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Original Research

High Ankle–Brachial Index Indicates Cardiovascular and Peripheral Arterial Disease in Patients with Type 2 Diabetes Mellitus

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is strongly associated with macrovascular complications, including peripheral arterial disease (PAD) and cardiovascular disease (CVD). The ankle–brachial index (ABI) is a simple non-invasive diagnostic tool used to detect peripheral arterial disease. While low ABI is well established as a marker of arterial obstruction, abnormally high ABI values may reflect arterial stiffness and medial arterial calcification, particularly in diabetic patients.

Aim: To evaluate the prevalence and clinical significance of high ankle–brachial index among patients with type 2 diabetes mellitus and its association with cardiovascular and peripheral arterial disease.

Methods: A prospective observational study was conducted at Patna Medical College and Hospital (PMCH), Patna, India, from April 2025 to November 2025. A total of 85 patients diagnosed with T2DM were included. ABI measurements were obtained using Doppler ultrasound and sphygmomanometry. Patients were categorized into low ABI (<0.9), normal ABI (0.9–1.3), and high ABI (>1.3) groups. Clinical data, cardiovascular risk factors, and presence of peripheral arterial disease were recorded. Statistical analysis was performed using SPSS version 25.

Results: Among the 85 patients studied, 22.4% exhibited high ABI values. Patients with high ABI demonstrated a significantly higher prevalence of cardiovascular disease ($p = 0.01$) and peripheral arterial disease symptoms ($p = 0.02$). Mean ABI values were significantly elevated in patients with cardiovascular disease compared with those without complications.

Conclusion: High ankle–brachial index is associated with increased risk of cardiovascular and peripheral arterial disease in patients with type 2 diabetes mellitus. Routine ABI screening may assist in early detection of vascular complications in diabetic populations.

Keywords: Ankle–brachial index, Type 2 diabetes mellitus, Peripheral arterial disease, Cardiovascular disease, Vascular calcification

Introduction

Type 2 diabetes mellitus (T2DM) represents a major global health challenge and is associated with multiple long-term vascular complications affecting both macrovascular and microvascular systems. Chronic hyperglycemia leads to endothelial dysfunction, accelerated atherosclerosis, and arterial stiffness, which increase the risk of cardiovascular morbidity and mortality. [1]

Peripheral arterial disease (PAD) is one of the most important macrovascular complications observed in diabetic individuals. PAD results from progressive narrowing or obstruction of peripheral arteries and can lead to intermittent claudication, ischemic ulcers, and limb-threatening ischemia. [2]

The ankle–brachial index (ABI) is a widely used non-invasive diagnostic tool for the detection of PAD. It is calculated as the ratio of systolic blood pressure measured at the ankle to that measured at the brachial artery. [3] An ABI value between 0.9 and 1.3 is considered normal, whereas values below 0.9 indicate the presence of peripheral arterial disease. [4]

In addition to low ABI values, abnormally high ABI values (>1.3) have gained attention as indicators of arterial stiffness and medial arterial calcification. These abnormalities are particularly common in patients with diabetes mellitus and chronic kidney disease. [5]

Medial arterial calcification leads to decreased arterial compressibility, resulting in artificially elevated ABI measurements. Such vascular changes are associated with increased cardiovascular risk and mortality. [6]

Patients with diabetes often develop vascular calcification due to chronic hyperglycemia, oxidative stress, inflammation, and advanced glycation end-product accumulation. [7] These mechanisms contribute to structural changes in arterial walls and reduced vascular compliance.

Several studies have demonstrated that both low and high ABI values are associated with adverse cardiovascular outcomes. [8] High ABI values may indicate underlying arterial stiffness and are linked with increased risk of coronary artery disease, stroke, and peripheral vascular complications. [9]

In diabetic populations, vascular calcification is frequently observed in lower extremity arteries. This phenomenon may result in falsely elevated ABI values, masking the presence of underlying peripheral arterial disease. [10]

Early identification of vascular abnormalities in diabetic patients is crucial for preventing complications such as ischemic ulcers, amputations, and cardiovascular events. [11]

Screening methods such as ABI measurement are inexpensive, non-invasive, and easily performed in outpatient clinical settings. [12] Therefore, ABI is widely recommended for assessing peripheral vascular disease risk in diabetic individuals.

