EVALUATION OF ARTERIAL STIFFNESS USING BRACHIAL-ANKLE PULSE WAVE VELOCITY IN TYPE 2 DIABETES PATIENTS AT 175 MILITARY HOSPITAL

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ABSTRACT

Objective: *Assess arterial stiffness using brachial-ankle pulse wave velocity (baPWV) and its correlation with certain clinical and subclinical characteristics in type 2 diabetes (T2DM) patients at 175 Military Hospital.*

Subjects and Methods: *A cross-sectional descriptive study was conducted on 200 participants (160 patients with T2DM and 40 in age and sex-matched healthy control group) at Military Hospital 175 from June 2022 to June 2024. BaPWV was measured by the OMRON VP-1000 PLUS machine.*

Results: *Patients with T2DM had a mean age of 59.95 ± 12.62 years, with males accounting for 45%. The most common atherosclerotic cardiovascular risk factors were hypertension (HTN) and dyslipidemia (72.5% and 71.25%, respectively). The T2DM group had a significantly higher mean baPWV compared with the healthy control group matched for age and sex (1821.22 ± 433.56 vs. 1544.93 ± 302.36 cm/s; $p < 0.05$), as well as a significantly higher prevalence of arterial stiffness (baPWV > 1450 cm/s) (45% vs. 21.88%; $p = 0.003$). In patients with T2DM, baPWV showed a statistically significant positive correlation with age ($r = 0.477$; $p < 0.05$), heart rate ($r = 0.20$; $p = 0.11$), and mean arterial pressure ($r = 0.441$; $p < 0.05$). Arterial stiffness in patients with T2DM was significantly associated with hypertension [OR 4.75 (2.14–10.53), $p < 0.001$], metabolic syndrome [OR 3.53 (1.60–7.76), $p = 0.004$], chronic kidney disease [OR 2.94 (1.20–7.25), $p = 0.016$], poor glycemic control with HbA1c > 6.5% [OR 3.77*

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(1.41–4.48), p = 0.01], and microalbuminuria [OR 1.91 (0.84–4.33), p < 0.01]. Patients with T2DM and concomitant hypertension had significantly higher baPWV compared with those without hypertension (1910.22 ± 439.57 vs. 1586.65 ± 317.47 cm/s; p < 0.001). Among patients with T2DM and hypertension, those who achieved target blood pressure control had significantly lower baPWV than those who did not achieve blood pressure targets (1828.09 ± 400.02 vs. 2004.28 ± 467.11 cm/s; p = 0.03).

Conclusion: *In patients with T2DM, mean baPWV values and the prevalence of increased arterial stiffness were significantly higher than in healthy controls matched for age and sex. baPWV was significantly associated with age, mean arterial pressure, and heart rate. Arterial stiffness was significantly associated with several atherosclerotic cardiovascular risk factors, including hypertension, metabolic syndrome, chronic kidney disease, poor glycemic control (HbA1c > 6.5%), and positive microalbuminuria. Patients with T2DM and hypertension who achieved target blood pressure control had significantly lower baPWV compared with those who did not achieve blood pressure targets.*

Keywords: *clinical characteristics, paraclinical characteristics, arterial stiffness, pulse wave velocity.*

1. INTRODUCTION

Atherosclerotic cardiovascular disease is a common major cardiovascular complication and the leading cause of mortality in patients with type 2 diabetes mellitus (T2DM) [1]. Arterial stiffness (AS) is a term used to describe the ability of arteries to expand and contract in response to the cardiac ejection cycle [2]. Arterial stiffness through pulse wave velocity (PWV) is an independent risk factor of cardiovascular disease development, all-cause mortality, and cardiovascular mortality in patients with diabetes [3].

Carotid–femoral pulse wave velocity (cfPWV) is the gold standard for assessing aortic stiffness and has independent prognostic value for cardiovascular events in patients with hypertension. The clinical value of cfPWV with a threshold >1200 cm/s has been recognized by the European Society of Hypertension and the European Society of Cardiology, and its use is recommended in guidelines for the assessment of hypertension-mediated organ damage [4]. However, this method is relatively complex and difficult to apply in routine clinical practice.

