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VERTEBRAL ARTERY HYPOPLASIA: CHARACTERISTICS IN A CROATIAN POPULATION SAMPLE

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SUMMARY – Vertebral arteries are responsible for 1/3 of the brain blood supply, supplying primarily posterior parts of the brain. About 15% of all strokes occur in posterior parts of the brain, which should be kept in mind when dealing with disorders that can cause hemodynamic changes in vertebral arteries. Vertebral artery hypoplasia (VAH) is an inborn abnormality of vertebral artery defined by smaller lumen diameter and lower blood flow velocities, and is most commonly found in healthy subjects. The aim of this study was to establish the characteristics of VAH in a Croatian population sample, and to determine differences in its presentation according to sex and affected side. Study results may prove valuable for future identification of individuals at an increased risk of cerebrovascular incidents or traumatic injuries that could lead to adverse changes of posterior circulation. Color Doppler flow imaging (CDFI) reports of 277 patients were analyzed. All measurements were obtained in the V2 segment of vertebral artery, between the C6-C5 vertebrae, using a linear 7.5 MHz probe on an Aloka Prosound SSD-5500. The criteria for normal vertebral arteries were lumen diameter of 2.5-4.5 mm, systolic mean blood flow velocity of 0.35-0.70 m/s, and normal resistance pattern. Study results showed the left vertebral artery to be dominant in 57% of study subjects, VAH to be more common in women, and right vertebral artery to be more often involved by hypoplasia than the left one. The width of the "wider" vertebral artery was greater in the group with VAH, suggesting a way of the deficit compensation. The study demonstrated that the deficit caused by VAH cannot be fully compensated for despite larger arterial diameter.

Key words: *Vertebral artery – abnormalities; Vertebral artery – ultrasonography; Brain blood supply; Brain blood ischemia – etiology; Croatia – epidemiology*

Introduction

Vertebral arteries are the second largest blood supplier of the brain, responsible for about 30% of the brain blood supply. They form the posterior part of the circle of Willis and are responsible for blood supply of the cerebellum, pons, middle ear, and upper parts of medulla spinalis and its meninges. Keeping this in mind, investigation of vertebral arteries is important since 15% of all strokes occur in their irrigation territory. Stroke is still the first cause of death and disability in Croatia. Because of their anatomical position, vertebral arteries were neglected in research until ultrasound methods have become widely available in daily practice[1,2]. Ultrasound allows a noninvasive view into the human body. Cerebral circulation can be quickly and painlessly assessed at bedside by performing color Doppler flow imaging (CDFI) of the head and neck blood vessels[3-5]. Despite advanced technological tools, the knowledge in this area remains insufficient. The morphology and hemodynamics of normal vertebral arteries have been investigated in different populations[6-8]. Some disorders of vertebral arteries, such as vertebral artery hypoplasia (VAH), are proven to be the possible causes of stroke in children and young adults. This certainly makes investigation of posterior circulation worthwhile. Changes of vertebral arteries, both atherosclerotic and congenital, can also

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serve as unfavorable prognostic factors in chronic degenerative changes of cervical spine, trauma[9] or atherosclerotic[10] changes of other vessels.

VAH is an abnormality of vertebral artery defined by "narrower" lumen diameter and lower blood flow velocities, and is usually found in healthy subjects. It is an inborn condition with great variability in its incidence in the general population, ranging from 2% to 20% in reports from different countries. Previous investigations in Croatia showed a 2.34% prevalence in the general population[11]. The presence of VAH was observed earlier in some neurological disorders such as migraine with aura[12], cerebellar ischemia, vertebral artery dissection or early atherosclerotic changes. Some of these disorders were later studied in more detail.

The aim of this study was to establish the characteristics of VAH in a Croatian population sample, and to determine differences in its presentation according to sex and affected side. We believe that the study of these differences in these parameters of vertebral arteries between subjects with and without VAH may help identify individuals at an increased risk of cerebrovascular incidents[13] or traumatic injuries that can lead to adverse changes of posterior cerebral circulation.

