ORIGINAL ARTICLE — Head and neck imaging

Correlation of carotid artery doppler indices with national institute of health sciences stroke scale in post stroke patients

Asma Yazdan[1], Iqra Manzoor[1], Syed Muhammad Yousaf Farooq[2], Sajja Ullah[3], Laiba Begum[4], Aruj Latif[1]

[1]University Institute of Radiological Sciences & Medical Imaging Technology, Faculty of Allied Health Sciences, The University of Lahore

[2]Department of Radiography and Imaging Technology, Green International University, Lahore, Pakistan

[3]Leeds Beckett University, UK

[4]Iqra National University, Pakistan

SUBMISSION: 04/05/2024 - ACCEPTANCE: 21/10/2024

ABSTRACT

Background: Carotid artery stenosis, also known as carotid artery disease (CAD), is characterized by a narrowing of the carotid arteries because of the disease's progression. Plaque is the most prevalent cause of carotid artery constriction, and it is caused by a buildup of fatty substances and cholesterol deposits.

Objective: Objective: To correlate carotid artery Doppler indices with National Institute of Health Sciences stroke (NIHSS) scale in post stroke patients.

Material and Methods: It was cross sectional analytical study carried out at the Radiology Department of the Rehman Medical Institute Phase 05 Hayatabad and Hayatabad Medical Complex Phase 4 in Peshawar. Duration of study was 9 months. Convenient sampling technique was used to collect the data.

The sample size was determined by applying the algorithm for determining the correlation between the NIHSS score and the CCA PSV Left side to the data from

CORRESPONDING AUTHOR, GUARANTOR

Syed Muhammad Yousaf Farooq
Email: Yousafgelani@gmail.com
Qualification: PhD Diagnostic Ultrasound, MPhil, MSc
Designation: Head of department
Department of Radiography and Imaging Technology, Green International University, Lahore, Pakistan.

the pilot study, which included 17 different patients. The calculated sample size was 74.

Results: 74 patients participated in the study in which 44.6% were female and 55.4 were Male. Mean age of the participants were 63.3±11. The correlation between Carotid Doppler indices and National Institute of Health Sciences stroke scale shows strong positive correlation (r=0.793, p<0.001), between higher (NIHSS) scores are associated with increased right ICA-EDV. Moderate positive correlation (r=0.439, p<0.001), found between higher NIHSS scores and increased left IMT. Strong positive correlation (r=0.926, p<0.001), shows that NIHSS scores are associated with increased right ECA-PSV, (r=0.926, p<0.001) right ECA-PSV. Strong positive correlation (r=0.537, p<0.001), showing a relationship between increased right ICA-EDV and left IMT. Moderate positive correlation (r=0.375, p=0.001), suggesting a relationship between left CCA-PSV and left ICA-PSV. Strong positive correlation (r=0.827, p<0.001), indicating an association between increased right ICA-PSV and right ECA-PSV. Strong positive correlation (r=0.886, p<0.001), showing a relationship between increased left ICA-EDV and right ECA-PSV.

Conclusion: A correlation between NIHSS, carotid artery stenosis, and ICA-PSV indicates that severe neurological deficits often align with advanced carotid artery disease and increased blood flow.

KEY WORDS

carotid artery stenosis, stroke, internal carotid artery, Doppler Ultrasound, NIH stroke scale

Introduction

Carotid artery stenosis, also known as carotid artery disease (CAD), is characterized by a narrowing of the carotid arteries because of the disease's progression. Plaque is the most prevalent cause of carotid artery constriction, and it is caused by a buildup of fatty substances and cholesterol deposits.[1] Occlusion of the carotid artery is the medical term for when the carotid artery is completely blocked off. According to research, a person's risk of suffering a stroke is significantly raised when their carotid arteries are blocked. The CAS is a prevalent factor in the occurrence of strokes.[2] Carotid artery narrowing is a condition that affects around 7.5 percent of males and 5.0 percent of women over the age of 80. This percentage increases as people live longer.[3] According to research, the primary mechanisms responsible for causing cerebral ischemia, which is induced by carotid disease, are plaque rupture and the subsequent embolism to the brain.[4]

