

CASE STUDY



QUANTITATIVE MEASUREMENTS OF BLOOD FLOW PARAMETERS IN NORMAL INTERNAL CAROTID ARTERIES WITH COLOR DOPPLER ULTRASONOGRAPHY AND VASCULAR STENOSIS INDEX OF STENOTIC VESSELS

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Abstract

OBJECTIVES

The aim of this study was to determine the values of peak systolic velocity (PSV), end-diastolic velocity (EDV), resistive index (RI), pulsatility index (PI), and blood flow in normal internal carotid arteries (ICA) together with the percentage of stenosis (for diameter and area), and vascular stenosis index (VSI) in stenotic ICA.

MATERIALS AND METHODS

Fifteen male and 16 female adult patients aged between 50-71 with atherosclerotic plaques with different thicknesses in the internal carotid arteries, and together with 20 normal adult males and 20 females aged between 25 and 45 years were included in this work.

The values of PSV, EDV, RI, PI, and blood flow volume of normal ICA were measured. Stenosis percentages and VSI values were obtained in the narrowed vessels due to atherosclerotic plaques. All parameters were shown as mean \pm SD.

For the statistical analysis, Statistical Package for Social Sciences Version 15.0 (SPSS Inc., Chicago, IL, USA) software was used.

RESULTS

We have shown the data together in Table 2,3 without discriminating between gender and right left side. The normal lumen diameter of the ICA, the diameter of the stenotic lumen, the percentage of stenosis for diameter, normal lumen area, stenotic lumen area, the percentage of stenosis for the area, and VSI values were shown in Table 3.

CONCLUSION

We believe that this data can be useful in evaluating cerebral hemodynamics in healthy and sick people because we cannot find any study on VSI in ICA stenosis in the literature.

Keywords: Internal carotid artery, atherosclerosis, Doppler ultrasonography, vascular stenosis index, blood flow

1 | INTRODUCTION

Carotid artery system is a very important vascular system that feeds all organs and tissues in the head, especially the brain, with the vertebral artery system (1).

Cerebrovascular accident is one of the leading causes of death and persistent disease in humans. 80% of the ischemic processes occur due to atherosclerosis. The most common location of these plaques is in the carotid bulb and carotid bifurcation segment (1-3).

Society of Radiologists in Ultrasound (SRU) consensus developed recommendations for the diagnosis and stratification of internal carotid artery (ICA) stenosis in Table 1 (4).

TABLE 1: Society of Radiologists in Ultrasound (SRU) consensus developed recommendations for the diagnosis and stratification of ICA stenosis.

ICA stenosis	PSV of ICA (cm/sec)	EDV of ICA (cm/sec)	ICA/CCA PSV ratio
Normal	<125	<40	<2,0
<50 (plaque or intimal thickening is visible sonographically)	<125	<40	<2,0
50-69	125-230	40-100	2,0-4,0
≥70 (less than near occlusion)	>230	>100	>4,0
Near occlusion (velocities may be high, low, or undetectable)	variable	variable	variable
Complete occlusion	no flow	no flow	no flow

PSV: peak systolic velocity, EDV: end-diastolic velocity, ICA: internal carotid artery, CCA: common carotid artery

A large number of studies demonstrates previously the results of blood flow parameters for normal internal carotid artery (ICA) in the literature. While there are few studies on the vasospasm index (VI) in the ICA spasm, in the literature we did not find any study on vascular stenosis index (VSI) in cases of stenosis due to atherosclerosis.

The aim of this study was to determine the values of peak systolic velocity (PSV), end-diastolic velocity (EDV), resistive index (RI), pulsatility index (PI), and blood flow in normal ICA together with the percentage of stenosis (for diameter and area), and VSI in stenotic ICA.

2 | MATERIALS AND METHODS

Fifteen male and 16 female adult patients aged between 50-71 with atherosclerotic plaques with different thicknesses in the internal carotid arteries, and together with 20 normal adult males and 20 females aged between 25 and 45 years were included in this work.

In our study which was approved by the ethics committee was performed by an only radiologist within 6 months.

We used a high resolution, an ultrasound probe of 7 MHz with a linear array. Doppler angle was adjusted between 30-60 degrees in parallel to the vessel wall.

