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# Duplex ultrasonography as prognostic tool of acute ischemic stroke patients



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## Abstract

**Background:** Cerebral stroke is a major source of mortality and morbidity. Duplex ultrasonography is used to evaluate carotid and cerebral arteries. The objectives of this work are to study the correlation between carotid duplex parameters with risk factors of ischemic stroke and evaluate duplex parameter as prognostic tool of ischemic stroke.

**Methods:** The study was conducted on 100 patients presented by acute ischemic stroke submitted to history taking, medical, and neurological examination. Neurological deficit was assessed by National Institute of Health Stroke Scale (NIHSS); the functional state of the patients was assessed by modified Rankin scale (mRS). Brain CT and/or MRI, routine laboratory investigations, extracranial, and transcranial duplex (TCD) were done.

**Results:** The end diastolic velocities (EDVs) and peak systolic velocities (PSVs) of common carotid arteries (CCA) were significantly decreased in smokers and hypertensive ( $P < 0.05$ ). Smoking and hypertension were positively correlated with resistive index (RI). In 80 patients, PSV in the symptomatic middle cerebral artery (MCA) did not exceed 70 cm/s within averaged  $50.7 \pm 4.6$  cm/s. EDV was  $12.0 \pm 3.0$  cm/s, RI was  $0.78 \pm 0.05$ , and pulsatility index (PI) was  $1.61 \pm 0.09$ . There was significant difference in all hemodynamic parameters in comparison with the asymptomatic side.

**Conclusion:** Patients who have risk factors of stroke should be evaluated with duplex ultrasonography. Duplex parameters can give informative data about prognosis and outcome.

**Keywords:** Ischemic stroke, TCD, Carotid duplex

## Background

Cerebral stroke is a major health problem, represents the second most common cause of morbidity worldwide and is the leading cause of disability. Hypertension, diabetes mellitus, atherosclerosis, and smoking are the most common modified risk factors [1].

Emergent brain imaging is essential for evaluation of acute ischemic stroke. Carotid duplex is a non-invasive tool used to assess carotid arteries for evaluating blood flow velocity, provides accurate diagnosis of vascular abnormalities and stenosis which are used to identify patients who need surgical treatment [2]. Certain parameters such as PI, RI, PSV, and EDV are used to evaluate

obstructive and occlusive diseases of the carotids [3]. We aimed to study the correlation between carotid duplex parameters with risk factors of ischemic stroke and evaluate duplex parameter as prognostic tool of ischemic stroke.

## Methods

The study was an observational retrospective case control study conducted on 100 patients presented by acute ischemic stroke (anterior circulation). Exclusion criteria comprised patients with hemorrhagic stroke, cryptogenic stroke, and recurrent ischemic stroke. Patients who have poor insonation window were also excluded.

The study's protocol was approved by The Research Ethics Committee and Quality Assurance Unit. Participations were voluntary, informed consents were approved by

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**Table 1** The correlations of risk factors of stroke with duplex parameters of CCA in studied patients

		PSV(CCA)	EDV	RI	PI
Age (years)	R	-0.037	-0.135	0.038	0.046
	P value	0.716	0.182	0.709	0.647
RBG	r	0.170	-0.114	0.038	0.061
	P value	0.092	0.261	0.709	0.545
MABP	r	-0.231	-0.313	0.255	0.257
	P value	0.025*	0.002*	0.012*	0.007*
S. cholesterol	r	0.160	-0.114	0.038	0.051
	P value	0.082	0.261	0.709	0.445
Smoking index	r	-0.507	-0.541	0.405	0.402
	P value	0.002*	0.001*	0.014*	0.015*

(\*) means statistically significant

all participants' guardians and any possible risks were clarified.

Included subjects were submitted to thorough history taking, medical, neurological examination; neurological deficit was assessed by NIHSS [4]. The functional independent state of the patients was assessed by mRS [5], radiological evaluation by brain CT and/or MRI, routine laboratory investigations, extracranial, and transcranial duplex.

The duplex parameter includes PSV, EDV, PI, and RI of the CCA and MCA were measured in all studied patients and compare the symptomatic and asymptomatic side with each other. The asymptomatic side is the reference of the normal value of each patient.

Follow-up of patients after 3 months from the stroke onset was done by TCD and all parameters were recorded. The functional state of the studied patients was assessed by mRS and compares the duplex parameter with the functional state of patients.

Statistical analysis was conducted using SPSS Prism, version 20, 2013 created by IBM, Chicago, IL, USA.

Statistical differences between the studied groups were tested using chi-square for categorical variables and *t* test as well as ANOVA test for numerical ones. P values < 0.05 were considered statistically significant.