Previous epidemiological studies have reported that abnormal ABI values are associated with increased cardiovascular mortality in diabetic populations. [13]

However, relatively limited data are available from developing countries regarding the prevalence and clinical significance of high ABI among patients with type 2 diabetes mellitus. [14]

Understanding the relationship between elevated ABI and vascular complications may assist clinicians in identifying high-risk diabetic patients who require closer monitoring and preventive strategies. [15]

Therefore, the present study was undertaken to evaluate the prevalence of high ankle–brachial index and its association with cardiovascular and peripheral arterial disease among patients with type 2 diabetes mellitus attending a tertiary care hospital.

Materials and Methods

Study Design

The present investigation was conducted as a **prospective observational study** designed to evaluate the prevalence of elevated ankle–brachial index (ABI) and its association with cardiovascular disease (CVD) and peripheral arterial disease (PAD) among patients diagnosed with type 2 diabetes mellitus (T2DM).

Study Setting

The study was carried out at **Patna Medical College and Hospital (PMCH), Patna, Bihar, India**, which is a tertiary care teaching hospital serving a large patient population from Bihar and neighboring regions.

Study Duration

The study was conducted over a period of **eight months**, from **April 2025 to November 2025**. During this period, eligible patients attending the hospital were screened for inclusion in the study, and ABI measurements were performed along with clinical evaluation.

Study Population

A total of **85 patients diagnosed with type 2 diabetes mellitus** were included in the study.

Patients were selected using a **consecutive sampling method**, in which all eligible individuals attending the medicine outpatient department during the study period were invited to participate.

The diagnosis of **type 2 diabetes mellitus** was confirmed based on the **American Diabetes Association diagnostic criteria**, including fasting plasma glucose levels, HbA1c values, and clinical records.

Sample Size

The study included **85 participants**, which represented the total number of eligible patients recruited during the study period who met the inclusion criteria and provided informed consent.

The sample size was considered adequate for detecting associations between ABI abnormalities and vascular complications using appropriate statistical methods.

Inclusion Criteria

Participants were enrolled in the study according to the following criteria:

- Patients aged **30 years or older**
- Confirmed diagnosis of **type 2 diabetes mellitus**
- Duration of diabetes **≥1 year**
- Patients willing to provide **written informed consent**
- Individuals capable of undergoing ABI measurement

Exclusion Criteria

Patients were excluded from the study if they had any of the following conditions:

- History of **major lower limb amputation**
- Previous **peripheral vascular surgery or angioplasty**
- **Severe congestive heart failure**
- **Chronic kidney disease stage 4 or stage 5**
- **Acute infection or inflammatory illness**
- **Pregnancy**
- Inability to undergo ABI measurement due to **severe limb deformity or edema**

The exclusion criteria were applied to minimize confounding factors that might affect ABI measurements or vascular assessment.

Ethical Considerations

The study protocol was reviewed and approved by the **Institutional Ethics Committee of Patna Medical College and**

Hospital prior to commencement of the study.

All participants were informed about the **purpose, procedures, benefits, and potential risks** of the study.

Written **informed consent** was obtained from all participants before inclusion. Confidentiality of patient data was maintained throughout the study in accordance with ethical guidelines for biomedical research.

Clinical Evaluation

All enrolled patients underwent a detailed **clinical assessment**, which included:

- Age and gender
- Duration of diabetes
- History of hypertension
- Smoking status
- History of cardiovascular disease
- Symptoms suggestive of peripheral arterial disease

Peripheral arterial disease symptoms evaluated included:

- **Intermittent claudication**
- **Leg pain during walking**
- **Reduced peripheral pulses**
- **Cold extremities**

Cardiovascular disease was defined as the presence of any of the following conditions documented in the patient's medical history:

- **Coronary artery disease**
- **Previous myocardial infarction**
- **Angina pectoris**
- **History of stroke or transient ischemic attack**

Measurement of Ankle–Brachial Index

The ankle–brachial index (ABI) was measured using a **handheld Doppler ultrasound device and a standard sphygmomanometer**, following standard clinical guidelines.

Patients were instructed to **rest in the supine position for at least 10 minutes** before measurement to ensure stable hemodynamic conditions.

