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Morphological and Hemodynamic Features of the Carotid Artery on Color Doppler Ultrasound in Hypertensive Patients

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Abstract

Objective:

1. Described the characteristics and morphology of the carotid artery on color Doppler ultrasonography in patients with hypertensive.
2. Determine the relationship between carotid intima-media thickness (cIMT) on color Doppler ultrasound images and some clinical and laboratory parameters and some risk factors in hypertensive patients.

Subjects and methods: This was a cross-sectional descriptive study on 64 hospitalized hypertensive patients.

Results: 62.5% are female. Mean age 66.41±11.91. The right common cIMT 0.74 (0.7-0.81) mm; the left was 0.8 (0.7-0.8) mm; the average cIMT on both sides was 0.75 (0.75-0.79) mm. Mean peak systolic velocity of the right common carotid artery 58.03±14.74 cm/s; left side 60.71±15.73 cm/s. Right common carotid end-diastolic velocity 14.68±4.88 cm/s; left side 16.09±6.04 cm/s. Right common carotid resistance index 0.75±0.063; left side 0.74±0.067. There were 25 (39.1%) cases of right common carotid atherosclerotic plaque with the thickest 2.50±0.71mm and 33 (51.6%) cases of left common carotid plaque with the thickest 2.3 (1.99-2)mm. There were an independent correlation between age and sex with the cIMT on both sides with correlation coefficients of R=0.514, p=0.013; R=0.514, p < 0.0001, respectively.

Conclusion: There were a correlation between the common cIMT with age and sex, every 1 year increase will increase the thickness of the common cIMT by 0.005 mm. cIMT was higher than in men.

Keywords: Hypertension, Carotid Intima Media Thickness, Age, Sex

1. Introduction

The frequency of hypertension continues to increase not only in the world but also in our country. Globally, there are currently 1 billion people with hypertension and is expected to increase to 1.5 billion by 2025. The frequency of hypertension in European countries ranges from 30-45% of the general population and increases with age. There are differences in average blood pressure between European countries. In the United States, the prevalence of hypertension is 29.6%. According to the most recent survey (2008) conducted by the Vietnam Heart Institute in adults (≥ 25 years old) in 8 provinces and cities of our country, the rate of hypertension has increased to 25.1%. This means that 1 out of every 4 adults in our country has high blood pressure. Hypertension is the leading cause of premature death for about 10 million people in 2015; Of which 4.9 million were due to coronary artery disease and 3.5 million were due to stroke. It is also a major risk factor for heart failure, atrial fibrillation, chronic kidney disease, peripheral vascular disease, and impaired cognitive function [1-4]. Assessing changes in carotid artery morphology and function helps treat, predict and prevent disease complications. There are many research projects on large blood vessels in hypertensive patients, diabetic patients, and coronary artery disease patients that have been and are being conducted around the world. In Vietnam, in order to understand the damage and complications caused by vascular damage, there have been a number of research studies examining the morphology and function of large blood vessels, especially the carotid artery system, and found a link between them. relationship between morphological and functional changes of the carotid artery with hypertension, diabetes, and coronary artery disease [5, 6]. At HCMC Hospital for Rehabilitation-Professional Diseases, there has been no research on this issue. Therefore, we conducted research on the topic: "Morphological and hemodynamic characteristics of the carotid artery on color Doppler ultrasound in hypertensive patients at

the HCMC Hospital for Rehabilitation-Professional Diseases ".

2. Subjects and methods

2.1 Subjects

All patients diagnosed with hypertension according to the standards of the European Society of Cardiology [3] were hospitalized at the HCMC Hospital for Rehabilitation-Professional Diseases from June 01, 2022 to August 22, 2023. Patients are determined to have hypertension when systolic blood pressure is ≥ 140mmHg and/or diastolic blood pressure is ≥ 90mmHg.

2.2 Methods

2.2.1 Study design: Cross-sectional research

2.2.2 Statistical analysis

Data were processed using SPSS 26.0 software. Quantitative variables are expressed as mean ± standard deviation (normal distribution) or median ± interquartile range (IQR: Inter-quartile range) if they do not belong to a normal distribution. Compare the difference between two averages using the unpaired t test (if the averages belong to the normal distribution), the Mann-Whitney U test (if the averages do not belong to the normal distribution). Qualitative variables are displayed by frequency (percentage). Compare the difference between two proportions using the $\chi 2$ test; Fisher's exact test for 2x2 tables with expected frequency < 5. Univariate linear regression analysis between quantitative variables. According to author Hosmer DW [7], variables with p value < 0.25 are selected into the multivariable linear regression model. The test is statistically significant when $p < 0.05$.