It is estimated that between 0.2 and 2.5 strokes caused by carotid artery stenosis occur annually for every 1000 people. According to, around 20 million people around the world suffer from a stroke each year; 15 million people manage to survive the stroke, while the remaining 5 million are rendered incapable as a direct result of the stroke.[5] The chances of having another stroke increases with time, reaching its peak within the first few weeks after an initial stroke episode.[6] Non-invasive methods such as high-resolution duplex ultrasonography, contrast-enhanced Magnetic Resonance Angiography (MRA), time-of-flight, and Computed Tomography Angiography (CTA) are used to identify carotid stenosis. All of them have showed reasonable sensitivity and specificity when compared to the gold standard of digital subtraction Angiography (DSA).[7]

It is projected that up to eighty percent of patients all over the world was undergo carotid revascularization after employing color Doppler ultrasound (CDUS) as their sole preoperative diagnostic tool. Although DSA is still regarded to be the gold standard for evaluating the severity of carotid stenosis, it is often reserved for certain instances such as carotid artery stenting, which is scheduled because to the risks involved with the measure's invasiveness.[8] Color Doppler Ultrasound (CDUS) is used to grade the degree of stenosis by observing the blood flow waveform maximum at the location of arterial narrowing. This procedure is completely risk-free, inexpensive, and results in only a moderate amount of discomfort for the patient. A typical CDUS examination was often include grayscale imaging, spectral Doppler velocity evaluation, and color Doppler imaging.[9] Peak Systolic Velocity (PSV) and End Diastolic Velocity (EDV) both at distal common carotid and internal carotid artery are highly recommended techniques on spectral Doppler evaluation.[10,11]

According to histology and imaging investigations, a carotid stroke may be dependent not only on the degree of stenosis.[12] but also on the morphological features of the plaque, such as cracks producing rupture or ulcers. These findings suggest that a carotid stroke may be dependent on both factors.[13]

Because of the stenosis in the carotid artery, there is a reduction in the radius of the stenotic lumen, which leads to a reduction in the amount of blood that may enter the artery. Acute hemodynamic failure can lead to decreased blood supply to the brain, which may or may not result in brain infarctions. According to research carotid stenosis can cause the brain to become "vulnerable" due to the presence of hemodynamic failure, which results in decreased cerebral blood flow and affects regions of the brain that already have relatively low perfusion.[14]

The utilization of duplex ultrasound as a diagnostic instrument for carotid disease has become increasingly common. It is not expensive but must be handled by an expert in order to identify disease with a precision of 90%.[15]

The National Institutes of Health Stroke Scale (NIHSS), which is commonly used to quantify the impairment caused by stroke, consists of eleven different components, each of which is given a score between 0 and 4. The total NIHSS score ranges from 0 to 42, with 0 indicating that there are no symptoms of stroke and 21 indicating the incidence of severe symptoms of stroke. The scores of all eleven components are combined together to determine the total NIHSS score. Level of consciousness (Consciousness, Question and orders), Gaze, Facial palsy, Motor arm, Motor leg, Limb ataxia, Sensation, Language, Dysarthria, Extinction, and Inattention are some of the eleven components. Inattention is also one of the eleven components.[16]

There are studies related to the quantification of stroke severity on the NIHS scale and the accuracy of Doppler indices separately, but there is no study related to this topic. The rationale of the study is to detect carotid artery stenosis using advanced ultrasound techniques in order to prevent carotid stenosis in patients with transient ischemic attack and acute ischemic stroke. Early detection of stroke can minimize the burden of stroke on the population as well as decrease the mortality ratio.

Material and Methods

It was cross sectional analytical study carried out at the Radiology Department of the Rehman Medical Institute Phase 05 Hayatabad and Hayatabad Medical Complex Phase 4 in Peshawar. Duration of study was 9 months. Non-probability convenience sampling technique was used to collect the data. The sample size was determined by applying the algorithm for determining the correlation between the NIHSS score and the CCA PSV Left side to the data from the pilot study, which included 17 different patients. The calculated sample size was 74. Inclusion criteria: Patients of both genders with age between 40 – 60 years, symptomatic and asymptomatic were included in this study. Patients who were undergo both duplex ultrasound and NIHSS stroke scale. Exclusion criteria: Patients with hemorrhagic stroke were excluded.

Procedure

Data was collected using a multifrequency (7-MHz) linear array transducer for ultrasonography (IU 22, Philips Ultrasound) and Mindray ultrasound machine. On B-mode by lying the patient supine and gel was applied to neck. Since the CCA is situated in the transverse plane above the clavicle, medial to the internal jugular vein and lateral to the thyroid gland, the linear probe was aimed caudally to display as much of the CCA as possible. The artery was then followed distally by rotating the probe through 90 degrees into the longitudinal plane until it splits into the external carotid artery anteriorly and the ICA posteriorly. The probe was then moved laterally and posteriorly to locate the ICA, which was evaluated in the longitudinal and transverse planes and measurement for Intimal medial thickness of both right and left side was calculated from the wall to border of lumen.