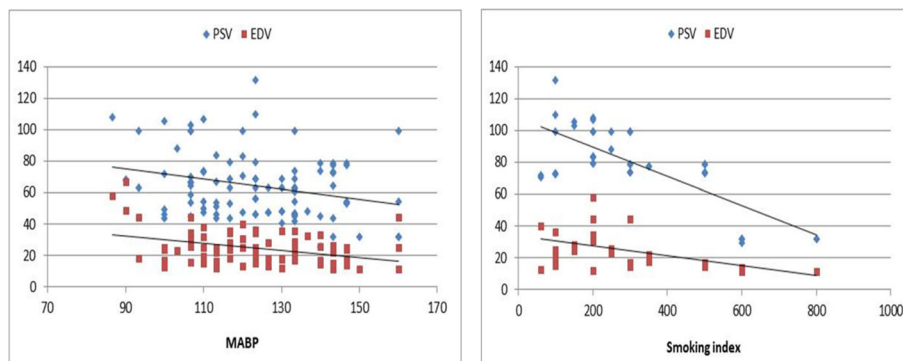
**Results**

Among the studied patients, 62 patients (62%) were males. Mean age of the patients was 63.95 ± 10.3. Hypertension was present in 61 patients (61%), 42 patients (42%) were diabetic. Seventy-nine patients had cardiac problems, 29% had myocardial infarction/coronary artery disease (MI/CAD), and 50% had atrial fibrillation (AF). Dyslipidemia was found in 56 patients (56%). Smoking was present in 42 patients (42%) with mean duration of smoking 31.9 ± 10 years.

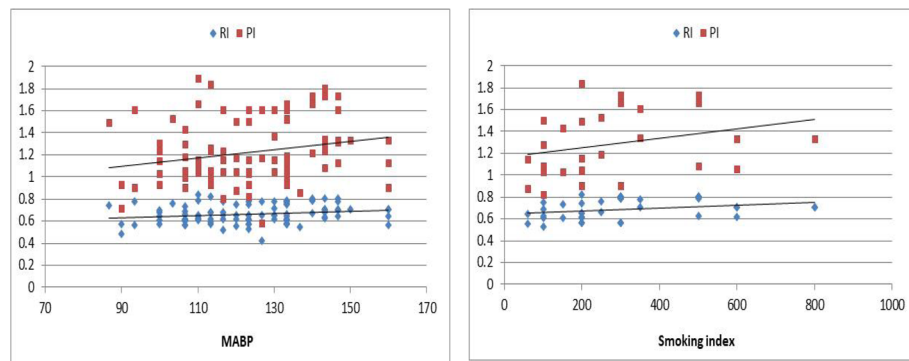
Cardioembolic stroke represent 31% of patients while large artery disease (LAD) represents 30%, small artery disease (SAD) and undetermined stroke represent 15% and 24% respectively. In the assessment of stroke severity [4] on admission, we found that 40 patients had mild to moderate degree, 60 patients had severe degree by NIHSS.

Among the recorder risk factors, hypertension and smoking were significantly correlated with the duplex parameters (Table 1). The end diastolic velocities (EDVs) and peak systolic velocities (PSVs) of CCA were significantly decreased in smokers and hypertensive (P < 0.05). Hypertension and smoking had a negative correlation with EDV and PSV (Fig. 1). RI and PI were positively correlated with smoking and hypertension (Fig. 2). Other risk factors, age, dyslipidemia, and DM were not significantly correlated with the duplex.

Among the recorder risk factors, hypertension and smoking were significantly correlated with the duplex parameter (Table 2). The end diastolic velocities (EDVs) and peak systolic velocities (PSVs) of CCA were significantly decreased in smokers and hypertensive (P < 0.05). Hypertension and smoking had a negative correlation



**Fig. 1** Negative correlations between hypertension (MABP) and PSV and EDV (left) also negative correlations between smoking (smoking index) and PSV and EDV (right)



**Fig. 2** RI and PI were positively correlated with hypertension (MABP) (left) and smoking (smoking index) (right)

with EDV and PSV (Fig. 1). RI and PI were positively correlated with smoking and hypertension (Fig. 2).

In this study, there was a decrease in PSV and EDV, an increase in RI and PI of the symptomatic MCA. PSV was  $50.7 \pm 4.6$  cm/s, EDV was  $12.0 \pm 3.0$  cm/s, RI was  $0.78 \pm 0.05$ , and PI was  $1.61 \pm 0.09$ . There was significant difference in all hemodynamic parameters in MCA between symptomatic and asymptomatic side (Table 2).

There were significant differences in the hemodynamic parameters (PSV and RI) between patients with favorable and unfavorable outcome on admission (Table 3). Follow-up was conducted on the 21st day of the disease. Forty-five patients had poor functional outcome ( $mRS > 2$ ). A good functional outcome ( $mRS < 2$ ) was noted in 50 patients. In 5 cases, a lethal outcome was recorded. The hemodynamic parameters among patients with a bad outcome on follow-up of the disease did not differ from the results on admission. In patients with good outcome, there was significant improvement of these parameters from the results on admission. PSV increased by 50-60% of the result on admission (Table 3).

**Discussion**

Ultrasonography has been used for evaluation of carotid arteries in ischemic stroke patients. However, the association of hemodynamics of carotid arteries in stroke patients with different risk factors was not clearly studied. We have measured the IMT, PSV, EDV, PI, and RI of

the CCA and MCA and evaluate their association with different risk factors. The study also investigated whether duplex parameters could predict functional outcomes as assessed by NIHSS, mRS, and Barthel index in ischemic stroke patients.