3. Results

3.1 Baseline characteristics of study population

During the period from June 2022 to August 2023, there were 64 cases of hypertension that met the inclusion criteria and did not have exclusion criteria were included in the study. We then proceed to describe the characteristics and morphology of the carotid artery on color Doppler ultrasound and find the relationship between the carotid intima media thickness with some of clinical, laboratory parameters and risk factors in hypertensive patients. We obtain the following results in Table 1.

Table 1: Baseline characteristics of patients

Variables	Value
Age (year)	66.41 ± 11.91
Sex(Male/Female)	24 (37.5)/40 (62.5)
BMI (kg/m^2)	22.39 ± 3.24
History, n (%) Lipid disorder Diabetes Mellitus Ischemic heart disease /Old myocardial infarction Smoking Alcohol consumption Stroke Heart failure Chronic kidney disease	 64 (100) 29 (45.3) 27 (42.2) 24 (37.5) 23 (35.9) 10 (15.6) 5 (7.8) 4 (6.3)
Vital signs Heart rate (bpm) Systolic blood pressure, mmHg Diastolic blood pressure, mmHg Respirarory rate (bpm) SpO2 (%)	 80 (78 - 82) 130 (120 - 130) 80 (70 - 80) 17 (16 - 18) 97 (97 - 98)
Diagnosis Stroke Atrial fibrillation Pneumonia Others (hyperthyroidism, asthma, venous insufficiency)	 42 (65.6) 8 (12.5) 4 (6.3) 10 (15.6)
Hospitalization stay (days)	17 (11 – 25.62)
EF (%)	63.58 ± 8.11
Granulocyte (K/µL)	6.5 (6.04 – 6.73)
Hb (g/dL)	12.5 (12.27 – 12.93)
AST (UI/L)	28.15 (24.47 – 33.59)
ALT (UI/L)	23.95 (21.67 – 28.99)
Ure (mmol/L)	5.73 (5.34 – 6.21)
Creatinin (µmol/L)	74.85 (65.5 – 79.91)
Na+ (mmol/L)	138 (136 - 140)
K+ (mmol/L)	4.11 ± 0.55
Cl - (mmol/L)	100 (100 - 101)
Total cholesterol (mmol/L)	4.22 (3.85 – 4.69)
HDL-C (mmol/L)	1.17 ± 0.32
LDL-C (mmol/L)	2.21 (1.85 – 2.54)
Triglycerid (mmol/L)	1.62 (1.42 – 1.97)

Data in the form: n (%) for qualitative variables, mean ± standard deviation for quantitative variables

3.2 Ultrasonography characteristics of the carotid artery

The results of carotid artery morphology and function are shown in Table 2.

3.3 The relationship between carotid intima media thickness and some clinical, laboratory parameters and risk factors (See Table 3)

Table 2: Characteristics of carotid artery morphology and velocity on ultrasonography

Variable		Right carotid artery				Left carotid artery				Both
		Common	Internal	External	Vertebrae	Common	Internal	External	Vertebrae	
IMT (mm)		0.74 (0.7 – 0.81)	-	-	-	0.8 (0.7 – 0.8)	-	-	-	0.75 (0.75-0.79)
PSV (cm/s)		58.03 ± 14.74	56 (49 – 69.62)	67 (53.53 – 77.31)	39.19 ± 13.11	60.71 ± 15.73	57 (53 – 68.09)	67 (63.07 - 75)	38 (35 – 42.86)	-
EDV (cm/s)		14.68 ± 4.88	14.68 ± 4.88	13.39 ± 5.98	12.98 ± 5.15	16.09 ± 6.04	22.47 ± 9.64	11.9 (11 - 13)	13.86 ± 4.92	-
RI		0.75 ± 0.063	0.67 ± 0.094	0.82 (0.8 – 0.83)	0.66 ± 0.11	0.74 ± 0.067	0.64 ± 0.086	0.82 (0.8 – 0.85)	0.65 ± 0.11	-
Plaque	n (%)	25 (39.1)	5 (7.8)	3 (4.7)	0	33 (51.6)	11 (17.2)	1 (1.6)	0	-
	Maximum thickness (mm)	2.50 ± 0.71	2.94 ± 0.61	2.1 ± 0.85	-	2.3 (1.99 – 2.6)	3.05 ± 1.18	1.3	-	-

