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Research Article

Methodical Aspects of Doppler Ultrasound of the Vertebrobasilar System

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Abstract

Introduction: Various pathologies of the cervical vertebrae (instability of the atlanto-axial junction, uncovertebral arthrosis, herniation of intervertebral disks) with combined rotational movements of the neck may contribute to the violation of vertebrobasillary hemodynamics. Doppler ultrasound imaging allows non-invasive recording of blood flow in all segments of the vertebral artery and the basal artery, to evaluate its quantitative parameters.

Aim: To assess the capabilities of various ultrasound transducers in imaging the segments of the vertebral arteries and the basal artery, to determine the quantitative parameters of blood flow in them in triplex mode.

Materials and Methods: Doppler ultrasound in the 1st, 2nd, 3rd and 4th segments of the Vertebral Arteries (VA) and Basilar artery (BA) was performed in 51 health patients aged 18 - 35 years. Patients with pathologies of the cervical vertebrae and intervertebral discs were not included in the study.

In all segments of the vertebral artery and in the Basal artery the maximum Systolic Velocity (Vs), the end Diastolic Velocity (Vd), the Resistance Index (RI) was determined. Doppler ultrasound was conducted on a Philips HD 11XE device using a linear (5 - 10 MHz), convex (2 - 5 MHz), sector (2 - 4 MHz) and microconvex (4 - 9 MHz) transducers (T).

Results: The comparative analysis of the possibility of various ultrasound transducers (T) in the visualization of segments of the VA was performed. With the help of a linear T, the I segment of the right VA was visualized in 82.3%, the left VA - in 72.5% of cases. The mouth of the VA using a convex T was visualized better than linear - in 90.2% cases ($P < 0.05$). For visualization of I and II segments of the VA, the use of a sector T was impractical. Using a microconvex T, the mouth of both VA were visualized in all 100% of cases. The II segment of the VA with a linear T was visualized in 98.0% cases, with a convex and microconvex T - in 100% cases. The III segment of the VA with a linear T was visualized in 92.2% cases, with convex and sector T in 100% of cases, and with a microconvex T - in 94.1% cases, respectively. The IV segment of the VA with a linear T was not visualized. Visualization of IV segment with a convex and sector Ts was carried out in all 100% of cases, and with microconvex T - in 68.6% cases ($P < 0.001$). The BA with a convex T was visualized in 90.2%, with a sector T in 100% and microconvex T - in 45.1% cases ($P < 0.001$), respectively.

In all segments of the VA and in the BA, the Vs ranged from 42 cm/s to 59 cm/s, the Vd - from 18 cm/s to 25 cm/s and RI - from 0,56 to 0,65 respectively. In I segment the average value of Vs was 51,2 ± 4,7 cm/s; in II segment - 50,6 ± 5,2 cm/s; in III segment - 48,3 ± 4,5 cm/s, in IV segment - 50,3 ± 5,1 cm/s and in the BA - 54,3 ± 5,6 cm/s. The average parameters for Vd was: 20,9 ± 2,1 cm/s; 19,8 ± 1,7 cm/s; 19,2 ± 2,1 cm/s; 20,4 ± 1,9 cm/s and 22,1 ± 2,3 cm/s respectively. The average value of RI in I segment of VA was 0,59 ± 0,03; in II segment - 0,61 ± 0,03; in III segment - 0,60 ± 0,03; in IV segment - 0,59 ± 0,03 and in the BA - 0,59 ± 0,04, respectively.

Conclusion: Doppler ultrasound in triplex mode justify the noninvasive approach to obtain quantitative parameters of blood flow, which can be used in various pathological conditions leading to disruption of Vertebrobasilar system hemodynamics.

To visualize the first segment of the vertebral artery, especially its mouth, it is advisable to use a micro-convex transducer.

In most cases, the second segment of the PA is better to visualize with a linear transducer, and in patients with a short and wide neck - with a convex and microconvex transducers.

The third and fourth segments, as well as the basal artery, are equally well visualized by convex and sector transducers.

The maximum systolic and end-diastolic velocity, the resistance index in different segments of the vertebral arteries do not differ significantly.

Keywords: *Doppler Ultrasound; Methodological Aspects; Vertebral Arteries; Basal Artery; Linear, Convex, Sector and Microconvex Transducers*

Introduction

About 15 - 20% of the cardiac output provides cerebral circulation. The main cerebral distribution center for blood flow is the Circle of Willis. Blood is delivered to the brain through the two internal carotid arteries that contribute 80% of the blood supply, and the two vertebral arteries that join intracranially to form the basilar artery. The basilar artery bifurcates into the right and left posterior cerebral arteries, which perfuse the posterior parts of the brain (the occipital lobe, cerebellum and the brain stem).

