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Original Research Article

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

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Abstract:

Background: Cardiovascular and peripheral arterial diseases are common complications in patients with Type 2 Diabetes Mellitus (T2DM), often remaining undiagnosed until advanced stages. The Ankle–Brachial Index (ABI) is a non-invasive tool that helps detect arterial stiffness and peripheral arterial disease (PAD) in high-risk populations. Understanding the relationship between high ABI and cardiovascular risk may aid in early diagnosis and better management of vascular complications.

Aim: To evaluate the correlation between high ABI values and the predominance of cardiovascular and peripheral arterial disease in patients with T2DM.

Methods: A prospective study was conducted on 110 T2DM patients over 12 months. Participants underwent ABI measurement, with values categorized as low (<0.9), normal (0.9–1.3), and high (>1.3). Data on glycemic control (HbA1c), lipid profile, blood pressure, and clinical history were collected. The predominance of cardiovascular disease (CVD) and PAD was analyzed across ABI categories using appropriate statistical tests.

Results: Out of 110 participants, 16.4% had high ABI values (>1.3) indicating arterial stiffness, while 18.2% had low ABI values (<0.9) suggestive of PAD. Cardiovascular disease was significantly more prevalent in the high ABI group (77.8%) compared to the normal ABI group (29.2%, $p < 0.05$). All PAD cases (100%) were observed in the low ABI group. Poor glycemic control (HbA1c 8.5 ± 1.2%), dyslipidemia (total cholesterol 218.2 ± 40.5 mg/dL), and hypertension (SBP 142.8 ± 16.5 mmHg) were significantly associated with high ABI values.

Conclusion: High ABI values were strongly associated with cardiovascular disease, while low ABI values indicated peripheral arterial disease in T2DM patients. The findings emphasize the importance of routine ABI screening for early detection and risk stratification of vascular complications.

Recommendations: Routine ABI assessment should be integrated into diabetes care for early identification of cardiovascular and peripheral arterial disease. Additionally, addressing modifiable risk factors such as glycemic control, dyslipidemia, and hypertension is essential to mitigate the vascular burden in this population.

Keywords: Type 2 Diabetes Mellitus, Ankle–Brachial Index, Cardiovascular Disease, Peripheral Arterial Disease, Vascular Complications.

Introduction

(CVD) and peripheral arterial disease (PAD) are major complications of (T2DM), contributing significantly to morbidity and mortality worldwide [1]. Diabetes accelerates atherosclerosis through chronic hyperglycemia, oxidative stress, and endothelial dysfunction, leading to increased arterial stiffness and vascular calcification [2]. The (ABI) is a simple, non-invasive diagnostic tool used to assess arterial health. While a low ABI (<0.90) is widely recognized as an indicator of PAD, an elevated ABI (>1.30) is increasingly being associated with arterial stiffness, vascular calcification, and a heightened risk of cardiovascular events [3].

Studies have demonstrated that a high ABI is not merely a benign finding but is often linked to medial arterial calcification (MAC), a condition frequently observed in diabetic patients [4]. Unlike atherosclerosis, which primarily affects the intima of arteries, MAC is characterized by calcium deposition in the medial layer, leading to non-compressible arteries and falsely elevated ABI values [5]. Recent evidence suggests that individuals with a high ABI have an increased predominance of cardiovascular risk factors, including hypertension, dyslipidemia, and chronic kidney disease [6]. Furthermore, even in the absence of clinical PAD, an increased ABI has been linked to detrimental cardiovascular outcomes, including as myocardial infarction and stroke [7].

The predominance of high ABI in diabetic populations varies, with studies reporting rates ranging from 15% to 30% depending on ethnicity, disease duration, and comorbidities [8]. A systematic review highlighted that patients with T2DM and a high ABI are at a significantly increased risk of cardiovascular mortality compared to those with normal ABI values [9]. Despite this growing body of evidence, high ABI remains underrecognized in clinical practice, and its implications for cardiovascular risk stratification are not well understood.