In recent years, brachial–ankle pulse wave velocity (baPWV) has been widely used due to its simple, non-invasive, and convenient measurement method. Numerous studies have shown that elevated baPWV is a independent predictor of mortality and cardiovascular events across

various patient populations. Results from several studies suggest that baPWV not only provides information similar to aortic PWV but also reflects arterial stiffness in peripheral arteries [5]. A baPWV value >1450 cm/s is considered equivalent to a cfPWV threshold >1200 cm/s [6].

At Military Hospital 175, no studies have yet evaluated arterial stiffness in patients with type 2 diabetes mellitus. Therefore, we conducted this study with two objectives:

To assess arterial stiffness using brachial–ankle pulse wave velocity (baPWV) measurement in patients with type 2 diabetes mellitus.

To examine the association between arterial stiffness and selected clinical parameters, laboratory findings, and cardiovascular risk factors in patients with type 2 diabetes mellitus.

2. SUBJECTS AND METHODS

2.1 Study population

The study population consisted of 200 participants aged 18 years and older, including 160 patients with type 2 diabetes mellitus and 40 healthy individuals matched for age and sex with the patient group.

Exclusion criteria:

Patient group: Patients with type 1 diabetes mellitus, gestational diabetes, or secondary diabetes; patients with uncontrolled acute diabetic complications (hyperosmolar hyperglycemic state, diabetic ketoacidosis, lactic acidosis, unstable acute infections, etc.); patients with an ankle–brachial index (ABI) < 0.9; and individuals who did not consent to participate.

Control group: Individuals with a confirmed or suspected diagnosis of diabetes mellitus; a history or current presence of psychiatric disorders, cardiovascular disease, renal disease, endocrine or metabolic disorders; pregnant or breastfeeding women; and individuals who did not consent to participate.

2.2 Methods

Study design: Prospective cross-sectional descriptive study.

Location and duration: Conducted at Military Hospital 175 from June 2022 to June 2024.

Sampling method: Convenience sampling, based on the chronological order of hospital admission.

Diagnostic criteria used in the study:

Type 2 diabetes mellitus and diabetic chronic kidney disease: According to the ADA 2022 criteria.

Dyslipidemia: According to the Vietnam Heart Association (2015).

- Hypertension: According to the Vietnam Heart Association (2022).

- Heart failure: According to the European Society of Cardiology guidelines (2021), updated in the Vietnam Heart Association recommendations (2022).

- Metabolic syndrome: According to the Ministry of Health guideline "Diagnosis and treatment of endocrine–metabolic diseases" (2017).

- HbA1c and blood pressure targets in patients with T2DM: According to the Ministry of Health guideline on diagnosis and treatment of type 2 diabetes mellitus (2020).

- Chronic coronary artery syndrome: According to the Ministry of Health guideline "Practice in diagnosis and treatment of coronary artery disease" (2020).

- Body mass index (BMI): Assessed according to WHO criteria (2004) for Asian populations.

Studyprocedures:

Participants were enrolled and assigned a study medical record. Clinical and laboratory data were collected. baPWV was measured using the OMRON VP-1000 PLUS device (Omron, Japan). A baPWV value >1450 cm/s was considered indicative of increased arterial stiffness, as proposed by Tanaka et al. (2009) in a study comparing baPWV and cfPWV measurements in 2,287 subjects [6].

Collected variables included:

- Age, sex, diagnosis of type 2 diabetes mellitus, hypertension, chronic kidney disease, metabolic syndrome.

- Achievement of blood pressure, HbA1c, and lipid control targets.

- Height, weight, BMI, waist circumference.

- Fasting venous plasma glucose, HbA1c, urea, creatinine, total cholesterol, HDL-C, LDL-C, triglycerides, and microalbuminuria (MAU), defined as positive when the urinary albumin-to-creatinine ratio >30 mg/g [1].

2.3 Data analysis

Data were processed and analyzed using SPSS software version 20.0.

3. RESULTS

3.1 General characteristics of the study Subjects

Table 1. General Characteristics of the Study Subjects

	Patient Group (n=160)	Control Group (n=40)	p
Parameter	**X ± SD**	**X ± SD**	**p**
Age (years)	59.95 ± 12.62	62.79 ± 10.55	> 0.05
Height (cm)	158.64 ± 8.72	157.80 ± 7.80	> 0.05
Weight (kg)	58.53 ± 11.66	58.26 ± 9.63	> 0.05
Waist circumference (cm)	88.49 ± 13.25	88.27 ± 9.60	> 0.05
BMI (kg/m^2)	23.11 ± 4.04	23.37 ± 3.16	> 0.05
Fasting venous blood glucose (mmol/L)	13.68 ± 9.40	5.6 ± 4.32	< 0.001
HbA1c (%)	10.34 ± 3.62	5.3 ± 1.41	< 0.001
Male proportion (%)	45	53.75	> 0.05

Remark: No significant differences in age, sex, height, weight, waist circumference, or BMI between the patient group and the control group ($p > 0.05$).