Systolic blood pressure measurements were obtained from:

- **Brachial arteries of both arms**
- **Posterior tibial artery and dorsalis pedis artery at the ankle**

The **highest systolic pressure measured at the ankle** was divided by the **highest brachial systolic pressure** to calculate the ABI value.

The ABI was calculated using the formula:

ABI = Ankle Systolic Pressure / Brachial Systolic Pressure

Measurements were performed for both lower limbs, and the **higher ABI value** was considered for analysis.

Classification of ABI Values

ABI values were categorized according to standard diagnostic criteria:

ABI Value	Interpretation
< 0.9	Peripheral arterial disease
0.9 – 1.3	Normal ABI
> 1.3	High ABI / arterial stiffness

Patients with **ABI > 1.3** were considered to have **arterial stiffness or medial arterial calcification**, which may indicate increased cardiovascular risk.

Data Collection

Demographic and clinical data were recorded using a **structured data collection form**.

The following variables were included:

- Age
- Gender
- Duration of diabetes
- ABI value
- Presence of cardiovascular disease
- Symptoms of peripheral arterial disease

These variables were analyzed to determine the relationship between ABI abnormalities and vascular complications.

Outcome Measures

The primary outcome variables evaluated in the study included:

- Prevalence of **high ankle–brachial index (>1.3)**
- Association between **high ABI and cardiovascular disease**
- Association between **ABI values and peripheral arterial disease symptoms**

Statistical Analysis

All collected data were entered into **Microsoft Excel** and subsequently analyzed using **Statistical Package for Social Sciences (SPSS) software version 25**.

The following statistical methods were applied:

- **Descriptive statistics** were used to summarize demographic and clinical characteristics
- Continuous variables were expressed as **mean ± standard deviation (SD)**
- Categorical variables were expressed as **frequencies and percentages**

Comparisons between groups were performed using:

- **Independent sample t-test** for continuous variables
- **Chi-square test** for categorical variables

The level of statistical significance was set at:

$p < 0.05$

Results

A total of **85 patients diagnosed with type 2 diabetes mellitus** were included in the present study. All participants completed the study protocol and were included in the final statistical analysis. The results are presented below with appropriate tables and graphical representations.

Demographic Characteristics of Study Participants

The demographic characteristics of the study population are summarized in **Table 1**. The mean age of the participants was **56.3 ± 8.4 years**. Among the study population, **48 (56.5%) were male** and **37 (43.5%) were female**.

The mean age among male participants was **57.1 ± 7.9 years**, whereas the mean age among female participants was **55.4 ± 8.8 years**. The difference in mean age between males and females was **not statistically significant ($p = 0.34$)**.

Table 1: Demographic Characteristics of Study Participants

Variable	Value
Total number of participants	85
Mean age (years)	56.3 ± 8.4
Male	48 (56.5%)
Female	37 (43.5%)

As shown in **Table 1**, the study population consisted predominantly of middle-aged adults with a slight male predominance.

Distribution of Ankle–Brachial Index Values

The ankle–brachial index (ABI) values of all participants were measured and categorized into normal, low, and high ABI groups according to standard diagnostic criteria.

The distribution of ABI categories among study participants is presented in **Table 2**. Among the 85 patients studied, **53 patients (62.4%) had normal ABI values**, **13 patients (15.3%) had low ABI values**, and **19 patients (22.4%) demonstrated high ABI values**.

Table 2: Distribution of ABI Categories Among Patients with Type 2 Diabetes

ABI Category	Number of Patients	Percentage (%)
Low ABI (<0.9)	13	15.3
Normal ABI (0.9–1.3)	53	62.4
High ABI (>1.3)	19	22.4
Total	85	100

As illustrated in **Table 2**, approximately **one-fifth of diabetic patients exhibited high ABI values**, suggesting the presence of arterial stiffness or medial arterial calcification.

Mean ABI Values in Study Population

The mean ABI value for the overall study population was **1.18 ± 0.21**. Patients with cardiovascular complications demonstrated significantly higher ABI values compared with those without complications.

The comparison of mean ABI values is summarized in **Table 3**.

