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Quantitative Ultrasonographic Measures of Common Carotid Artery Blood Flow Velocity in Individuals with Prediabetes

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Abstract

Objectives: Prediabetes is often considered an intermediate stage in the development of diabetes. Studies have explored the relationship between prediabetes and various cardiovascular parameters, including quantitative measures of common carotid artery blood flow velocity using ultrasonography. Our research examined prediabetic patients' carotid flow velocity (CFV).

Materials and Methods: The study sample included 120 individuals with prediabetes and 120 controls. In individuals with prediabetes, fasting blood sugar levels ranged from 5.6 to 6.9 millimolar, whereas the levels of glycated hemoglobin ranged from 5.7% to 6.4%. Measurements were performed for the CFVs.

Results: In individuals with prediabetes, there was a significant increase in pulsatility index, and resistive index. Carotid artery blood flow velocity patterns were significantly associated with prediabetes (p<0.05 for all).

Conclusion: Prediabetes promoted lower CFV. Prediabetes may cause carotid flow rate decreases owing to endothelial dysfunction.

Keywords: End diastolic velocity, peak systolic velocity, prediabetes, pulsatility index, resistive inde

Introduction

Prediabetes is the transition between type 2 diabetes and normoglycemia. With impaired fasting glucose levels, plasma glucose levels can range from 100 to 125 mg/dL. A 75-g/g oral glucose tolerance test may also diagnose decreased glucose tolerance. Two-hour plasma glucose values between 140 and 199 mg/dL indicate prediabetes. The ADA 2010 guidelines define prediabetes as an HbA1c level of 5.7% -6.4%. Approximately 5% -10% of patients with prediabetes develop type 2 diabetes annually[1,2].

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Brachial artery flow-mediated dilation (FMD) determines the response of arterial diameter to increasing flow. Increased intima-media thickness (IMT) and reduced flow-mediated diameter (FMD) are linked to atherosclerosis. Each Doppler ultrasound stage requires a decision from the examiner. Coronary artery disease (CAD) and death are linked to carotid flow rate(3). This study examined carotid flow rate parameters in patients undergoing prediabetics.

Materials and Methods

This observational clinical trial was conducted from December 2021 to April 2022. Approval was obtained from the Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval no.: 2021/07-30, date: 30.07.2021) and all participants provided written informed consent.

Study Population

The study included 120 patients with prediabetes (72 men, 48 women) and 120 controls (68 men, 52 women). All participants had normal blood pressure (BP) and no coronary disease. The diagnosis of prediabetes follows current standards(4). In patients with prediabetes, fasting blood sugar was 5.6-6.9 mM and HbA1c 5.7% -6.4%(5). The exclusion criteria were heart failure, CAD hypertension, and diabetes.

M-mode echocardiograms were conducted in the left lateral decubitus position using Vivid E9 equipment (Bioject Medical Technologies Inc., Portland, OR, USA). ASE guidelines were used to acquire images(6). Post-physical examination demographics were collected. Smoking status was determined by pack year. The blood glucose, lipid profile, and creatinine levels of all participants were recorded.

Brachial Arterial Reactivity

Ultrasound was used to assess endothelium-dependent dilatation(7). Alcohol and coffee consumption was restricted for 12 hours before treatment. Imaging was performed in a quiet, dark environment at ambient temperature. All vasoactive medicines were stopped 24 hour before the measurements. The basal diameter was the average of three right brachial artery intima-to-intima measurements after 30 minutes of rest. Imaging and measuring the arterial diameter above the cuff. To induce reactive hyperemia, the longitudinal artery picture was taken 30 seconds before and 2 minutes after deflation after inflating the cuff to 300 mmHg for 5 minutes. The rest of the photos were taken after 5 minutes. After administering 400 g of sublingual glyceryl trinitrate, final arterial images were taken after 3 minutes. A brachial artery EDD indicates endothelial function and predicts cardiovascular (CV) events. Ultrasound was performed following coronary angiography. A brachial artery diameter increase of 10% or more indicated good endothelial function(7).

Laboratory Parameters

All patients underwent antecubital vein punctures to draw blood. Over 30 min, dipotassium-EDTA-treated blood samples were analyzed. Hematological parameters were measured using a Sysmex America Inc. XT-2000i analyzer (Mundelein, IL, USA). Standard laboratory methods assess all biochemical parameters.