Table 2. Characteristics of selected cardiovascular risk factors and comorbidities in the patient group

Risk factor	Number (n)	Rate (%)
Smoking	55	34.38
Alcohol abuse	57	35.63
Obesity (BMI ≥ 30)	8	5
Hypertension	116	72.5
Dyslipidemia	114	71.25
Microalbuminuria (+)*	64	41.03
Chronic kidney disease	60	37.5
Chronic coronary artery disease	63	39.38
Heart failure	14	8.8

Remark: Hypertension and dyslipidemia are the two most common comorbidities in patients with type 2 diabetes mellitus.

3.2. Relationship between arterial stiffness and type 2 diabetes mellitus

Table 3. Arterial stiffness in the type 2 diabetes mellitus group and the control group

Parameter	Patient group (n=160)	Control group (n=40)	p
baPWV (cm/s)	1821.22 ± 433.56	1544.93 ± 302.36	< 0.05
Prevalence of increased arterial stiffness (%)	45 %	22%	0.003

Remark: Patients with type 2 diabetes mellitus had a significantly higher mean baPWV value and a substantially higher prevalence of increased arterial stiffness compared with the age- and sex-matched control group.

3.3. Relationship Between Arterial Stiffness and Age

Table 4. baPWV Index by Age Group

Age group (years)	Patient group (n=160)		Control group (n=40)		p
	n	X ± SD	N	X ± SD	
≤ 60	67	1596.48 ± 277.35	19	1375.11 ± 175.54	<0.001
> 60	93	1983.12 ± 454.25	21	1714.86 ± 294.45	0.01
p	<0.001		<0.001		

Remark: In both the patient group and the control group, baPWV values in participants older than 60 years were significantly higher than those in participants aged 60 years or younger, and this difference was statistically significant.

3.4. Relationship Between Arterial Stiffness and Certain Clinical and Paraclinical Parameters in Patients with Type 2 Diabetes Mellitus

3.4.1. Relationship between arterial stiffness and hypertension

Table 5. Relationship between pulse wave velocity and hypertension, and achievement of blood pressure targets

Hypertension / Parameter	Yes		No		
	N	X ± SD	n	X ± SD	
baPWV (cm/s)	116	1910.22 ± 439.57	44	1586.65 ± 317.47	<0.001
Achievement of blood pressure targets / Parameter	**Achieved target**		**Not achieved the target**		**p**
	N	**X ± SD**	**n**	**X ± SD**	
baPWV (cm/s)	62	1828.09 ± 400.02	44	2004.28 ± 467.11	0.03

Remark: The baPWV value in the patient group with hypertension was higher than in those without hypertension, and this difference was statistically significant ($p < 0.05$). Among 116 patients with type 2 diabetes mellitus (T2DM) and concomitant hypertension, baPWV was lower in patients who achieved blood pressure targets compared with those who did not, and this difference was statistically significant ($p < 0.05$).

3.4.2. Relationship between arterial stiffness and selected clinical and paraclinical indicators

Table 6. Relationship between increased arterial stiffness and selected cardiovascular risk factors

Characteristics (n=160)	baPWV≥ 1450 cm/s (n = 125)	baPWV<1450 cm/s (n = 35)	OR (95%CI)	p
Hypertension	100 (80%)	16 (45.61%)	4.75 (2.14; 10.53)	<0.001¥
Metabolic syndrome	81 (72.66%)	12 (20.34%)	3.53 (1.60; 7.76)	0.004¥
Chronic kidney disease	52 (42.4%)	72 (57.6%)	2.94 (1.20; 7.25)	0.016 ¥

HbA1c > 6.5	113 (90.4%)	12 (54.5 %)	3.77(1.41 ; 4.48)	0.01¥
Microalbuminuria (+)	54 (44.26%) * n=122	10 (29.41%) *n=34	1.91 (0.84; 4.33)	<0.01¥
Obesity	5 (6.3%)	3 (1.8%)	0.44 (0.10;1.96)	0.374¶
Dyslipidemia	93 (74.4%)	21 (60 %)	1.94 (0.88; 4.25)	0.09¥

¥ *Chi-square test*

¶ *Fisher's Exact test*

Remark: Patients with type 2 diabetes mellitus who had hypertension, metabolic syndrome, chronic kidney disease, HbA1c > 6.5%, or positive microalbuminuria showed a statistically significantly higher prevalence of arterial stiffness.