The morphology and hemodynamics of vertebral arteries have been investigated in different populations, but the presence of VAH in other diseases has not yet been proven. There are reports on individual cases of VAH in some serious disorders such as hemifacial spasm. It is also an unfavorable prognostic factor in chronic degenerative changes of cervical spine, trauma or atherosclerotic changes of other vessels.

Patients and Methods

CDFI of vertebral arteries was performed in 277 patients at University Department of Neurology, Sestre milosrdnice University Hospital, Zagreb, Croatia. All measurements were done by extracranial color Doppler technique using a 7.5 MHz probe on an Aloka Prosound 5500. Vertebral arteries were measured in the V2 segment, between the C6 and C5 vertebrae. The criteria used for normal vertebral arteries were lumen diameter 2.5-4.5 mm, mean blood flow velocities 0.35-0.70 m/s, and absence of increased resistance pattern (dyastolic velocities above 0.05 m/s). All measurements were performed in supine position, with head in mid-position, elevated by 45 degrees, chin facing upwards. By moving the probe horizontally, keeping in contact with the skin, a vertebral artery appears[8,14,15] (Fig. 1).

The criteria used for the diagnosis of VAH were lumen diameter less than 2 mm, mean blood flow velocities under 0.35 m/s, and increased resistance pattern (diastolic velocities under 0.05 m/s or absent dyastoles even though systolic values are high)[16].

The two groups were compared according to several parameters: sex, age, diameter of right, left and both vertebral arteries, narrower vertebral artery (being the one with smaller diameter in both groups), hemodynamics in right and left vertebral artery, and resistance patterns.

Subjects with abnormalities of vertebral arteries other than VAH were excluded from the study (abnormalities such as vertebral artery stenosis, occlusion of vertebral artery, extravertebral flow, etc.)

Data were analyzed descriptively, and differences between groups were analyzed using Student's t-test and χ^2-test.

Results

CDFI reports of vertebral arteries performed in 277 healthy subjects were analyzed. There were 118 men and 159 women. VAH was present in 122 subjects, 50 (41%) male and 72 (59%) female, whereas normal vertebral arteries were found in 155 subjects, 68 (44%) male and 87 (56%) female. The right vertebral artery was found to be narrower than the left vertebral artery in most subjects from both groups with and without VAH (Table 1). A narrower right vertebral artery was observed

Table 1. Presence of vertebral artery hypoplasia (VAH) according to sex and affected side compared to normal vertebral arteries

	Side of "narrower" vertebral artery (hypoplastic or normal)						
	VAH (≤2 mm)			VA with normal diameter (>2mm)			
	Right	Left	Total	Right	Left	Right=left	Total
Men	31 (62%)	19 (38%)	50	37 (56%)	24 (36%)	7 (8%)	68
Women	47 (65%)	25 (35%)	72	51 (58%)	32 (37%)	4 (5%)	87
Total	78 (64%)	44 (36%)	122	88 (57%)	56 (36%)	11 (6%)	155

Table 2. Comparison of mean values of tested parameters between subjects with and without vertebral artery hypoplasia (VAH)

	Subjects with VAH	Subjects without VAH
Age (yrs)	49.07	42.52**
AV-R (mm)	2.43	3.18***
AV-L (mm)	3.02	3.33**
AV-R hemo (m/s)	0.36	0.46***
AV-L hemo (m/s)	0.41	0.47***
AV-R+AV-L (mm)	5.45	6.51***
AV-R+L hemo (m/s)	0.77	0.94***
Narrower (mm)	1.73	2.95***
Wider VA (mm)	3.72	3.57*

* p≤0.005; **p≤0.01; ***p≤0.001

AV-R, diameter of right vertebral artery; AV-L, diameter of left vertebral artery; AV-R hemo, hemodynamics of right vertebral artery; AV-L hemo, hemodynamics of left vertebral artery; AV-R+AV-L, diameter of both vertebral arteries; AV-R+L hemo, hemodynamics of both vertebral arteries; Narrower, diameter of the "narrower" vertebral artery; Wider VA, diameter of the "wider" vertebral artery

in 64% of subjects with VAH and 57% of subjects without VAH. A narrower left vertebral artery was present in 36% of subjects with VAH and those without VAH, whereas an equal width was present in 6% of subjects without VAH. Within group comparison yielded slight sex differences in this percentage (Table 1).