Data in the form: n (%) for qualitative variables, mean±standard deviation for quantitative variables

IMT: Intima Media Thickness, PSV: Peak Systolic Velocity, EDV: End Diastolic Velocity, RI: Resistance Index

Table 3: Univariate and multivariate linear regression analysis of factors that correlate with bilateral mean carotid intima media thickness

Univariate linear regression					Multivariate linear regression				
Variables	**Coefficient β**	**Standard Error (SE)**	**p**	**R^2**	**Coefficient β**	**Standard Error (SE)**	**p**	**R^2**	**R**
Age	0.625	0.137	**<0.0001**	0.071	0.005	**0.002**	**0.013**	0.264	0.514
Gender	0.109	0.077	**<0.0001**	0.439	-0.197	**0.045**	**<0.0001**		
Smoking	1.075	0.078	**<0.0001**	0.389	-0.137		0.660		
Alcohol consumption	1.053	0.081	**<0.0001**	0.314	0.000		0.999		
IHD/old MI	0.978	0.083	**<0.0001**	0.154	-0,160		0.164		
CKD	1.193	0.273	**<0.0001**	0.072	-0.107		0.344		
SBP	1,087	0.199	**<0.0001**	0.071	-0.057		0.616		
DBP	1,122	0.225	**<0.0001**	0.071	-0.051		0.656		
HDL-C	0.946	0.090	<0.0001	0.085	0.030		0.814		

IHD: Ischemic Heart Disease, MI: Myocardial Infarction, CKD: Chronic Kidney Disease, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure. Bold values are statistically significant ($p < 0.05$).

Through univariate regression analysis between common carotid artery intima media thickness and correlated variables. The results showed that the variables: Age, gender, smoking, alcohol consumption, IHD/old MI, chronic kidney disease, systolic blood pressure, diastolic blood pressure, HDL-C were correlated with layer common carotid intima thickness (Table 3). Conducting multivariate linear regression analysis of factors correlated with common carotid artery intima-media thickness, the results are as follows: There is an independent correlation between age and common carotid artery intima-media thickness. with correlation coefficient R=0.514, p=0.013. There is an independent correlation between gender and common carotid artery intima-media thickness with correlation coefficient R=0.514, p<0.0001. From the results of the Table 3 we see: Age correlates independently and less closely with common carotid artery intima media thickness with correlation coefficient R=0.514, p=0.013. Gender is independently and closely correlated with common carotid artery intima media thickness with correlation coefficient R=0.514, p<0.0001.