Table 7. Correlation between baPWV values and selected clinical and paraclinical parameters

Parameter	n	R^2	p
Age	160	0.492	<0.001
BMI	160	0.492	0.472
Heart rate	160	0.492	0.015
Mean arterial pressure	160	0.492	<0.001
Fasting venous blood glucose	160	0.492	0.561
Creatinine	160	0.492	0.909
Cholesterol	160	0.492	0.561
LDL-C	160	0.492	0.554
Triglycerides	160	0.492	0.645

Remark: Multivariate linear regression analysis showed that baPWV was significantly correlated with age, mean arterial pressure, and heart rate.

4. DISCUSSION

4.1 Characteristics of the Study Subjects

Patients with type 2 diabetes mellitus (T2DM) had a mean age of 59.95 ± 12.62 years, while the control group had a mean age of 62.79 ± 10.55 years. There was no significant age difference between the patient group and the control group ($p > 0.05$). The mean age of diabetic patients in our study was higher than that reported by Pham Tuan Duong (2016), which was 55.86 ± 2.61 years [7]. The gender distribution in our study was 45% male and 55% female, which is comparable to the study by Nguyen Van Dieu (2019), where males accounted for 41.1% and females for 58.9% [8]. These differences are reasonable, as the data reflect the actual patient populations at different healthcare facilities.

In the study by Nguyễn Văn Diệu (2019), dyslipidemia and hypertension were the two most common comorbidities among patients with type 2 diabetes in Vietnam, with prevalence rates of 81.2% and 74.8%, respectively [8]. In our study, the proportion of diabetic patients with concomitant hypertension and dyslipidemia was also high, accounting for 72.5% and 71.25%, respectively.

4.2 Arterial Stiffness in Patients with Diabetes Mellitus

In the diabetic group, the prevalence of increased arterial stiffness (defined as baPWV > 1450 cm/s) was 45%, which was significantly higher than that in the control group (21.88%), with $p = 0.003$. The mean baPWV value in our study was higher than that reported by Pham Tuan Duong et al. (1821.22 ± 433.56 cm/s vs. 1517.79 ± 250.55 cm/s). This difference may be explained by the higher mean age in our study compared with that of Pham Tuan Duong (59.95 ± 12.62 vs. 55.86 ± 2.61 years) [7].

When comparing the diabetic group with the control group matched for age, sex, height, weight, waist circumference, and BMI, the results showed that baPWV in the diabetic group was significantly higher than in the control group (1821.22 ± 433.56 cm/s vs. 1544.93 ± 302.36 cm/s, $p < 0.05$). Our findings are consistent with the study by Pham Tuan Duong et al. (baPWV in the diabetic group: 1517.79 ± 250.55 cm/s vs. 1236.95 ± 99.48 cm/s) [7] and with the study by Liu (2011) (1678 cm/s vs. 1583 cm/s, $p = 0.018$) [9]. Increased arterial stiffness in the diabetic group compared with the control group was consistent across all age groups.

4.3 Relationship Between Arterial Stiffness and Cardiovascular Risk Factors in Patients with Diabetes Mellitus

4.3.1. Relationship Between Arterial Stiffness and Age

Age is one of the most important factors affecting arterial stiffness [5]. In our study, in both the diabetic and control groups, the mean baPWV in individuals aged over 60 years was significantly higher than in those under 60 years, and this difference was statistically significant. In the diabetic group, patients older than 60 years had a significantly higher mean baPWV compared with those under 60 years (1596.48 ± 277.35 cm/s, $p < 0.0001$). In multivariable linear regression analysis with baPWV as the dependent variable, age remained a statistically significant factor associated with baPWV ($p < 0.05$).

4.3.2. Relationship Between Arterial Stiffness and Hypertension

Based on the results of a meta-analysis, Cecelja et al. reported that age and blood pressure are the key determinants of arterial stiffness [10,11].