Statistical Analysis

All statistical data were calculated using SPSS for Windows (25.0; SPSS Inc., Chicago, IL, USA). The chi-square test was used to evaluate categorical variables across groups. Spearman's rank correlation analysis and Pearson's tests indicated correlations. For statistical significance, $p<0.05$ was used.

Results

The study included 120 patients with prediabetes (mean age: 58.1±0.3 years) and 120 controls (mean age: 57.2±0.4 years). In patients with prediabetes, smoking and hyperlipidemia were considerably greater ($p<0.001$) (Table 1). IMT, pulsatility index (PI), and resistive index (RI) were significantly increased in patients with prediabetes ($p<0.001$, $p=0.013$, and $p=0.024$, respectively) (Table 2). The findings demonstrated a robust positive correlation between prediabetes and RI, PI, and IMT (r=0.634, p<0.001; r=0.456, p=0.001; r=0.857, p<0.001, respectively) (Table 3).

Discussion

In this study, carotid artery blood flow velocity patterns were associated with prediabetes. The first study to link carotid artery flow velocity to prediabetes. Prediabetes was associated with considerably lower carotid flow velocity, greater upper carotid IMT, and impaired FMD.

Prediabetes and carotid artery blood flow velocity have been studied. Blood flow alterations may indicate vascular dysfunction in patients with prediabetes, which increases the risk of CV disease (CVD). Increased velocity, disrupted flow, or turbulence may cause atherosclerosis, which narrows and hardens the arteries[8,9]. According to some studies, prediabetes may cause carotid artery blood flow alterations that may lead to more serious CV complications. Flow velocity patterns, notably increased velocity or disrupted flow, may indicate early atherosclerotic alterations[10,11].

The basic concept of arterial hemodynamics states that blood flow and BP primarily affect luminal radius and wall thickness[12]. Low NO bioavailability causes arterial endothelial dysfunction (ED), which leads to atherosclerosis, as collagen and elastin thicken walls[3]. Doppler ultrasonography can identify early atherosclerosis in carotid IMT. Suwaidi et al.[13] found that coronary ED increased CVD without obstructive lesions. Our findings revealed that individuals with prediabetes had elevated IMT levels, which was significantly correlated with the presence of prediabetes.

Artery-brachial FMD may help diagnose CAD. Patients with low-FMD may benefit from lifestyle adjustments and other preventive measures. Lower FMD in patients with moderate CAD suggests that FMD can predict early CAD[14]. FMD was linked to increased IMT over a 6-year period. This implies that endothelial function causes atherogenesis[15]. However, Enderle et al.[16] found no correlation between FMD and CAD severity. Lower carotis communis artery (CCA) PSV is associated with greater internal carotid artery (ICA) stenosis[3]. In contrast,

Table 1. Characteristics of the study population

	Controls (n=120)	Prediabetes (n= 120)	p-value
Age, years	57.2±0.4	58.1±0.3	0.612
Gender, male, n, (%)	68	72	0.552
Smoking, n, (%)	22	38	**<0.001**
HL, n, (%)	20	42	**<0.001**
LVEF, (%)	55.4±0.4	55.2±0.6	0.874
BMI, kg/m^2	25.2±0.4	28.6±0.4	**<0.001**
Fasting plasma glucose (mg/dL)	88.2±2.4	114.6±5.7	**<0.001**
HbA1c (%)	4.8±0.3	6.3±0.3	**<0.001**
Cre (mg/dL)	0.72 0.2	0.77±0.1	0.756
TG, mg/dL	174.2±2.8	198.1±2.2	**0.003**
HDL-C, mg/dL	40.6±0.7	33.2±1.4	**0.011**
LDL-C, mg/dL	102.4±3.2	133.3±4.7	**0.022**
TC (mg/dL	142.4±6.0	192.4±5.8	**0.002**
WBC (10^3 × μL)	6.4±1.1	7.6±1.8	0.312
Hgb (g/dL)	13.6±0.3	13.7±0.2	0.734

p-value<0.05. BMI: Body mass index, BP: Blood pressure, Cre: Creatinine, CX: Circumfl ex artery, Glu: Glucose, HGB: Hemoglobin, HbA1c: Glycolized hemoglobin, HDL: High-density lipoprotein, Hl: Hyperlipidemia, LDL: Low-density lipoprotein, LVEF: Left ventricular ejection fraction, TC: Total cholesterol, TG: Triglyceride, WBC: white blood cell