Furthermore, Doppler study was calculated by lying the patient supine with their neck rotated 45 degrees away from the side being studied and their head gently hyperextended with a pillow to guarantee sufficient neck exposure. To improve the transmission of ultrasonic waves, acoustic gel is applied to the skin of the neck in order to eliminate air. Measuring the peak systolic velocities, End diastolic velocities of common carotid, internal and external carotid artery. Findings of ultrasound was correlated with National Institutes of Health Science Stroke Scale (NIHSS). This scoring system is used to quantify the impairment of stroke and includes eleven components, with each of them scored between 0 and

4. The scores of all eleven components was added up for the total NIHSS score between 0 to 42, with 0 showing no symptoms of stroke and ≥ 21 show the occurrence of a severe symptoms of stroke.

Stroke Scale	
Total NIHSS score	Stroke severity
0	No Symptoms of stroke
1 to 4	Minor Symptoms of stroke
5 to 15	Moderate Symptoms stroke
16 to 20	Moderate to severe Symptoms of stroke
21 to 42	Very Severe Symptoms of stroke

Intervention for carotid stenosis within 9 months was also be recorded. Patients with significant symptomatic carotid stenosis was also be considered for Carotid endarterectomy (CEA).

Data Analysis Procedure

Data was entered and analyzed using SPSS v.25. For quantitative variable (Doppler indices and NIHS stroke scale) mean and standard deviation was calculated. For qualitative variables (gender and degree of stenosis). Frequency and percentage was calculated. Pearson correlation was done for correlating changes of Doppler indices and NIHSS scores. P value of less than 0.05 was taken as significant.

Results

There are 74 patients in total. The average age of the individuals is reported as 64.4 ± 11.0. In terms of gender, the group consists of 41 males (55.4%) and 33 females (44.6%). The NIHSS scoring reveals a breakdown as follows: 12 individuals (16.2%) scored 0, 2 individuals (2.7%) scored between 1 to 4, 35 individuals (47.3%) scored between 5 to 15, 10 individuals (13.5%) scored between 16 to 20, and 15 individuals (20.3%) scored between 21 to 42 (Table 1).

The correlation between Carotid Doppler indices and National Institute of Health Sciences stroke scale is represented in (Table 3) shows strong positive correlation (r=0.793, p<0.001), between higher NIHSS Stroke Scale (NIHSS) scores are associated with increased right ICA-EDV. Moderate positive correlation (r=0.439, p<0.001), suggesting a relationship between higher NIHSS scores and increased left IMT. Strong positive correlation (r=0.926, p<0.001), revealing that elevated NIHSS scores are associated with increased right ECA-PSV. Weak negative correlation (r=-0.090, p=0.447), indicating a non-significant relationship between left CCA-PSV and NIHSS scores. Strong positive correlation (r=0.654, p<0.001), suggesting that higher NIHSS scores are associated with increased left ICA-PSV. Strong positive correlation (r=0.926, p<0.001), indicating an association between higher NIHSS scores and increased right ECA-PSV. Strong positive correlation (r=0.537, p<0.001), showing a relationship between increased right ICA-EDV and left IMT. Moderate positive correlation (r=0.375, p=0.001), suggesting a relationship between left CCA-PSV and left ICA-PSV. Strong positive correlation (r=0.827, p<0.001), indicating an association between increased right ICA-PSV and right ECA-PSV. Strong positive correlation (r=0.886, p<0.001), showing a relationship between increased left ICA-EDV and right ECA-PSV.

According to (Table 4), the mean IMT significantly varies across groups (p=0.000), indicating differences in the thickness of the right carotid artery wall. Similar to the right side, the left IMT shows significant differences (p=0.001) among the groups, suggesting variations in the thickness of the left carotid artery wall. No significant difference is observed in the right CCA-PSV (p=0.860), implying relatively consistent peak systolic velocity in the common carotid artery. There is a significant difference in the right ICA-EDV (p=0.004), indicating variations in end-diastolic velocity in the right internal carotid artery. No significant difference is found in the left ICA-PSV (p=0.530), suggesting consistent peak systolic velocity in the left internal carotid artery. Similar to the left side, the right ICA-PSV shows no significant difference (p=0.223) among the groups. Significant differences in the left CCA-PSV (p=0.032) indicate variations in peak systolic velocity in the common carotid artery. The mean ECA-PSV is significantly different (p=0.010) among the groups, suggesting variations in peak systolic velocity in the external carotid artery. The ICAA\CCA PSV ratio exhibits significant differences (p=0.159), indicating variations in the ratio of peak systolic velocities between the internal and common carotid arteries. Significant differences in the left ICA-EDV (p=0.030) suggest variations in end-diastolic velocity in the left internal carotid artery. The mean ECA-PSV on the left side is significantly different (p=0.012), indicating variations in peak systolic ve-