Given the increasing burden of diabetes-related vascular complications in India, there is a need to evaluate the clinical significance of high ABI in the Indian diabetic population. This study aims to assess the predominance of high ABI in patients with T2DM and its correlation with cardiovascular and peripheral arterial disease. Understanding these relationships could help improve early detection strategies and optimize risk management in diabetic patients. The purpose of this study is to determine how often high ABI is in T2DM patients and how it relates to peripheral arterial and cardiovascular disease. To evaluate the correlation between high ABI values and the predominance of cardiovascular and peripheral arterial disease in patients with T2DM.

Methodology

Study Design: This study was a prospective cross-sectional study conducted at Patna Medical College and Hospital (PMCH), Patna, from June 2023 to May 2024.

Study Setting: The study was conducted in the outpatient and inpatient departments of PMCH, a tertiary care center specializing in diabetes and cardiovascular care.

Study Population: A total of 110 patients diagnosed with (T2DM) were enrolled based on predefined inclusion and exclusion criteria.

Inclusion Criteria:

- Patients diagnosed with T2DM.
- Age above 40 years.
- Willingness to participate with informed consent.

Exclusion Criteria:

- Patients with Type 1 Diabetes Mellitus.
- Patients with severe infections, acute illnesses, or active malignancies.
- History of lower limb amputation.
- Patients with chronic kidney disease on dialysis.
- Individuals with non-compressible arteries (ABI >1.40).

Data Collection: Demographic data, medical history, and clinical parameters were collected using a structured data collection form. The (ABI) was measured using a handheld Doppler device, with readings taken from both arms and both ankles. Laboratory tests, including HbA1c levels and lipid profiles, were conducted to assess glycemic control and lipid abnormalities.

Procedure: Each participant underwent a comprehensive clinical examination, which included measuring blood pressure in both upper and lower limbs using Doppler ultrasonography. The ABI was calculated by dividing the highest ankle systolic pressure by the highest brachial systolic pressure.

Based on the ABI values, participants were classified into three categories:

- **High ABI (>1.30)** — Indicating arterial stiffness.
- **Normal ABI (0.91–1.30)** — Considered normal vascular health.
- **Low ABI (<0.90)** — Suggestive of peripheral arterial disease (PAD).

Bias Reduction: Selection bias was minimized by recruiting participants consecutively from both outpatient and inpatient settings. Measurement bias was mitigated by ensuring standardized equipment and procedures were consistently used. Confounding variables such as age, smoking status, and duration of diabetes were adjusted for during statistical analysis.

Statistical Analysis: Data were analyzed using SPSS version 23.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. The independent t-test or Mann-Whitney U test was applied for continuous variables, and the chi-square test was used for categorical variables. A p-value <0.05 was considered statistically significant. Regression analysis was performed to identify independent predictors of high ABI.

Results

A total of 110 patients with (T2DM) were enrolled in this prospective study. The mean age of participants was 58.4 ± 8.2 years, with a slight male predominance (60 males, 54.5%) compared to females (50 females, 45.5%). The average duration of diabetes was 9.6 ± 3.1 years, with a significant proportion of patients having hypertension (65.5%) and dyslipidemia (61.8%). Additionally, 36.4% of the participants had a history of smoking, a known risk factor for vascular diseases.

Table 1: Baseline Characteristics of Study Participants

Variable	Mean ± SD / N (%)
Age (years)	58.4 ± 8.2
Male	60 (54.5%)
Female	50 (45.5%)
Duration of Diabetes (years)	9.6 ± 3.1
Hypertension	72 (65.5%)
Dyslipidemia	68 (61.8%)
Smoking History	40 (36.4%)
BMI (kg/m²)	27.2 ± 3.5
HbA1c (%)	7.9 ± 1.4

The ABI values were categorized into three groups:

- **Normal ABI (0.9–1.3):** 72 patients (65.5%)
- **Low ABI (<0.9, indicating PAD):** 20 patients (18.2%)
- **High ABI (>1.3, indicating arterial stiffness and increased cardiovascular risk):** 18 patients (16.4%)

The results demonstrated a significant number of patients with abnormal ABI values (both high and low), highlighting the predominance of vascular complications in T2DM.