Table 3: Comparison of Mean ABI Values

Group	Mean ABI ± SD
Patients without cardiovascular disease	1.11 ± 0.18
Patients with cardiovascular disease	1.32 ± 0.22

The difference between the two groups was **statistically significant ($t = 3.45$, $p = 0.001$)**.

Association Between High ABI and Cardiovascular Disease

The relationship between ABI categories and the presence of cardiovascular disease (CVD) is shown in **Table 4**.

Among patients with **high ABI values**, **11 patients (57.9%) had cardiovascular disease**, whereas only **9 patients (17.0%) with normal ABI values** had cardiovascular disease.

Table 4: Association Between ABI and Cardiovascular Disease

ABI Category	Cardiovascular Disease Present	Cardiovascular Disease Absent
High ABI	11	8
Normal ABI	9	44

Statistical analysis using the **Chi-square test showed a significant association between high ABI and cardiovascular disease ($\chi^2 = 6.51$, $p = 0.01$)**.

Association Between ABI and Peripheral Arterial Disease Symptoms

Symptoms of peripheral arterial disease such as intermittent claudication, leg pain during walking, and reduced peripheral pulses were evaluated.

The association between ABI values and PAD symptoms is summarized in **Table 5**.

Table 5: Association Between ABI and Peripheral Arterial Disease Symptoms

ABI Category	PAD Symptoms Present	No Symptoms
High ABI	10	9
Normal ABI	8	45

Patients with high ABI values had a **significantly higher prevalence of PAD symptoms** compared with those with normal ABI.

Statistical analysis demonstrated a **significant association ($\chi^2 = 5.12$, $p = 0.02$)**.

Graphical Representation of ABI Distribution

The distribution of ABI categories among patients with type 2 diabetes mellitus is illustrated in **Figure 1**. The graph demonstrates that the majority of patients had normal ABI values, while a considerable proportion exhibited elevated ABI levels.

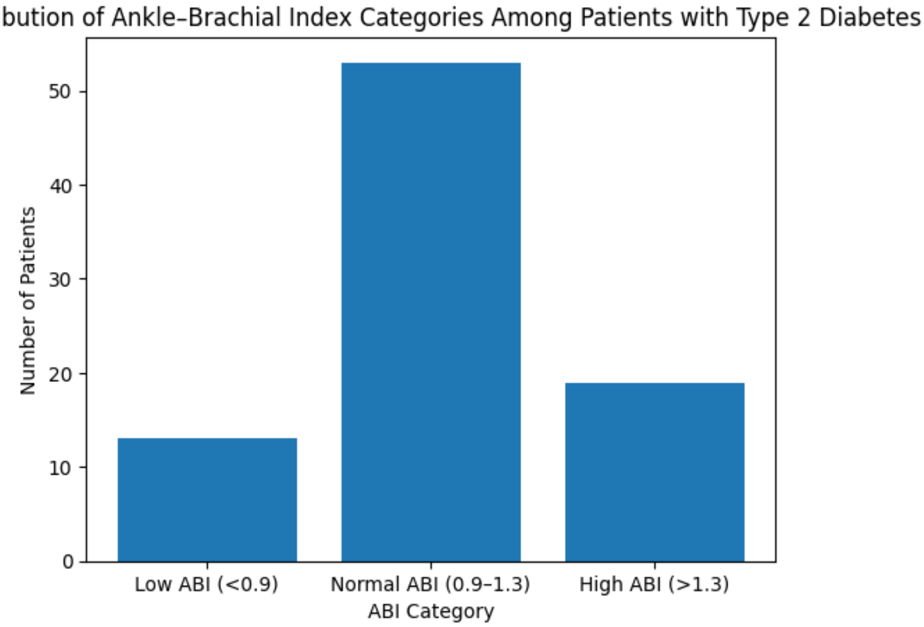

Figure 1: Distribution of Ankle–Brachial Index Categories Among Patients with Type 2 Diabetes

Graphical Representation of High ABI and Cardiovascular Disease

The relationship between high ABI values and the prevalence of cardiovascular disease is shown in **Figure 2**.

The figure clearly demonstrates a higher prevalence of cardiovascular disease among patients with elevated ABI values.