Table 2. Brachial and carotid artery doppler ultrasound measurements

Brachial doppler measurements	Controls (n=120)	Prediabetes (n=120)	p-value
Brachial vessel diameter (mm)	3.0±0.1	2.9±0.1	0.902
Flow-mediated increase in diameter (mm)	0.32±0.2	0.24±0.3	**<0.001**
Brachial vascular reactivities			
EDD (%)	10.4±0.3	7.6±0.4	**<0.001**
NID (%)	11.2±0.4	9.2±0.4	**0.024**
Hyperaemia (%)	463.2±8.5	427.4±8.6	**0.044**
Carotid doppler measurements			
IMT (mm)	0.74±0.18	1.32±0.14	**<0.001**
PSV (cm/s)	86.2±3.1	77.2±3.1	**0.013**
EDV (cm/s)	31.2±1.5	23.2±2.4	**0.002**
MV (cm/s)	63.6±4.1	55.8±3.8	**0.008**
RI	1.7±0.2	2.4±0.3	**0.024**
PI	0.86±0.1	0.99±0.1	**0.003**

**p-value<0.05. EDD: Endothelium dependent dilation, EDV: End diastolic velocity, IMT: Intima-media thickness, MV: Mean velocity, NID: Nitroglycerin-induced dilation, RI: Resistive index, PI: Pulsatility index, PSV: Peac systolic velocity*

Table 3. Factors associated with prediabetes

Variables	Correlation coefficient (r)	p-value
Age, years	-0.186	0.262
LVEF, (%)	0.004	0.882
Brachial vessel diameter	0.158	0.312
Flow-mediated increase in diameter	-0.648	**<0.001**
EDD (%)	-0.898	**<0.001**
NID (%)	-0.867	**<0.001**
Hyperaemia (%)	-0.752	**<0.001**
IMT (mm)	0.857	**<0.001**
PSV (cm/s)	-0.659	**<0.001**
EDV (cm/s)	-0.758	**<0.001**
MV (cm/s)	-0.713	**<0.001**
RI	0.634	**<0.001**
PI	0.456	**<0.001**

**p-value<0.05, *We conducted a Spearman correlation analysis between the categorical variable prediabetes and other variables. EDD: Endothelium dependent dilation, EDV: End diastolic velocity, IMT: Intima-media thickness, LV-EF: Left ventricular ejection fraction, MV: Mean velocity, NID: Nitroglycerin-induced dilation, RI: Resistive index, PI: Pulsatility index, PSV: Peac systolic velocity*

our study showed that individuals with prediabetes did not have plaque or stenosis in their CCAs. In our study, individuals with prediabetes had normal left ventricular ejection fraction.

Several studies have linked abnormalities in the communis artery (CA) lumen and wall to CV risk factors[17]. CCA measures are less variable and more reliable than ICA and external CA samples[3]. In contrast to carotid atherosclerosis and CVD risk factors, CCA flow velocity and diameter are linked to ischemic stroke[18]. Because fractional shortening and PSV are positively correlated, the carotid flow rate is sensitive to cardiac hemodynamic changes. In addition, middle cerebral artery flow velocity and cardiac index are synergistic in normotensive individuals. The participants in our research had normal BP levels and did not present any cardiac insufficiency symptoms.

Owolabi et al.[19] found a relationship between carotid artery diameter and blood flow velocity in stroke patients. External factors, such as physical activity, temperature, food consumption, light, and noise, can affect carotid flow rates[3]. PI is a semiquantitative indicator that measures arteriolar tone by representing blood flow impedance downstream of sampling[20].

Study Limitations

Limited numbers of patients and controls were included in this study. We did not follow-up long-term.

Left ventricular function, coronary blood flow, carotid blood flow velocity, and arterial stiffness are affected by pulse wave velocity (PWV). Without the PWV estimation, this investigation was limited. Without angiography, subclinical CAD cannot be excluded. However, our patients were asymptomatic and had no echocardiographic evidence of ischemic heart disease. Fifth, we cannot validate the diabetes rate among patients with prediabetes. Finally, extrinsic factors, including physical activity, temperature, food consumption, light, and noise, affect carotid flow rates.

Conclusion

This is the first study to examine carotid blood flow velocity patterns in patients with prediabetes. Reduced carotid flow rate may be caused by ED, increased microvascular resistance in people who are at risk for developing diabetes.

Ethics

Ethics Committee Approval: Approval was obtained from the Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval no.: 2021/07-30, date: 30.07.2021).

Informed Consent: All participants provided written informed consent.

Footnotes

Conflict of Interest: The author declare no conflicts of interest concerning the authorship or publication of this article.

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