Various pathologies of the cervical vertebrae (instability of the atlanto-axial junction, uncovertebral arthrosis, herniation of intervertebral disks) with combined rotational movements of the neck may contribute to the violation of vertebrobasillary system hemodynamics [1,2]. There is evidence in the literature that manual therapy may be complicated by vertebrobasilar insufficiency [3,4].

It has been established that anatomical variation in the level of entry into the bone canal, as well as doubling of the vertebral arteries, creates prerequisites for pathological changes of hemodynamics in them under various functional loads and timely diagnosis is important for the prevention of these disorders [5-7].

A large number of studies are devoted to the study of blood flow in the vertebral arteries [8-10]. In these studies, the possibilities of triplex echography are presented one-sidedly, that is, hemodynamic features are shown in only one or two segments of the vertebral artery. In previously published articles, there are insufficient data on hemodynamics of the first and 4th segments of the vertebral arteries, as well as the basal artery in healthy individuals with functional loads.

Objective of the Study

To assess the capabilities of various ultrasound transducers in imaging the segments of the vertebral arteries and the basal artery, to determine the quantitative parameters of blood flow in them in triplex mode.

Materials and Methods

Doppler ultrasound in the 1st, 2nd, 3rd and 4th segments of the Vertebral Arteries (VA) and Basilar artery (BA) was performed in 51 health patients aged 18 - 35 years. Patients with pathologies of the cervical vertebrae and intervertebral discs were not included in the study.

In all segments of the vertebral artery and in the Basal artery the maximum Systolic Velocity (Vs), the end Diastolic Velocity (Vd), the Resistance Index (RI) was determined. Doppler ultrasound was conducted on a Philips HD 11XE device using a linear (5 - 10 MHz), convex (2 - 5 MHz), sector (2 - 4 MHz) and microconvex (4 - 9 MHz) transducers (T).

Results

We carried out a comparative analysis of the possibility of various ultrasound transducers in the visualization of segments of the vertebral arteries. As can be seen from table 1, with the help of a linear transducer, the I segment of the right vertebral artery (RVA) together with its origin was visualized in 42 (82.3 ± 5.3%), the left vertebral artery (LVA) - in 37 (72.5 ± 6.3%) of cases. The main limitation of visualization of the origin of the VA was that the transducer rested against the clavicle. The right subclavian artery to the transducer was closer than the left, as it departed from the brachiocephalic trunk. The origin of the vertebral arteries using a convex transducer was visualized better than linear - in 46 (90.2 ± 4.2%) and 45 (88.2 ± 4.5%) cases, respectively. In visualization of the mouth of the left vertebral artery, the difference between linear and convex transducers was significant ($P < 0.05$).

For visualization of I and II segments of the vertebral arteries, the use of a sector transducer was impractical. Using a microconvex transducer, the origins of both vertebral arteries were visualized in all 100% of cases (Figure 1).

The second segment of the VA with a linear transducer was visualized in 50 (98.0 ± 2.0%) cases, with a convex and microconvex transducers - in 100% cases (Figure 2).

The III segment of the VA with a linear transducer was visualized in 47 (92.2 ± 3.8%) cases, with convex and sector transducer in 100% of cases, and with a microconvex transducer - in 48 (94.1 ± 3.3%) cases, respectively. The IV segment of the VA with a linear transducer was not visualized. Visualization of IV segment with a convex and sector transducers was carried out in all 100% of cases, and with microconvex transducer - in 35 (68.6 ± 5.7%) cases ($P < 0.001$). The basal artery with a convex transducer was visualized in 46 (90.2 ± 4.2%), with a sector transducer in 100% and microconvex in 23 (45.1 ± 7.0%) cases ($P < 0.001$), respectively (Figure 3 and 4).

