; mean age  $52.3 \pm 14.1$  years) who underwent cranial and cervical MRI at the Grodno Regional Emergency Hospital were retrospectively enrolled. VA diameters were measured bilaterally at the C5-C6 level. Asymmetry was defined as an Asymmetry Index (AI) exceeding 25%. Hypoplasia was defined as a diameter below 2.0 mm. Statistical analysis was performed using the Mann-Whitney U test and chi-square test.

**Results:** The mean right VA diameter was  $3.42 \pm 0.61$  mm and the mean left VA diameter was  $3.18 \pm 0.58$  mm ( $p=0.043$ ). Significant asymmetry ( $AI > 25\%$ ) was detected in 14 patients (28.0%). Right-sided dominance was observed in 31 patients (62.0%), left-sided dominance in 12 (24.0%), and codominance in 7 (14.0%). VA hypoplasia was identified in 10 patients (20.0%). Patients with VA hypoplasia reported a significantly higher prevalence of vestibular symptoms and headache ( $p < 0.05$ ).

**Conclusion:** VA asymmetry and hypoplasia are common findings on routine MRI. These variants should be considered in clinical practice when evaluating patients with posterior circulation symptoms. Population-based morphometric data can contribute to improved radiological interpretation and neurosurgical planning.

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**Introduction**

The vertebral artery (VA) is the primary vessel supplying the posterior cranial fossa, brainstem, cerebellum, and occipital lobes. It arises from the subclavian artery and is conventionally divided into four segments (V1-V4), with the intracranial segment forming the basilar artery after merging at the pontomedullary junction [1]. Despite its critical functional role, considerable morphological variability exists in VA diameter, symmetry, and dominance pattern.

VA asymmetry, defined as a discrepancy in diameter between the right and left vessels, is one of the most frequently encountered anatomical variants in clinical practice. Reported prevalence rates vary broadly across studies, ranging from 18% to 41%, depending on methodology and threshold criteria used [2,3]. Unilateral VA hypoplasia (diameter  $< 2.0$  mm) is a more severe form of this asymmetry and has been associated with vertebrobasilar insufficiency, posterior circulation stroke, and neurological deficits referable to the posterior circulation [4,5].

The exact clinical implications of VA asymmetry remain a subject of ongoing debate. Some authors argue that isolated asymmetry without additional hemodynamic compromise represents a benign variant, while others have demonstrated altered flow dynamics and increased thromboembolic risk in hypoplastic vessels [3,6]. Furthermore, VA asymmetry may affect surgical decision-making during posterior cervical or skull base procedures, highlighting the importance of preoperative morphometric evaluation [7].

Magnetic resonance imaging (MRI), including MR angiography (MRA), has become the preferred non-invasive modality for VA assessment due to its excellent soft-tissue resolution and absence of ionizing radiation [8]. However, population-specific normative data for the Belarusian cohort are currently lacking in the literature.

The aim of this study was to determine the frequency and degree of VA asymmetry in patients undergoing routine MRI at a tertiary emergency hospital in Grodno, Belarus, and to investigate the association between asymmetry and clinical symptoms of posterior circulation insufficiency.

**Materials and Methods**

**Study Design and Patient Selection:** This retrospective observational study included 50 consecutive patients (22 men

[44.0%] and 28 women [56.0%]; mean age 52.3±14.1 years; range 21-78 years) who underwent cranial and cervical MRI at the Grodno Regional Emergency Hospital between January 2025 and August 2025. Patients were referred for MRI due to symptoms including headache, dizziness, cervicgia, and neurological deficit. Exclusion criteria comprised known vertebral or carotid artery disease, previous cervical surgery, trauma, tumors of the neck or posterior fossa, and poor image quality.

**MRI Protocol:** All examinations were performed on a 1.5 T MRI scanner (MAGNETOM Essenza, Siemens Healthineers, Germany). The protocol included T1-weighted, T2-weighted, and FLAIR sequences in axial and coronal planes, as well as Time-of-Flight (TOF) MR angiography of the intracranial vessels with three-dimensional reconstruction. For VA diameter measurement, axial T2-weighted images at the C5-C6 intervertebral level were used, with a slice thickness of 3.0 mm and in-plane resolution of 0.6 × 0.6 mm.

**Morphometric Measurements:** VA diameters were measured bilaterally by two independent radiologists using OsiriX MD v.11.0 software (Pixmeo SARL, Switzerland). The outer vessel diameter was measured perpendicular to the vessel axis. Interobserver agreement was assessed using the Intraclass Correlation Coefficient (ICC). The Asymmetry Index (AI) was calculated as follows: AI (%) = [(Dmax - Dmin) / Dmax] × 100%, where Dmax and Dmin represent the larger and smaller vessel diameters, respectively. Significant asymmetry was defined as AI>25% [3]. Hypoplasia was defined as VA diameter <2.0 mm [4].