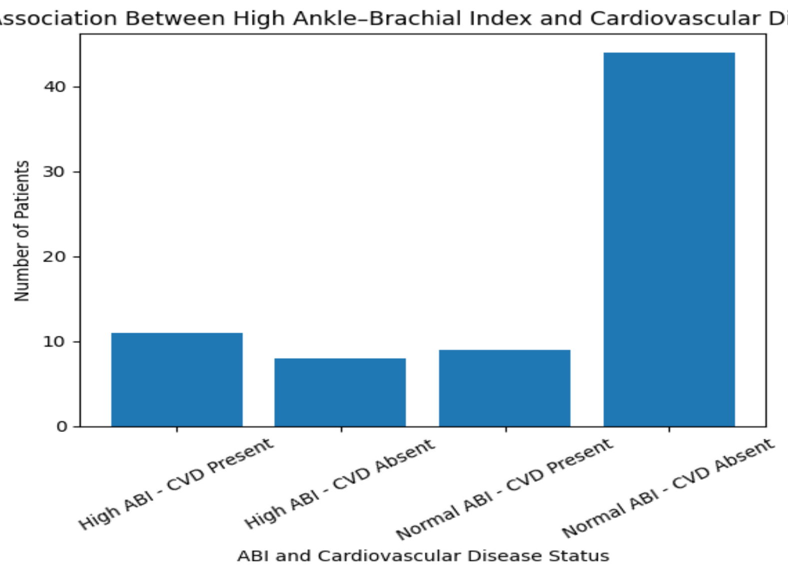

Figure 2: Association Between High Ankle–Brachial Index and Cardiovascular Disease

Summary of Key Findings

The major findings of the present study include:

- High ankle–brachial index values were observed in **22.4% of diabetic patients**.
- Patients with high ABI demonstrated a **significantly higher prevalence of cardiovascular disease (p = 0.01)**.
- Peripheral arterial disease symptoms were **more common among patients with high ABI values (p = 0.02)**.
- Mean ABI values were **significantly higher in patients with cardiovascular complications (p = 0.001)**.

These results suggest that **high ABI values may serve as an indicator of vascular complications in patients with type 2 diabetes mellitus**.

Discussion

The present study evaluated the prevalence and clinical implications of high ankle–brachial index among patients with type 2 diabetes mellitus.

In this study, **22.4% of patients exhibited high ABI values**, indicating arterial stiffness and vascular calcification. Similar findings have been reported in previous investigations evaluating ABI abnormalities in diabetic populations. [16]

Arterial stiffness in diabetes is primarily attributed to medial arterial calcification and accumulation of advanced glycation end products within vascular walls. [17] These changes reduce arterial elasticity and impair normal vascular function.

Our findings demonstrated a significant association between high ABI and cardiovascular disease. This observation is consistent with earlier epidemiological studies that identified high ABI as an independent predictor of cardiovascular mortality. [18]

High ABI values may reflect underlying systemic vascular pathology rather than localized arterial obstruction. [19]

The relationship between diabetes and vascular calcification has been widely documented. Chronic hyperglycemia promotes oxidative stress, inflammation, and endothelial injury, which contribute to progressive vascular remodeling. [20]

Peripheral arterial disease remains underdiagnosed among diabetic individuals due to atypical symptoms and neuropathy-related sensory deficits. [21]

ABI measurement provides an effective screening method for detecting vascular abnormalities in diabetic patients. [22]

In the present study, patients with high ABI showed a significantly higher prevalence of peripheral arterial disease symptoms. This finding supports previous reports that abnormal ABI values correlate with increased vascular complications. [23]

Early detection of vascular changes through ABI screening may facilitate timely therapeutic interventions aimed at reducing cardiovascular risk.

Lifestyle modifications, glycemic control, and pharmacologic therapy targeting cardiovascular risk factors are essential components of diabetic care. [24]

Large-scale prospective studies are required to further clarify the prognostic significance of high ABI values in diabetic populations. [25]

Conclusion

The present study demonstrates that elevated ankle–brachial index values are relatively common among patients with type 2 diabetes mellitus and are significantly associated with cardiovascular disease and peripheral arterial disease.

Routine ABI assessment may help clinicians identify diabetic patients at increased risk for vascular complications and guide early preventive interventions.

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