Sixty-two percent of men with VAH had narrower right vertebral artery as opposed to 56% of men without VAH. The left vertebral artery was narrower in 38% of men with VAH and 36% of men without VAH, whereas an equal width was present in 8% of men without VAH (Table 1). Sixty-four percent of women with VAH had narrower right vertebral artery as opposed to 57% of women without VAH. The left vertebral artery was narrower in 36% of women with and without VAH, while an equal width was present in 5% of women without VAH (Table 1).

Among 277 study subjects, the group of 122 subjects with VAH differed greatly in all parameters from the group of 155 subjects without VAH (Table 2). All differences were statistically significant. The subjects with hypoplasia were on an average seven years older than the subjects without hypoplasia. The group with VAH had smaller diameters of both right and left vertebral arteries. These differences, although statistically significant at both sides, were greater at the right side. Hemodynamics was also lower in both vertebral arteries of the subjects with VAH than in those without hypoplasia. The group without hypoplasia showed very similar mean blood flow velocities in both vertebral arteries, while the group with hypoplasia showed better blood flow through the left than through the right vertebral artery. When comparing the sum of both left and right vertebral artery diameters, it was again greater among subjects without VAH. The same was found for mean blood flow velocities in both vertebral arteries; they were lower in subjects with VAH. As expected, the width of the "narrower" vertebral artery was smaller in the group with hypoplasia. However, the width of the "wider" vertebral artery was greater in subjects with VAH (Table 2).

Discussion

Because of their anatomic location and inconvenient access for surgical procedures, vertebral arteries stayed neglected in research for a long time[16-19], even though 15% of all strokes occur in their irrigation territory. Greater interest in vertebral arteries followed the introduction of noninvasive ultrasound methods to the study of blood vessels[20,21].

The results obtained in this study confirmed some earlier findings on the subject. Back in 1999, Seidel *et al.*[22] showed that mean blood flow velocities were lower in right vertebral arteries and that lumen diameters of right vertebral arteries were smaller than those on the left side. Our results showed different findings in regard to mean blood flow velocities, which did not differ greatly between the right and left vertebral artery. Our study confirmed some results of earlier studies by Karayenbuehel and Yasargila in 1957[23]. They found that vertebral arteries had different diameters in 74% of the population, and 42% of the population had a dominant left

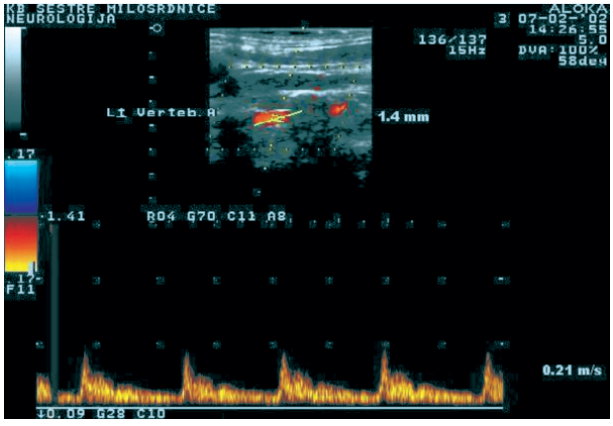

Fig. 1. Hypoplastic vertebral artery as seen by CDFI.

vertebral artery. Our study showed different diameters of the right and left vertebral artery in 92% of men and 95% of women. Touboul *et al*.[15] found a dominant left vertebral artery in 48% of subjects, with 14% having dominant right vertebral artery. In 1999, Lovrenčić-Huzjan *et al*.[8] found 64% of dominant left vertebral arteries in a Croatian population. We found 57% of dominant left vertebral arteries in subjects with normal vertebral arteries and 64% of dominant left vertebral arteries among subjects with VAH. On comparison of these two groups, we noticed the group with VAH to have a significantly smaller diameter of the right vertebral artery and lower mean blood flow velocities than the group without VAH. These findings could point to different hemodynamic behavior of vertebral arteries and is worthy of further investigation.