Vertebral artery Segments and Basal artery	Total number of studies (n = 51)			
	Linear transducer 5 - 10 MHz	Convex Transducer 2 - 5 MHz	Sector Transducer 2 - 4 MHz	Microconvex Transducer 4 - 9 MHz
I segment with the origin of the RVA	42 (82,3 ± 5,3%)	46 (90,2 ± 4,2%)	Not used	51 (100,0 ± 1,4%)
I segment with the origin of the LVA	37 (72,5 ± 6,3%)	45 (88,2 ± 4,5%) P < 0,05	Not used	51 (100,0 ± 1,4%)
II segment	50 (98,0 ± 2,0%)	51 (100,0 ± 1,4%)	Not used	51 (100,0 ± 1,4%)
III segment	47 (92.2 ± 3.8%)	51 (100,0 ± 1,4%)	51 (100,0 ± 1,4%)	48 (94,1 ± 3,3%)
IV segment	-	51 (100,0 ± 1,4%)	51 (100,0 ± 1,4%)	35 (68,6 ± 5,7%) P < 0,001
Basilar artery	-	46 (90,2 ± 4,2%)	51 (100,0 ± 1,4%)	23 (45,1 ± 7,0%) P < 0,001

Table 1: *Frequency of visualization of the basal artery and segments of vertebral artery using various transducers.*

Note*: It is not advisable to use a sector sensor to visualize the first and second segments of the VA.*

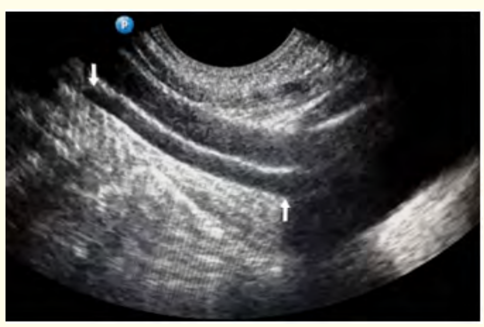

Figure 1: *Visualization of the first segment of the vertebral artery with a microconvex transducer.*
The right arrow shows the origin, the left arrow shows the place of entry of the artery into the canal for the VA.

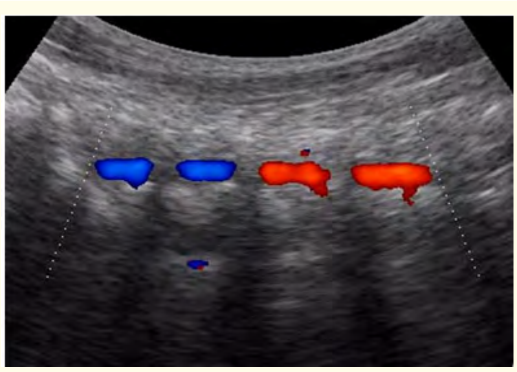

Figure 2: *Visualization of the second segment of the vertebral artery with a convex transducer.*
VA is visible at the level of 4 cervical intervertebral discs.

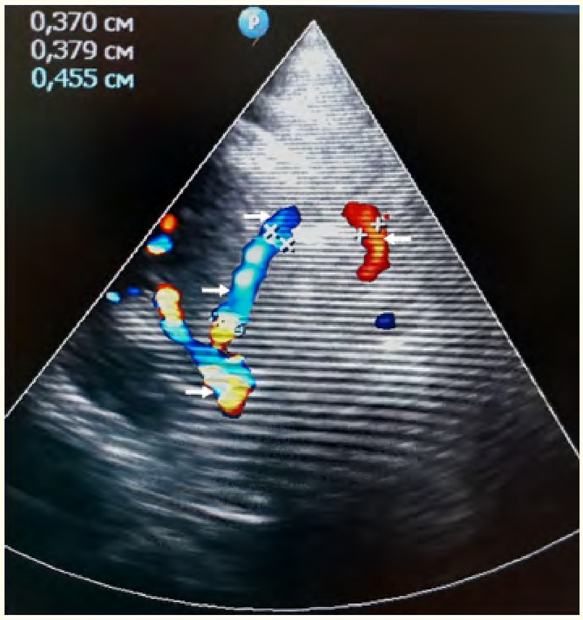

Figure 3: *Visualization of the thirds (the upper arrows) and fourth (the left middle arrow) segments of the vertebral artery and the basal artery (the lower arrow).*