4. Discussion

In our study, the mean age of hypertensive patients was 66.41 ± 11.91; The youngest is 44 years old and the oldest is 94 years old. This result is similar to the study of Tran Thi Truc Linh *et al* [6] with the mean age 66.84 ± 9.72. However, this result is higher than the study of Goméz-Marcos *et al* [8] with an average age of 55,051; This can be explained because our Department of Cardiology-Geriatrics is mostly elderly patients, so the average age is older. Male accounted for 37.5%, female accounted for 62.5%, female/male ratio = 1.67. Females accounted for more than males in the sample. This result is similar to the study of Ngo Thuy Ha *et al* [5] with the female/male ratio = 1.09. Meanwhile, this is different from the study of author Naseh *et al* [9] with the female/male ratio = 0.23. BMI value of the study sample is 22.39 ± 3.24 kg/m^2. This result is lower than that of author Ngo Thuy Ha *et al* [5] of 25.06 kg/m^2 and of author Naseh *et al* [9] with BMI of 29.1 kg/m^2. This may be because the majority of patients in our study are exhausted, eat poorly and are transferred from hospitals to practice rehabilitation and physical therapy. All patients had a history of dyslipidemia, followed by diabetes at 45.3%, IHD/old MI with 42.2%, smoking with 37.5% and drinking alcohol accounts for 35.9%. This is also consistent with the literature as these are traditional cardiovascular risk factors. Meanwhile, the smoking rate according to the research results of Nasir *et al* [10] is 27.9%, Goméz-Marcos *et al* [8] is 22.4%. Research by author Qiaoxia Yang *et al* [11] history of drinking alcohol is 15.7%. Heart rate of study subjects with a median of 80 beats/min and interquartile range (78 - 82). The average heart rate results in the normal range, this result is consistent with the study of the author Goméz-Marcos *et al*[8] which is 73.01 ± 12.33 beats/min. Systolic blood pressure with median 130 mmHg and interquartile range (120 - 130). This result is lower than the author Goméz-Marcos *et al* [8] 142.65 ± 16.92 mmHg, this may be because our patients have been treated with antihypertensive drugs before, so the blood pressure is lower. author's research. Diastolic blood pressure with median 80 mmHg and interquartile range (70 - 80). Similar results of author Nasir *et al*[10] with diastolic blood pressure of 81.89 ± 8.95 mmHg. But this result is lower than that of the author Goméz-Marcos *et al* [8] at 90.91 ± 10.43 mmHg, which can be explained because our patients have been treated with antihypertensive drugs before. blood pressure lower than the author's results. There were 65.6% diagnosed cerebral stroke, 12.5% diagnosed atrial fibrillation, 6.3% diagnosed pneumonia and 15.6% other diagnoses. This is also consistent with the reality at our hospital because our patients receive patients from hospitals with a diagnosis of stroke and the risk factor for stroke is atrial fibrillation, so atrial fibrillation accounts for a high percentage. The hospital stay with the median was 17 days and the interquartile range was (11 - 25.62) because most of our patients were admitted to the hospital for rehabilitation and physical therapy, so the hospital stay will be shorter. lengthen. Regarding echocardiographic results: The mean left ventricular ejection fraction was 63.58 ± 8.11%. Most of our patients have a normal ejection fraction. The total cholesterol test results have a median of 4.22 mmol/L and interquartile range of 3.85 - 4.69, this result is similar to the study results of Naseh *et al* [9] with average cholesterol of 4.15 mmol/L. The HDL-C concentration had a mean of 1.17 mmol/L and a standard deviation of 0.32. This result is similar to the study by author Naseh *et al* [9] with an average HDL-C of 1.29 mmol/L, lower than the study by author Goméz-Marcos *et al* [8] with HDL-C 1, 37 mmol/L, this may explain why our population has many cardiovascular risk factors so HDL-C is low <1.3 mmol/L. The median LDL-C concentration was 2.21 mmol/L and the interquartile range was 1.85-2.54, lower than the study by author Naseh *et al* [9] with LDL-C being 2.91. mmol/L, lower than the study by author Goméz-Marcos *et al* [8] with LDL-C 3.47 mmol/L, this may be explained by the fact that most patients were treated with statins. Triglyceride concentration had a median of 1.62 mmol/L and an interquartile range of 1.42 - 1.97,

this result is similar to the study by author Goméz-Marcos *et al* [8] with Triglyceride of 1.52. mmol/L.