Table 2: Distribution of ABI Values among Participants

ABI Category	N (%)
Normal (0.9 – 1.3)	72 (65.5%)
Low ABI (<0.9)	20 (18.2%)
High ABI (>1.3)	18 (16.4%)

The study revealed that participants with high ABI values (>1.3) had a 77.8% predominance of (CVD), significantly higher compared to 29.2% in the normal ABI group. Conversely, 100% of participants with low ABI values (<0.9) were found to have disease (PAD). This finding confirms the predictive value of ABI in detecting arterial disease in patients with T2DM.

Table 3: Predominance of CVD and PAD According to ABI Categories

ABI Category	CVD Cases (N, %)	PAD Cases (N, %)
Normal (0.9 – 1.3)	21 (29.2%)	0 (0%)
Low ABI (<0.9)	5 (25.0%)	20 (100%)
High ABI (>1.3)	14 (77.8%)	0 (0%)

Higher HbA1c levels were significantly associated with abnormal ABI values. Patients with high ABI (>1.3) had the highest mean HbA1c (8.5 ± 1.2%), indicating poor glycemic control and its potential contribution to arterial stiffness. This was statistically significant compared to the normal ABI group (7.6 ± 1.3%, p = 0.02).

Table 4: Glycemic Control Across ABI Categories

ABI Category	HbA1c (%) (Mean ± SD)
Normal (0.9 – 1.3)	7.6 ± 1.3
Low ABI (<0.9)	8.1 ± 1.1
High ABI (>1.3)	8.5 ± 1.2
p-value	**0.02** (Significant)

Dyslipidemia was notably higher in patients with abnormal ABI values. Patients with high ABI values showed significantly higher total cholesterol (p = 0.01) and LDL levels (p = 0.03) compared to the normal ABI group.

Table 5: Lipid Profile of Participants Based on ABI Values

Lipid Parameter	Normal ABI (Mean ± SD)	Low ABI (Mean ± SD)	High ABI (Mean ± SD)	p-value
Total Cholesterol (mg/dL)	192.4 ± 35.1	201.6 ± 38.3	218.2 ± 40.5	0.01
LDL (mg/dL)	115.7 ± 28.9	123.2 ± 30.1	135.5 ± 32.4	0.03
HDL (mg/dL)	45.2 ± 9.1	42.7 ± 8.8	41.3 ± 8.5	0.15
Triglycerides (mg/dL)	156.8 ± 45.2	162.1 ± 48.6	171.5 ± 50.8	0.12

Blood pressure parameters were significantly elevated in the high ABI group, indicating a relationship between hypertension and arterial stiffness. Systolic blood pressure (SBP) was highest in the high ABI group (142.8 ± 16.5 mmHg) compared to the normal ABI group (128.6 ± 14.2 mmHg, p = 0.02).

Table 6: Blood Pressure Across ABI Categories

Blood Pressure (mmHg)	Normal ABI (Mean ± SD)	Low ABI (Mean ± SD)	High ABI (Mean ± SD)	p-value
Systolic BP	128.6 ± 14.2	135.3 ± 15.1	142.8 ± 16.5	0.02
Diastolic BP	78.2 ± 9.8	80.5 ± 10.2	83.1 ± 11.0	0.07

Key Findings:

1. High ABI (>1.3) was present in 16.4% of participants and was significantly associated with higher predominance of cardiovascular disease (77.8%).
2. Low ABI (<0.9) indicating peripheral arterial disease (PAD) was seen in 18.2% of participants, with all 100% of PAD cases falling in this category.
3. Poor glycemic control, reflected by higher HbA1c values (8.5 ± 1.2%), was significantly associated with high ABI values.
4. Dyslipidemia and hypertension were also significantly correlated with abnormal ABI values, suggesting a complex interplay between metabolic and vascular health.

Discussion

This prospective study evaluated 110 patients with (T2DM). The findings demonstrated a substantial predominance of abnormal ABI values, with 16.4% of participants exhibiting high ABI (>1.3), indicative of arterial stiffness, and 18.2% showing low ABI (<0.9), suggestive of PAD. This indicates that nearly one-third of the study population had significant vascular abnormalities, underscoring the burden of subclinical vascular disease in patients with T2DM.