Table 1: Descriptive Statistics

Variable		Frequencies and Percentages
Age		64.4 ± 11.0
Gender	Male	41 (55.4%)
	Female	33 (44.6%)
NIHSS Scoring	0	12 (16.2%)
	1 to 4	2 (2.7%)
	5 to 15	35 (47.3%)
	16 to 20	10 (13.5%)
	21 to 42	15 (20.3%)

Table 2: Descriptive statistics of Doppler indices

Doppler Indices	Minimum	Maximum	Mean ± SD
Right - IMT	.40	1.80	1.05 ± 0.37
Left – IMT	.40	2.00	1.03 ± 0.39
Right - CCA-PSV	30.0	120.00	66.43 ± 16.87
Left - CCA-PSV	45.00	110.00	69.78 ±13.87
Right - ICA-PSV	25.00	285.00	83.91 ± 48.28
Left - ICA-PSV	35.00	235.00	84.58 ± 46.47
Right - ICA-EDV	9.00	125.00	29.27 ± 24.29
Left - ICA-EDV	8.40	110.00	29.68 ± 21.10
Right - ECA-PSV	24.00	245.00	83.14 ± 45.22
Left - ECA-PSV	25.00	255.00	84.29 ±46.64
ICAA\CCA PSV Ratio	.40	4.20	1.27 ± 0.77

Table 3: Correlation between NIHSS and inter Doppler indices

		NIHSS Scoring	Right - IMT	Left - IMT	Right - CCA-PSV	Left - CCA-PSV	Left - ICA-PSV	Right - ICA-EDV	Right - ICA-PSV	Left - ICA-EDV	Right - ECA-PSV	Left - ECA-PSV
NIH Scoring	Pearson Cor		.275*	.439**	-.090	.395**	.141	.359**	.238*	.277*	.357**	.385**
	Sig.		.018	**.000**	.447	**.000**	.231	.002	.042	.017	.002	.001
Right - IMT	Pearson Cor	.275*		.483**	.030	.136	.516**	.537**	.513**	.559**	.455**	.415**
	Sig.	**.018**		.000	.798	.247	.000	.000	.000	.000	.000	.000
Left - IMT	Pearson Cor	.439**	.483**		-.305**	.196	.360**	.274*	.236*	.265*	.256*	.235*
	Sig.	**.000**	.000		.008	.094	.002	.018	.043	.023	.028	.044
Right - CCA-PSV	Pearson Cor	-.090	.030	-.305**		.229*	-.131	.030	.235*	-.064	.024	-.066
	Sig.	**.447**	.798	.008		.049	.265	.801	.044	.587	.842	.575

Table 3: Correlation between NIHSS and inter Doppler indices

		NIHSS Scoring	Right - IMT	Left - IMT	Right - CCA-PSV	Left - CCA-PSV	Left - ICA-PSV	Right - ICA-EDV	Right - ICA-PSV	Left - ICA-EDV	Right - ECA-PSV	Left - ECA-PSV
Left - CCA-PSV	Pearson Cor	.395**	.136	.196	.229*		.375**	.200	.367**	.240*	.242*	.295*
	Sig.	**.000**	.247	.094	.049		.001	.088	.001	.040	.038	.011
Left - ICA-PSV	Pearson Cor	.141	.516**	.360**	-.131	.375**		.654**	.771**	.816**	.649**	.707**
	Sig.	**.231**	.000	.002	.265	.001		.000	.000	.000	.000	.000
Right - ICA-EDV	Pearson Cor	.359**	.537**	.274*	.030	.200	.654**		.793**	.909**	.849**	.811**
	Sig.	.002	.000	.018	.801	.088	.000		.000	.000	.000	.000
Right - ICA-PSV	Pearson Cor	.238*	.513**	.236*	.235*	.367**	.771**	.793**		.827**	.757**	.742**
	Sig.	.042	.000	.043	.044	.001	.000	.000		.000	.000	.000
Left - ICA-EDV	Pearson Cor	.277*	.559**	.265*	-.064	.240*	.816**	.909**	.827**		.865**	.886**
	Sig.	.017	.000	.023	.587	.040	.000	.000	.000		.000	.000
Right - ECA-PSV	Pearson Cor	.357**	.455**	.256*	.024	.242*	.649**	.849**	.757**	.865**		.926**
	Sig.	.002	.000	.028	.842	.038	.000	.000	.000	.000		.000
Left - ECA-PSV	Pearson Cor	.385**	.415**	.235*	-.066	.295*	.707**	.811**	.742**	.886**	.926**	
	Sig.	.001	.000	.044	.575	.011	.000	.000	.000	.000	.000	
DS	Pearson Cor											
	Sig.											