There are no data until now on different ways of compensation for smaller diameters or slower mean blood flow velocities. This is an interesting area to study because our data indicated possible differences in the hemodynamic behavior of the left and right vertebral artery.

In our study, an interesting result showed up, i.e. the fact that the "wider" vertebral artery was larger in subjects with VAH. This could point to another compensation mechanism in which the healthy side tries to compensate for the deficit through a larger diameter of the blood vessel. Unfortunately, the deficit caused by VAH could not be fully compensated for, irrespective of the healthy vessel diameter.

Conclusion

VAH is more common in women than in men (almost 60%:40%). The diameter of the right vertebral artery is narrower than the diameter of the left vertebral artery both in subjects with VAH and in healthy subjects. Also, the right vertebral artery is more often hypoplastic than the left one. The greater width of the "wider" vertebral artery in the group with VAH could point to a way of compensation for the deficit. Our study showed that despite larger diameters the deficit caused by VAH could not be fully compensated for. Differences between men and women are yet to be established. We believe that answers to these questions should be looked for through additional studies in a larger number of subjects.

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Sažetak

HIPOPLAZIJA VERTEBRALNE ARTERIJE: ZNAČAJKE U UZORKU HRVATSKE POPULACIJE

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Vertebralne arterije čine 30% krvne opskrbe mozga, opskrbljujući pretežito stražnje dijelove mozga. Petnaest posto svih moždanih udara nastaje u stražnjim dijelovima mozga, stoga je važno imati na umu značenje poremećaja koji uzrokuju hemodinamske promjene u vertebralnim arterijama. Hipoplazija vertebralne arterije je urođeno stanje koje obilježava uži lumen krvne žile i snižene srednje brzine strujanja krvi. Najčešće je prisutna kod zdravih pojedinaca. Cilj ovoga istraživanja bio je ustanoviti prisutnost i značenje hipoplazije vertebralne arterije u hrvatskoj populaciji, odrediti njenu pojavnost među spolovima i prema strani na kojoj se pojavljuje. Vjerovanja smo da je ovo istraživanje vrijedno zbog buduće lakše identifikacije pojedinaca izloženih većem riziku od nastanka cerebrovaskularnih poremećaja ili ozljeda koje mogu dovesti do problematičnih promjena u stražnjoj cirkulaciji. Analizirali smo nalaze 277 ispitanika. Sva mjerenja su izvedena u segmentu V2 vertebralne arterije, najčešće između vratnih kralježaka C6 i C5, upotrebom linearne sonde od 7,5 mHz na uređaju Aloka Prosound SSD-5500. Kriteriji za uredan nalaz CDFI nad vertebralnim arterijama su: promjer vertebralne arterije od 2,5-4,5 mm, sistolične srednje brzine strujanja krvi od 0,35-0,70 m/s i zadovoljavajući cirkulacijski otpor u vertebralnim arterijama. Dobiveni rezultati su pokazali da je lijeva vertebralna arterija dominantna kod 57% ispitanika, hipoplazija vertebralne arterije češće zahvaća žene, a desna vertebralna arterija je češće hipoplastična od lijeve. Također, širina "šire" vertebralne arterije je veća kod ispitanika s hipoplazijom vertebralne arterije, što bi moglo upućivati na mehanizam kompenzacije deficita uzrokovanog hipoplazijom. Ovo istraživanje je pokazalo kako unatoč većoj širini nehipoplastične vertebralne arterije nije moguće u potpunosti nadoknaditi nedostatak uzrokovan hipoplazijom.

Ključne riječi: Vertebralna arterija – nenormalnosti; Vertebralna arterija – ultrazvuk; Opskrba mozga krvlju; Moždana ishemija – etiologija; Hrvatska – epidemiologija