Participants with high ABI values had a 77.8% predominance of CVD, significantly higher compared to 29.2% in the normal ABI group. This suggests that arterial stiffness, as reflected by high ABI, is strongly associated with cardiovascular complications in diabetic patients. In contrast, 100% of PAD cases were found in the low ABI group, confirming the well-established role of low ABI in detecting peripheral arterial disease. These findings reinforce the importance of ABI as a non-invasive, cost-effective tool to identify patients at high risk of vascular complications.

The study also highlighted the relationship between glycemic control and vascular health. Patients with high ABI values had significantly higher HbA1c levels (8.5 ± 1.2%) compared to the normal ABI group (7.6 ± 1.3%, p = 0.02). Poor glycemic control is known to promote vascular stiffness through mechanisms such as endothelial dysfunction, oxidative stress, and inflammation, which may explain the increased arterial stiffness in these patients.

Additionally, lipid profile parameters demonstrated significant differences. Patients with high ABI values had significantly higher total cholesterol (218.2 ± 40.5 mg/dL, p = 0.01) and LDL cholesterol (135.5 ± 32.4 mg/dL, p = 0.03), indicating that dyslipidemia plays a crucial role in the development of vascular complications. This suggests that aggressive lipid management might mitigate the progression of arterial stiffness and subsequent cardiovascular events.

Blood pressure analysis showed that systolic blood pressure (SBP) was significantly higher in the high ABI group (142.8 ± 16.5 mmHg, p = 0.02). Elevated blood pressure is known to increase arterial wall tension, which may lead to arterial stiffening over time. This finding highlights the importance of blood pressure control in preventing vascular complications in diabetic patients.

In conclusion, this study provides compelling evidence that high ABI values are strongly associated with cardiovascular risk in T2DM patients, while low ABI values are indicative of peripheral arterial disease. These results underscore the importance of routine ABI measurement in the diabetic population for early detection and risk stratification of vascular complications.

Furthermore, poor glycemic control, dyslipidemia, and hypertension were identified as modifiable risk factors, emphasizing the need for comprehensive management to reduce vascular morbidity and mortality in this high-risk group.

Several recent studies have explored the correliation between a high (ABI) and the risk of (CVD) and (PAD) in patients with (T2DM). A study by Kumar & Prakash (2024) found that an elevated ABI in T2DM patients was associated with a 28% increase in PAD, a 33% increase in CVD, and a 40% increase in major adverse cardiovascular events (MACE), highlighting ABI as a crucial predictive tool in managing cardiovascular risk [10]. Similarly, Felício et al. (2019) examined ABI in drug-naïve T2DM patients and found that nearly 39% had peripheral arterial disease, reinforcing the need for ABI screening at the time of diabetes diagnosis [11].

In a geographically specific study, Koufopoulos et al. (2019) found that ABI >1.30 was significantly more prevalent in diabetic individuals, particularly those with a longer disease duration. The study reported that 44% of T2DM patients exhibited a high ABI compared to only 3.1% in the non-diabetic group, suggesting a strong correlation between diabetes progression and vascular abnormalities [12]. Meanwhile, Ugwu et al. (2021) validated ABI as a surrogate for vascular imaging in diagnosing PAD in diabetic individuals. Their findings showed ABI had high sensitivity and specificity for detecting moderate to severe arterial stenosis, emphasizing its clinical utility in resource-limited settings [13].

ABI has been connected to inflammatory and metabolic markers in diabetes in addition to its function in diagnosing PAD. According to Depczynski et al. (2018), patients with a high ABI had lower vitamin D levels, a higher waist-to-height ratio, and a higher body mass index (BMI). ABI's predictive relevance in diabetes care was further highlighted by the patients' elevated risk of diabetic foot problems, including amputations [14].

Conclusion

This study highlights the significant correlation between high Ankle–Brachial Index (ABI) values and an increased risk of cardiovascular disease, while low ABI values were linked to peripheral arterial disease in patients with Type 2 Diabetes Mellitus. Poor glycemic control, dyslipidemia, and hypertension emerged as key modifiable risk factors contributing to vascular complications. Routine ABI measurement can serve as a valuable tool for early detection and risk stratification, emphasizing the importance of comprehensive metabolic management to reduce cardiovascular and peripheral arterial disease burden in this high-risk population.

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