*. Correlation is significant at the 0.05 level (2-tailed).

NIH = National Institutes of Health Science Stroke Scale, IMT = Intima Media Thickness, CCA = Common Carotid Artery, ICA = Internal Carotid Artery, ECA = External Carotid Artery, PSV = Peak Systolic Velocity, EDV = End Diastolic Velocity, DS = Degree of Stenosis.

Table 4: Mean comparison between NIH scoring and Doppler Indices

NIHSS		Right - IMT	Left - IMT	Right - CCA-PSV	Right - ICA-EDV	Left - ICA-PSV	Right - ICA-PSV	Left - CCA-PSV	Right - ECA-PSV	ICAA\ CCA PSV RATIO	Left - ICA-EDV	Left - ECA-PSV
0 N=12	Mean ± SD	0.89 ± 0.17	0.84 ± 0.16	64.91 ± 15.81	25.75 ± 10.79	78.41 ± 27.68	73.58 ± 16.59	59.41 ± 9.38	70.83 ± 10.56	1.25 ± 41	28.75 ± 6.79	67.83 ± 10.33
1 to 4 N=2	Mean ± SD	1.05 ± 0.49	1.20 ± 0.84	59.00 ± 4.24	25.00 ± 11.31	89.00 ± 43.84	80.00 ± 35.35	70.00 ± 7.07	73.50 ± 4.94	1.30 ± 0.70	28.00 ± 9.89	72.50 ± 0.707
5 to 15 N=35	Mean ± SD	.84 ± 0.24	.92 ± 0.33	68.40 ± 15.99	21.57 ± 4.63	78.34 ± 32.01	76.28 ± 28.53	70.05 ± 11.21	70.56 ± 18.24	1.08 ± 0.43	22.91 ± 5.46	73.17 ± 20.96

Table 4: Mean comparison between NIH scoring and Doppler Indices

NIHSS		Right - IMT	Left - IMT	Right - CCA-PSV	Right - ICA-EDV	Left - ICA-PSV	Right - ICA-PSV	Left - CCA-PSV	Right - ECA-PSV	ICAA\CCA PSV RATIO	Left - ICA-EDV	Left - ECA-PSV
16 to 20 N=10	Mean ± SD	1.20 ± 0.44	1.09 ± 0.47	66.90 ± 18.46	30.70 ± 15.59	85.20 ± 59.25	85.20 ± 51.52	71.40 ± 20.29	92.70 ± 55.13	1.35 ± 1.130	34.44 ± 27.31	93.20 ± 66.28
21 to 42 N=15	Mean ± SD	1.32 ± 0.34	1.36 ± 0.35	63.73 ± 20.48	49.66 ± 46.46	103.06 ± 72.66	109.66 ± 84.94	76.33 ± 14.85	117.26 ± 77.20	1.69 ± 1.19	43.26 ± 37.37	119.06 ± 73.87
P-Value		0.000	0.001	15.99	0.004	0.530	0.223	0.032	0.010	0.159	0.030	0.012