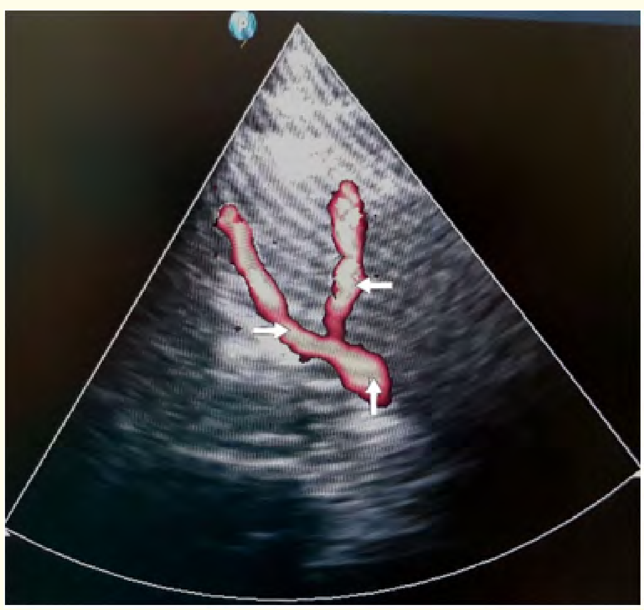

Figure 4: *Visualization of the fourth segments of the vertebral artery (horizontal arrows) and the basal artery (vertical arrow) using a sector transducer.*

The Doppler spectrum of the blood flow was monophasic, in all cases of the onset of diastole a narrow incision was noted. The maximum systolic velocity (Vs), the end diastolic velocity (Vd), the resistance index (RI) were determined. In all segments of the vertebral arteries and in the basal artery, the maximum systolic blood flow velocity ranged from 42 cm/s to 59 cm/s, the end diastolic velocity - from 18 cm/s to 25 cm/s and RI - from 0,56 to 0,65 respectively (Figures 5-10).

In I segment the average value of Vs was 51,2 ± 4,7 cm/s; in II segment - 50,6 ± 5,2 cm/s; in III segment - 48,3 ± 4,5 cm/s, in IV segment - 50,3 ± 5,1 cm/s and in the basilar artery - 54,3 ± 5,6 cm/s. The average parameters for diastolic velocity was: 20,9 ± 2,1 cm/s; 19,8 ± 1,7 cm/s; 19,2 ± 2,1 cm/s; 20,4 ± 1,9 cm/s and 22,1 ± 2,3 cm/s respectively. The average value of RI in I segment of vertebral artery was 0,59 ± 0,03; in II segment - 0,61 ± 0,03; in III segment - 0,60 ± 0,03; in IV segment - 0,59 ± 0,03 and in the basilar artery - 0,59 ± 0,04 respectively (Table 2).

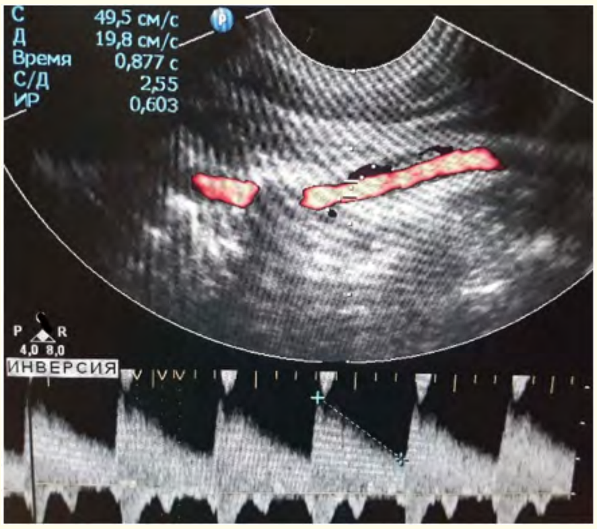

Figure 5: *Doppler spectrum of the blood flow in first segment of the vertebral artery in neutral position of patient. Vs is 49,5 cm/c, RI - 0,60.*

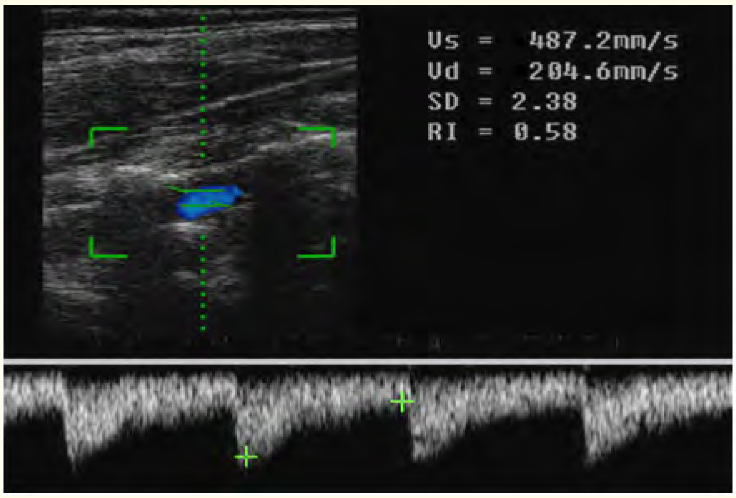

Figure 6: *Doppler spectrum of the blood flow in second segment of the vertebral artery in neutral position of patient. Vs is 48,7 cm/c, RI - 0,58.*