In this study, we observed negative correlation of PSV and EDV of CCA with hypertension and tobacco smoking. This finding coincides with Haq et al. [6] who reported a significant correlation of PSV with hypertension. Sarah et al. [7] also found that there was significant correlation of PSV in the carotid arteries with hypertension and tobacco smoking. This supported that hypertension and smoking were more risky for cerebral stroke.

We found that RI was significantly increased and positively correlated with smokers. Agunloye and colleagues [8] also found that there was a significant correlation between elevated RI and atherosclerosis, smoking, and clinical outcome.

In this study, we found that there was significant difference in all hemodynamic parameters in MCA between symptomatic and asymptomatic side. Reduction of PSV, increase in RI more than 0.70, PI more than 1.35 are prognostic signs of unfavorable outcome of ischemic stroke. These findings go in line with Abdullaiev and colleagues [1] as well as Vilela and colleagues [9] who found that reduction of systolic flow velocity, increase in resistance index, and pulsative index are indicators of unfavorable course of ischemic stroke.

Powers et al. [10] and Yu-Jun and colleagues [11] found that parameters of PI and RI were predictors of outcome of ischemic stroke patients and may assist in predicting the outcomes of patients who have undergone thrombolytic procedures.

**Conclusion**

Carotid sonography is a noninvasive tool which helps in predicting the functional outcomes of ischemic stroke patients. Hypertension and smoking are high risk factors

**Table 2** Comparison of duplex parameters between symptomatic and asymptomatic side in MCA on admission

On admission	MCA		P value
	Symptomatic side	Asymptomatic side	
PSV	$50.7 \pm 4.6$ cm/s	$96.3 \pm 9.7$ cm/s	.00001*
EDV	$12.0 \pm 3.0$ cm/s	$33.1 \pm 5.8$ cm/s	.00001*
RI	$0.78 \pm 0.05$	$0.56 \pm 0.04$	.00001*
PI	$1.61 \pm 0.09$	$0.85 \pm 0.11$	.00001*

(\*) means statistically significant

**Table 3** Comparison of outcome regarding studied variables

		On admission		P value	Follow-up		P value
		Favorable outcome N = 42	Unfavorable outcome N = 58		Favorable outcome N = 50	Unfavorable outcome N = 45	
		Mean ± SD	Mean ± SD		Mean±SD	Mean±SD	
MCA	PSV	45.52 ± 3.90	41.25 ± 6.75	0.0004*	87.35±5.83	48.73 + 10.23	< 0.0001*
	EDV	18.79 ± 15.6	16.91 ± 15.47	0.551	32.08 + 5.11	17.96 + 5.01	< 0.0001*
	PI	0.94 ± .33	0.96 ± .26	0.736	0.82 + 0.11	0.89 + 0.05	0.0002*
	RI	0.73 ± 0.04	0.98 ± 0.04	< 0.0001*	0.62 + 0.05	1.38 + 0.15	< 0.0001*

(\*) means statistically significant

for ischemic stroke. They have a significant effect on carotid artery hemodynamics.

Assessment of PSV, PI, and RI could provide information for making clinical decisions regarding treatment plan.

### Recommendations

Patients who have risk factors of stroke should be evaluated with duplex sonography as early as possible.

Follow-up of ischemic stroke by measuring different duplex parameters can give informative data about prognosis and outcome.

### Limitations

The sample size was small and there were no available reference values of RI, EDV, and IMT in Egyptian adults. Further studies with suitable sample size were recommended to confirm the initial results.

### Abbreviations

AF: Atrial fibrillation; AIS: Acute ischemic stroke; CCA: Common carotid arteries; CVS: Cerebrovascular stroke; EDV: End diastolic velocity; LAD: Large artery disease; MCA: Middle cerebral artery; MI/CAD: Myocardial infarction/coronary artery disease; mRS: Modified Rankin scale; NIHSS: National Institute of Health Stroke Scale; PI: Pulsativity index; PSV: Peak systolic velocity; RI: Resistive index; SAD: Small artery disease; SD: Standard deviation; SPSS: Statistical Package for Social Sciences; TCD: Transcranial duplex

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### Authors' contributions

The authors have participated in designing of the study, acquisition of data, data interpretation, and revision. ME recruited the patient and carried out clinical, neurological evaluation, vascular ultrasound assessment, and participated in interpretation of the study results and in editing the manuscript. SA recruited patient and carried out clinical, neurological evaluation, vascular ultrasound assessment, participated in interpretation of the study results and in editing the manuscript. The authors read and approved the final manuscript.

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### Availability of data and materials

All raw data will be available on the editor request.

### Declarations

#### Ethics approval and consent for participate

The study was revised and approved by the Research Ethical Committee of the Faculty of Medicine, Fayoum University (number: R144) on 11/10/2020 committee 77. All included physicians were informed about the aim of the study and the content. They signed an informed consent before starting the survey. The confidentiality of their information and their right not to participate in the study were both respected.

#### Consent for publication

Not applicable

#### Competing interests

The authors have no conflict of interest to disclose.

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