Discussion

The study underscores the utility of Carotid Doppler in assessing post-stroke hemodynamics, emphasizing the potential of specific indices as prognostic indicators. Variations in Doppler indices align with the diverse clinical presentations observed in stroke patients. Current study indicating significant variations in intima-media thickness (IMT) and end-diastolic velocity (ICA-EDV) in the right carotid artery. A prospective study by Walubembe et al. explores carotid atherosclerotic disease (CAD) Doppler findings; including carotid artery stenosis and thickened IMT.[17,] It suggests an association between high-risk features of carotid plaques and symptomatic carotid artery stenosis. Fernandes et al. utilize color Doppler sonography to evaluate carotid arteries in stroke patients, providing insights into hemodynamically significant conditions.[18] Simaan et al. compare Doppler ultrasound (DUS) with computed tomography angiography (CTA), revealing discrepancies in internal carotid and vertebral arteries.[19] Although the NIHSS and CCA-PSV have a marginally negative association ($r = -0.090$), this correlation does not meet the criteria for statistical significance at the 0.05 level. This indicates that when the NIH Scoring increases (which indicates more severe neurological abnormalities), there may be a minor drop in peak systolic velocity in the common carotid artery (CCA-PSV) as similar to Savaș et al. (2019).[20] On the other hand, the strength of this link is insufficient to achieve statistical significance. There is a statistically significant positive association between NIHS and ICA-PSV ($r = 0.238$, p 0.05). This indicates that there is a tendency for there to be an increase in the peak systolic velocity in the internal carotid artery (ICA-PSV) whenever there is an increase in the NIH Scoring. Based on this link, it appears that higher blood flow velocities in the internal carotid artery are related with more severe neurological impairments. The observed significant differences in the ICAA\CCA PSV ratio (p=0.159) suggest variability in the ratio of peak systolic velocities between the internal and common carotid arteries. This may have implications for blood flow dynamics and could be indicative of altered vascular conditions. The significant differences in the left internal carotid artery end-diastolic velocity (p=0.030) point towards variations in the end-diastolic phase, potentially influencing the overall blood flow pattern in the left internal carotid artery. The significant differences in the peak systolic velocity of the left external carotid artery (p=0.012) indicate variations in blood flow dynamics in this region. This finding could be crucial in understanding the perfusion patterns in the external carotid artery. While the present study provides valuable insights, a thorough comparison with existing literature is essential for a comprehensive understanding. Relevant studies such as the work by Rafati et al.[21] and Ain et al.[22] may offer additional perspectives on normal Doppler indices and atherosclerosis evaluation. Rafati's study, focusing on different ultrasonography indices, could provide a broader context for interpreting variations in Doppler parameters. Additionally, Ain's research on normal Doppler indices might serve as a reference point for comparison, helping to contextualize the significance of the observed differences in the current study.

The correlation between carotid Doppler findings and stroke severity, as measured by the NIHSS score, is a critical aspect of understanding cerebrovascular events.

Studies have suggested associations between high-risk features of carotid plaques and symptomatic carotid artery stenosis, emphasizing the importance of assessing vascular conditions in stroke patients.[17] Moreover, the correlation between carotid duplex parameters and risk factors of ischemic stroke underlines the potential prognostic value of duplex ultrasonography in acute ischemic stroke cases.[22] Additionally, the bivariate analysis demonstrating a correlation between admission NIHSS score and mRS score underscores the relevance of stroke severity in predicting patient outcomes.[23]

Conclusion:

Doppler indices provide insights into neurological issues, vascular factors, and blood flow in those at risk of cerebrovascular conditions. A correlation between NIHS, carotid artery stenosis, and ICA-PSV indicates that severe neurological deficits often align with advanced carotid artery disease and increased blood flow. This underscores the importance of assessing carotid artery health for overall well-being and treatment choices. **R**

Recommendations

When evaluating patients who have neurological abnormalities, especially those with higher NIH Scoring (NIHS), medical professionals ought to take into consideration the possibility of including carotid artery health assessments into the process.

A comprehensive assessment of carotid artery stenosis and blood flow velocities, including the ICA/CCA PSV Ratio (ICCA), can provide helpful insights into the potential contributions of the vasculature to neurological complaints.

There is a need for additional investigation into the diagnostic value of the ICA/CCA PSV Ratio (ICCA), both in the laboratory and in clinical settings. This ratio demonstrates potential as an indication of carotid artery pathology and has the potential to be a useful screening tool for the identification of patients who are at risk for cerebrovascular disorders. The findings of this study need to be validated and expanded upon by the conduct of more research. In order to ensure that the observed connections are generalizable, it is necessary to do research on patient populations that are both larger and more diverse. In addition, investigating the influence that therapy interventions have on these associations can provide extremely helpful insights into the clinical management of the condition.

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Asma Yazdan, Iqra Manzoor, Syed Muhammad Yousaf Farooq, Sajja Ullah, Laiba Begum, Aruj Latif. Correlation of carotid artery doppler indices with national institute of health sciences stroke scale in post stroke patients, *Hell J Radiol 2025*; 10(2): 2-10.