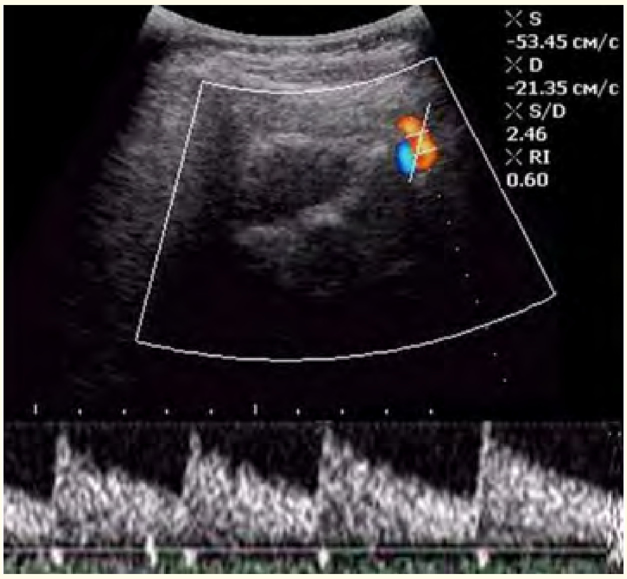

Figure 7: *The Doppler spectrum of blood flow was obtained from the ascending part of the third segment of the vertebral artery using a convex transducer. Vs is 53,45 cm/c, RI - 0,60.*

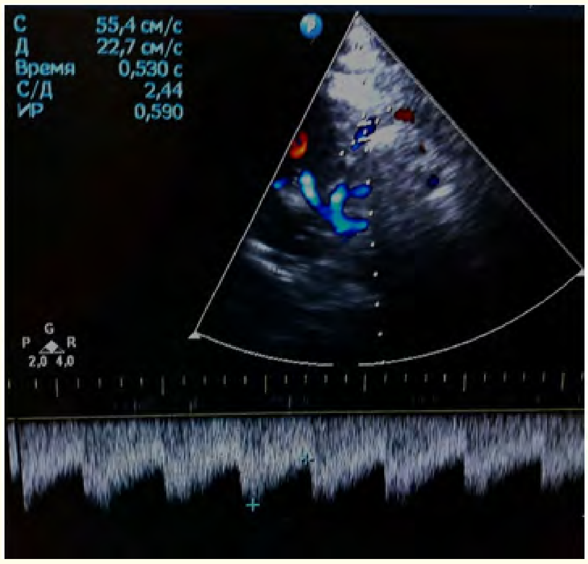

Figure 8: *The Doppler spectrum of blood flow was obtained from the descending part of the third segment of the vertebral artery using a sector transducer. Vs is 55,4 cm/c, RI - 0,59.*

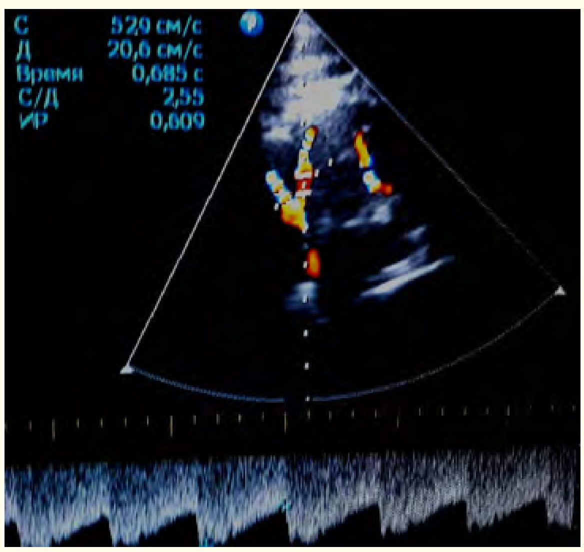

Figure 9: *Doppler spectrum of the blood flow in fourth segment of the vertebral artery in neutral position of patient. Vs is 52,9 cm/c, RI - 0,61.*