**Statistical Analysis:** Statistical analysis was performed using Statistica v.10.0. Continuous variables were expressed as mean± Standard Deviation (SD). Normality was assessed using the Shapiro-Wilk test. The Mann-Whitney U test was used for between-group comparisons of non-normally distributed data. Categorical variables were compared using the chi-square test or Fisher's exact test where appropriate. The significance level was set at p<0.05.

## Results

Excellent interobserver agreement was achieved for VA diameter measurements bilaterally (ICC = 0.94 for the right VA and ICC = 0.92 for the left VA).

The mean right VA diameter was 3.42±0.61 mm (range 1.6-5.2 mm) and the mean left VA diameter was 3.18±0.58 mm (range 1.4-4.9 mm). The difference was statistically significant (p=0.043). Detailed morphometric data are presented in Table 1.

**Table 1: Morphometric Parameters of the Vertebral Arteries**

Parameter	Right VA (mm)	Left VA (mm)	p-value
Mean diameter	3.42±0.61	3.18±0.58	0.043
Min diameter	1.6	1.4	–
Max diameter	5.2	4.9	–
Hypoplasia (<2.0 mm)	4 (8.0%)	6 (12.0%)	0.512

## VA-vertebral artery; values are mean±SD or n (%)

Right-sided VA dominance was identified in 31 patients (62.0%), left-sided dominance in 12 patients (24.0%), and codominance (AI≤10%) in 7 patients (14.0%). These proportions are consistent with previously reported data in the literature [2,6].

Significant VA asymmetry (AI>25%) was found in 14 of 50 patients (28.0%). VA hypoplasia was identified in 10 patients (20.0%): 4 cases on the right side (8.0%) and 6 on the left (12.0%; p=0.512). In 3 patients (6.0%), hypoplasia was associated with contralateral VA dominance and termination in the posterior inferior cerebellar artery (PICA), without contributing to basilar artery formation.

Patients with VA hypoplasia reported a significantly higher prevalence of vestibular symptoms (dizziness, imbalance) compared to those without hypoplasia (70.0% vs. 35.0%; p=0.031). Headache of occipital localization was also more frequent in the hypoplasia group (60.0% vs. 27.5%; p=0.044). No statistically significant differences were found between hypoplastic and non-hypoplastic groups regarding age, sex, or presence of cerebrovascular risk factors.

## Discussion

The present study demonstrated that VA asymmetry is a common finding in patients undergoing routine MRI in a Belarusian clinical setting, with a prevalence of 28.0% for significant asymmetry (AI>25%) and 20.0% for hypoplasia. These figures are within the range reported in other populations (18-41% for asymmetry and 2-26% for hypoplasia) reflecting both true population variability and differences in measurement methodology [2,3,6].

Right VA dominance (62.0%) was the predominant pattern in our cohort, which aligns with the findings of [2,6], who reported right-sided prevalence in 67% of cases with hypoplasia in a large 4D flow MRI study, and may be partly explained by the right subclavian artery's more favorable angle of origin from the brachiocephalic trunk. Notably, codominance was observed in only 14.0% of our patients, lower than in some published series [12], which may reflect differences in the definition threshold applied.

The clinical significance of VA asymmetry has been a topic of considerable interest. In the present study, VA hypoplasia was significantly associated with vestibular symptoms and occipital headache, consistent with the proposed mechanism of reduced posterior fossa perfusion and altered flow distribution in the basilar artery [4,5]. Our findings align with the observation by [5] that vertigo frequency is highest in VAH patients, and with the diagnostic criteria established by the Bárány Society in 2022, which emphasize the role of VA hypoplasia in vascular vestibular syndromes [9].

From a surgical perspective, accurate preoperative knowledge of VA anatomy is essential during posterior cervical fusion, occipitocervical fixation, and other skull base procedures. demonstrated that unrecognized anomalous VA anatomy significantly increases the risk of inadvertent vascular injury [7,8]. confirmed that MRI provides reliable VA morphometric assessment and should be reviewed systematically before posterior cervical surgery.

Limitations of this study include the relatively small sample size, the retrospective single-center design, and the use of a measurement level that, while standardized, may not fully represent the entire cervical course of the VA. Future prospective multicenter studies with larger cohorts are warranted to establish normative values for the Belarusian population and to further clarify the long-term clinical outcomes associated with VA asymmetry.

## Conclusion

Vertebral artery asymmetry is a frequent morphological finding, identifiable in over one-quarter of patients on routine MRI. Right-sided VA dominance is the most common pattern. VA hypoplasia

is associated with a higher prevalence of vestibular symptoms and headache, supporting its clinical relevance. Systematic assessment of VA morphometry on cervical and cranial MRI is recommended as part of standard radiological reporting, particularly in patients presenting with posterior circulation symptoms or planned for posterior cervical surgery.

**Conflict of interest:** The authors declare no conflicts of interest.

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