The preferred patient position for carotid ultrasonography (US) examination is in the head hyperextension when the body is in the supine position. The neck is in the neutral position or rotated between 30-45 degrees in the opposite direction of the evaluated side.

We started imaging the carotid arteries with Doppler US immediately above the clavicle and continued until 4-6 cm above the carotid bifurcation.

The values of PSV, EDV, RI, PI, and blood flow volume of normal ICA were measured (Figure 1).

Stenosis percentages and VSI values were obtained in the narrowed vessels due to atherosclerotic plaques (Figure 2).

Supplementary information The online version of this article contains supplementary material, which is available to authorized users.

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Quantitative Measurements of Blood Flow Parameters in Normal Internal Carotid Arteries with Color Doppler Ultrasonography and Vascular Stenosis Index Of Stenotic Vessels



FIGURE 1: Doppler ultrasonography measurement of the vessel diameter, peak-systolic velocity (PSV), end-diastolic velocity (EDV), resistive index (RI), pulsatility index (PI) (a), and blood flow in the Internal Carotid Artery (ICA) (b).

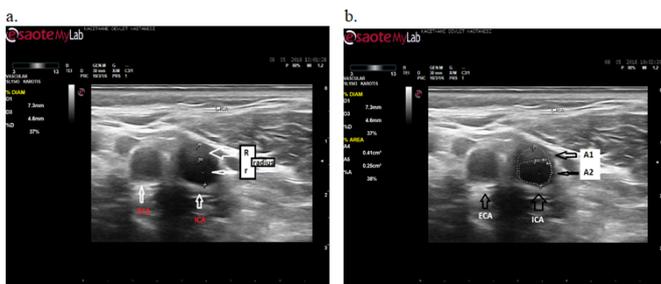


FIGURE 2: The value estimation method of Vascular Stenosis Index (VSI) is seen by measuring diameters in stenotic internal carotid artery (ICA) (a). The proportion of ICA wall surface values (wall ring) to lumen surface values was accepted as VSI. The VSI is the ratio of the Area 1 (A1) to Area 2 (A2) (b).

All parameters were shown as mean \pm SD. For the statistical analysis, Statistical Package for Social Sciences Version 15.0 (SPSS Inc., Chicago, IL, USA) software was used. ANOVA test, Mann-Whitney U tests, and paired samples t-test were used to determine if there was a difference between the right and left vessels and genders. The differences of VSI values of ICA were analyzed. P values less than or equal to 0.05 were considered as statistically significant.

3 | RESULTS

Significant differences in blood velocity and other flow parameters were not observed between the right and left ICA in either sex ($p > 0.05$). For these reasons, we have shown the results together in Table

2,3 without discriminating between gender and right left side.

In our study we found the data, ICA diameter was 7.99 ± 0.64 mm; PSV in ICA was 89.4 ± 10.4 cm/sec; EDV was 31.1 ± 8.2 cm/sec; RI was 1.28 ± 0.11 ; PI was 4.29 ± 0.69 ; ICA blood flow volume was 273.4 ± 30.7 mL/min in normal adults (Table 2).

TABLE 2: Data for blood velocity (PSV, EDV), resistive index (RI), pulsatility index (PI), and blood flow of normal internal carotid artery (ICA) in normal adults.

FLOW PARAMETERS	MEAN	\pm SD
Peak Systolic Velocity (PSV): cm/sec	89,4	10,4
End-Diastolic Velocity (EDV): cm/sec	31,1	8,2
Resistive Index (RI)	1,28	,11
Pulsatility Index (PI)	4,29	,69
Blood Flow Volume (mL/min)	273,4	30,7

The normal lumen diameter of the ICA, the diameter of the stenotic lumen, the percentage of stenosis for diameter, normal lumen area, stenotic lumen area, the percentage of stenosis for the area, and VSI values were shown in Table 3.

TABLE 3: The *percentage of stenosis* and Vascular Stenosis Index (VSI) values of stenotic internal carotid artery (ICA).