Right common carotid artery intima media thickness 0.74 (0.7 - 0.81) mm; on the left is 0.8 (0.7 - 0.8) mm; According to calculations, there is no difference between the intima media thickness of the right and left common carotid artery. Our results are higher than that of the study of author Naseh *et al* [9] who surveyed 43 patients with primary hypertension, recorded the average thickness of the right common carotid intima-media thickness is 0.58mm and 0.61mm on the left, this can explain our study has a stroke rate of 65.6% of patients whose IMT is a risk factor for stroke, so IMT is higher. However, our results are lower than that of the study of author Tran Thi Truc Linh *et al* [6] surveying on 121 patients with type 2 diabetes mellitus with hypertension recorded the mean arterial intima media thickness. The IMT right is 1.33 ± 0.66mm and on the left is 1.25 ± 0.68mm, which can explain that the research subject of the author Tran Thi Truc Linh [6] both had type 2 diabetes and hypertension patients increases the risk of atherosclerosis, the overall carotid intima media thickness is higher than our results. The average of the intima media hickness of the common carotid artery on both sides was 0.75 (0.75-0.79) mm. The mean of the bilateral carotid intima media thickness in men was 0.92 ± 0.23 mm; in women is 0.75 ± 0.14 mm, the mean of the carotid intima-media thickness on both sides is higher in men than in women and there is a significant difference in both sexes with p=0.0005. The mean peak systolic velocity of the right common carotid artery was 58.03 ± 14.74 cm/s; the left is 60.71 ± 15.73 cm/s; According to calculations, there is no difference between the mean peak systolic velocity of the right and left common carotid artery. Our results are lower than those of the author Atinuke M.Agunloye *et al* [12] who studied 135 hypertensive stroke patients with the mean peak systolic velocity of the right common carotid artery of 74, 1 ± 27.5cm/s; the left side is 76.4 ± 26.8cm/s; at the same time, our results are also lower than that of the author Ngo Thuy Ha *et al* [5] with the mean peak systolic velocity of the right common carotid artery is 74.53 ± 30.12cm/s; the left side is 73.91 ± 29.64cm/s. This can be explained because the assessment of blood flow velocity is affected by many factors such as: Lumen diameter, degree of stenosis, measurement location and angle between the ultrasound beam and blood flow, so the peak velocity results our common carotid artery PSV was lower. The right common carotid end diastolic velocity is 14.68 ± 4.88 cm/s; the left is 16.09 ± 6.04 cm/s; There is no difference between right and left. Our results are lower than those of the author Atinuke M.Agunloye *et al* [12] with the mean end diastolic velocity of the right common carotid artery is 20.1 ± 7.7cm/s; on the left is 20.2 ± 7.5cm/s. The results of our study are also lower than that of the author Ngo Thuy Ha *et al* [5] with the mean end diastolic velocity of the right common carotid artery is 19.62 ± 7.51cm/s; the left side is 20.87 ± 6.82cm/s. This can be explained because the process of evaluating blood flow velocity is influenced by many factors such as: Diameter of the vessel lumen, degree of narrowing, measurement location and angle between the ultrasound beam and blood flow. At the same time, end-diastolic velocity can be considered an index of carotid artery stiffness because it controls afterload and affects the left ventricular-vascular relationship. Low common carotid artery end-diastolic velocity is due to aging of the vessel wall (decreased elastin layer reduces the elasticity of the vessel wall). Low common carotid artery end-diastolic velocity is associated with a high rate of cerebral infarction consistent with the results of our study with a relatively high rate of patients with ischemic stroke of 65.6%. The average right common carotid artery resistance index was 0.75 ± 0.063; the left side had an average of 0.74 ± 0.067; According to calculations, there is no difference in right and left common carotid resistance index. Our results are similar to the study by author Dong Gyu Moon *et al* [13] with a common carotid resistance index of 0.71 ± 0.08. There were 25 cases of right common carotid artery atherosclerotic plaques, accounting for 39.1% with the thickest being 2.50 ± 0.71mm, and 33 cases of left common carotid artery atherosclerotic plaques, accounting for 51.6% of the cases. with the thickest 2.3(1.99-2)mm, however, there was no difference in the common atherosclerotic plaque on both sides. Our results are higher than the study by author Ngo Thuy Ha *et al* [5] with the rate of carotid artery plaques on the right side being 34.4% and the left side being 18.9%. This may be explained our study population was diagnosed with a high rate of stroke, 65.6%, and 1 in 3 causes of stroke is due to atherosclerosis, so the rate of atherosclerotic plaques is high. The plaque on both sides is higher. The majority of right common carotid artery atherosclerotic plaques cause mild stenosis with a rate of 92%, 4% mild - moderate stenosis, and 4% moderate stenosis. Similar to the right side, the majority of common carotid artery atherosclerotic plaques the left side causes mild stenosis with the rate of 91%, 6% mild - moderate stenosis and 3%.

Through univariate regression analysis between bilateral common carotid artery intima-media thickness and correlated variables, the results showed that the following variables were: Age, gender, smoking, alcohol consumption, IHD/old MI, chronic kidney disease, systolic blood pressure, diastolic blood pressure, and HDL-C levels are correlated with common carotid intima media thickness. Then, we conducted multivariate linear regression analysis of factors correlated with the of the intima media thickness of the common carotid artery on both sides, with the following results: There were an independent correlation between age and bilateral common carotid artery intima media thickness with correlation coefficient R=0.514, p=0.013; There is an independent correlation between gender and common carotid artery intima media thickness with correlation coefficient R=0.514, p <0.0001. Thus, it is noted that for every 1 year increase, the common carotid artery intima media thickness will increase by 0.005 mm.

5. Conclusion

Results of multivariable linear regression analysis of factors correlated with bilateral common carotid intima media thickness independent correlation between age with correlation coefficient R=0.514, p=0.013; There was an independent correlation between gender and common carotid artery intima media thickness with correlation coefficient R=0.514, p <0.0001. Thus, it is noted that for every 1 year increase, there will be an increase in the of the common carotid intima media thickness by 0.005 mm and the common carotid intima media thickness was higher in men.

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7. Disclosure of conflict of interest
None.

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