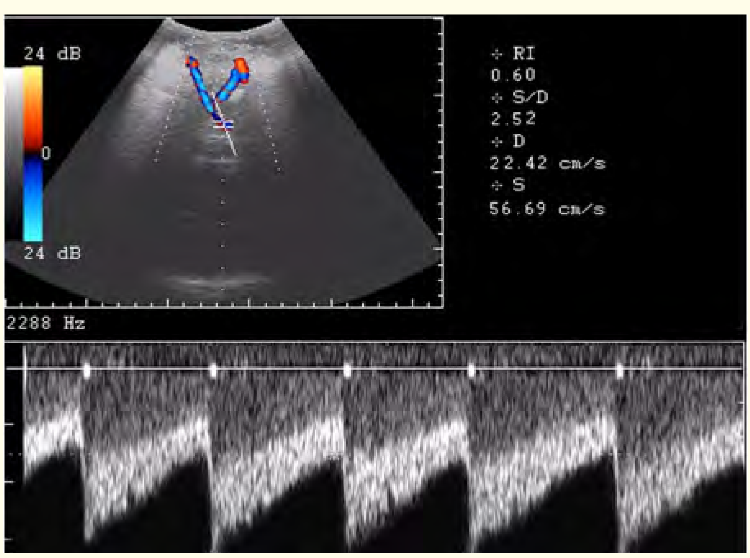

Figure 10: *Doppler spectrum of the blood flow in basal artery in neutral position of patient. Vs is 56,69 cm/c, RI - 0,60.*

Doppler parameters	I Segment of VA	II Segment of VA	III Segment of VA	IV Segment of VA	Basilar artery
Vs (cm/c)	51,2 ± 4,7	50,6 ± 5,2	48,3 ± 4,5	50,3 ± 5,1	54,3 ± 5,6
Vd (cm/c)	20,9 ± 2,1	19,8 ± 1,7	19,2 ± 2,1	20,4 ± 1,9	22,1 ± 2,3
RI	0,59 ± 0,03	0,61 ± 0,03	0,60 ± 0,03	0,59 ± 0,03	0,59 ± 0,04

Table 2: *Hemodynamic parameters of the blood flow in the vertebral arterial segments and basal artery.*

Discussion

About 20% of the blood flow in the Circle of Willis is provided by two vertebral arteries, which merging intracranially and form the basal artery. The most common cause of Vertebrobasilar insufficiency is atherosclerosis, which in most cases develops in the mouth of the vertebral arteries [3,11,12]. The most commonly used linear transducer in 20 - 30% of cases does not allow to visualize this area.

The literature contains data on the vulnerability of the 3rd segment of the vertebral artery (Atlanta loop) during manipulations in patients with pathologies of the cervical spine, accompanied by changes in blood flow in it and in the brain [8].

Yamaoka Y (2015) studied the role of ultrasound in diagnosing the degree of changes in the Atlanta loop with the maximum rotation of the head [2]. Studies by Brett A., *et al.* (2015) on the study of blood flow in healthy people at the level of the atlanto-axial articulation, in the suboccipital part of the 3rd segment of the vertebral artery at rest and when the head was bent to the right and left did not reveal significant changes [13].

It is established that the anatomical variation of the mouth, the level of entry into the foraminal canal, as well as doubling of the vertebral arteries creates prerequisites for pathological changes of hemodynamics in them at different functional loads and timely diagnosis is important to prevent these disorders [6,7,14,15].

In our study, the capabilities of various ultrasound transducers for imaging segments of the vertebral arteries and the basal artery are shown, and quantitative parameters of the blood flow to them in triplex mode are determined.

Comments

Due to the fact that the carotid and vertebral arteries are nearby, their research is more often carried out together, in cases of the appearance of clinical manifestations of cerebral hemodynamic disorders. Typically, these vessels are examined by linear transducer, and their intracranial part - with the sector transducer.

These transducers in 20 - 30% of cases do not provide high-quality visualization of the vertebro-basilar system.

In this regard, the use of other sensors, such as convex and microconvex, can help to obtain a high-quality image of various departments of the vertebrobasillary system.

Conclusion

Doppler ultrasound in triplex mode justify the noninvasive approach to obtain quantitative parameters of blood flow, which can be used in various pathological conditions leading to disruption of Vertebrobasilar system hemodynamics.

To visualize the first segment of the vertebral artery, especially its mouth, it is advisable to use a micro-convex transducer.

In most cases, the second segment of the PA is better to visualize with a linear transducer, and in patients with a short and wide neck - with a convex and microconvex transducers.

The third and fourth segments, as well as the basal artery, are equally well visualized by convex and sector transducers.

The maximum systolic and end-diastolic velocity, the resistance index in different segments of the vertebral arteries do not differ significantly.

Conflict of Interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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