	MEAN	\pm SD
The normal lumen diameter of the internal carotid artery (ICA)	7,99	,64
Diameter of the stenotic lumen	5,06	,43
DIAMETER - The percentage of stenosis	37,00	3,01
Normal lumen area (cm ²)	,50	,086
Stenotic lumen area (cm ²)	,26	,01
AREA - The percentage of stenosis	47,71	9,09
VSI = $(R^2 - r^2) / r^2$	1,50	,022

4 | DISCUSSION

Carotid arteries can be displayed at the higher resolution than in other modalities by ultrasound due to their superficial location, course and appropriate placement for unobstructed access to the sound wave. Doppler ultrasonography is a reliable, noninvasive imaging method used for the examination of carotid and vertebral arteries. In addition to morphological information, colored and spectral Doppler US can show real-time flow changes caused by vascular lesions (5-8).

Society of Radiologists in Ultrasound (SRU) consensus developed recommendations for the diagnosis and stratification of internal carotid artery (ICA) stenosis in Table 1 (4).

The estimation method of VSI is seen by measuring diameters in stenotic ICA in figure 2. The proportion of ICA wall surface values (wall ring) to lumen surface values was accepted as VSI. The VSI is the ratio of area 1 (A1) to area 2 (A2). Low luminal surface values and high VSI was accepted as prominent vascular stenosis (9-11). This index was calculated with the following formula:

$$VSI = (\pi R^2 - \pi r^2) / \pi r^2 = (R^2 - r^2) / r^2$$

While there are few studies on the VI in the ICA spasm, in the literature we did not find any study on VSI in cases of stenosis due to atherosclerosis (9-11). Therefore, we aimed that determining the values of PSV, EDV, RI, PI, and blood flow in normal ICA together with the percentage of stenosis (for diameter and area), and VSI in stenotic ICA.

Measurement of carotid artery intima-media thickness and evaluation of plaque structure are an important step of the method. The carotid intima-media thickness should normally be less than 0.8 mm. The fact that intima-media thickness exceeds 1.0 mm is considered to be definitive pathological (12-15).

In addition to atherosclerosis, Takayasu's disease and fibromuscular dysplasia are also possible causes of vascular constriction. Takayasu disease is a chronic, inflammatory main artery disease involving the aorta and its main branches. It is observed more frequently in women. Fibromuscular dysplasia is a disease of unknown origin that occurs in young

women and holds the internal carotid artery most frequently after renal arteries (16,17).

The rates of stricture in ICA determine the treatment approach. Medical treatment is applied in patients with stenosis less than 50% symptomatic. It is investigated whether there is a progression with Doppler US every 6 months in addition to medical treatment in 50-69% stenosis. Carotid endarterectomy is performed in patients with symptomatic symptoms in the group of a near occlusion and stenosis of more than 70%. In the case of complete occlusion, there is no surgical possibility (2,3,7,16).

Yazıcı et al. have reached the same conclusion with us about no significant differences were noted between the genders regarding ICA blood flow volume (3). Also, in some publications, carotid and vertebral artery diameters significantly increased with increasing age. A significant decrease was detected in the ICA blood velocity and blood flow volume with respect to aging (2,7,16).

No significant differences were noted in ICA diameter in between genders ($p > 0.05$). Significant differences in blood velocity and other flow parameters were not observed between the right and left ICA in either sex ($p > 0.05$). For these reasons, we have shown the results together in Table 2,3 without discriminating between gender and right left side.

The normal lumen diameter of the ICA, the diameter of the stenotic lumen, the percentage of stenosis for diameter, normal lumen area, stenotic lumen area, the percentage of stenosis of the area, and VSI values in stenotic vessels were shown in Table 3. However, table 4 demonstrates previously published blood flow results for normal ICA in the literature (3,17,18).

TABLE 4: It was demonstrated previously published bloodflow results for normal internal carotid artery (ICA).

Authors	MEAN	± SD
Schoning et al.	265	26
Dorfler et al.	238	45
Yazıcı et al.	231	59
This study	273	31

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5 | CONCLUSION

A large number of studies demonstrates previously the results of blood flow parameters for normal ICA in the literature. While there are few studies on the VI in the ICA spasm, in the literature we did not find any study on VSI in cases of stenosis due to atherosclerosis.

Therefore, we believe that these data could prove to be useful in the evaluation of cerebral hemodynamics in healthy and sick people.

6 | REFERENCES

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