In patients with type 2 diabetes, the mean baPWV was significantly higher in those with concomitant hypertension compared with those without hypertension ($p < 0.05$). The prevalence of arterial stiffness was also higher in the hypertensive group than in the non-hypertensive group (OR = 4.75; $p < 0.001$). These findings are consistent with the studies by Cao Trường Sinh, Phạm Tuấn Dương, and other international studies [7, 9–12].

In multivariable analysis, baPWV showed a statistically significant association with mean arterial pressure ($p < 0.05$). Furthermore, as shown in Table 5, among patients with concomitant type 2 diabetes and hypertension, those who achieved target blood pressure control had a significantly lower mean baPWV compared with those who did not achieve blood pressure targets ($p = 0.03$).

This finding can be explained by the fact that in hypertensive patients, nitric oxide (NO) levels are reduced due to decreased production and increased inhibition of NO secretion. Under the influence of hypertension, endothelial cells undergo increased apoptosis, facilitating the formation of atherosclerotic plaques. The primary mechanism driving endothelial apoptosis is the increased production of angiotensin II in both the circulation and tissues [13]. Therefore, hypertension is a major risk factor for atherosclerosis and progressively increased arterial stiffness.

4.3.3. Relationship Between Arterial Stiffness, Microalbuminuria, and Chronic Kidney Disease

Patients with concomitant chronic kidney disease had significantly higher baPWV values compared with those without chronic kidney disease. Patients with type 2 diabetes and chronic kidney disease had a higher prevalence of arterial stiffness than those without chronic kidney disease (OR = 2.94; $p = 0.016$).

The baPWV value was higher in

the microalbuminuria-positive (MAU+) group compared with the non-MAU group; however, this difference was not statistically significant ($p = 0.12$). Nevertheless, diabetic patients with microalbuminuria had a higher prevalence of arterial stiffness compared with those without increased arterial stiffness (OR = 1.906; $p < 0.01$).

In patients with diabetes, microalbuminuria is considered a marker for the development of vascular complications in general and microvascular complications in particular, especially diabetic nephropathy. MAU serves both as an early indicator of renal damage and as a reflection of declining renal function. Studies have shown that baPWV is associated with the progression of target organ damage, particularly kidney disease, in patients with diabetes [14].

4.3.4. Relationship Between Arterial Stiffness and Metabolic Syndrome

Patients with type 2 diabetes who had metabolic syndrome exhibited significantly higher mean baPWV values compared with those without metabolic syndrome ($p < 0.05$). This finding is consistent with the study by Phạm Tuấn Dương, which reported significantly higher baPWV in diabetic patients with metabolic syndrome compared with those without metabolic syndrome (1560.12 ± 282.65 cm/s vs. 1463.95 ± 191.89 cm/s; $p < 0.005$) [8].

Metabolic syndrome is associated with complex interactions among insulin resistance, obesity, dyslipidemia, and hypertension. These factors contribute to increased arterial stiffness through various pathogenic mechanisms.

4. CONCLUSIONS AND RECOMMENDATIONS

This study surveyed 200 participants, including 160 patients with type 2 diabetes and 40 healthy controls, at Military Hospital 175.

Regarding arterial stiffness in patients with type 2 diabetes, the mean baPWV was 1821.22 ± 433.56 cm/s, and the prevalence of increased arterial stiffness was 45%.

The mean baPWV and the prevalence of arterial stiffness in the type 2 diabetes group were significantly higher than in the age-, sex-, and BMI-matched healthy control group. This difference remained consistent when comparisons were made within both the >60-year and <60-year subgroups.

BaPWV showed statistically significant associations with age, mean arterial pressure, and heart rate. Patients with type 2 diabetes who had concomitant hypertension, metabolic syndrome, chronic kidney disease, or microalbuminuria had significantly higher

mean baPWV values. Among diabetic patients with hypertension, those who achieved target blood pressure control had significantly lower mean baPWV values compared with those who did not achieve blood pressure control.

BaPWV measured using the oscillometric method is a non-invasive indicator reflecting arterial stiffness and is easily applicable in clinical practice. Our group recommends that brachial–ankle pulse wave velocity measurement should be performed early and regularly in patients with type 2 diabetes, as it can provide useful information for early risk stratification of vascular complications in individuals with elevated baPWV.

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