

Diagnostic Accuracy of Stethoscope-Measured Ankle-Brachial Pressure Index for Early Detection of Peripheral Occlusive Vascular Disease in Asymptomatic Diabetic Patients: A Comparative Study with Doppler Ultrasonography

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ABSTRACT

Background: Peripheral occlusive vascular disease is a common yet underdiagnosed complication of diabetes mellitus and is associated with significant morbidity, including limb loss and cardiovascular events. Although Doppler ultrasonography is the standard diagnostic modality, its availability is limited in many primary healthcare settings. The ABPI (Ankle-Brachial Pressure Index) measured using a stethoscope may provide a simple, inexpensive, and accessible alternative for screening.

Methods: A cross-sectional diagnostic test evaluation was conducted among 106 diabetic patients without clinical features of (Peripheral Occlusive Vascular Disease) POVD attending a tertiary care center in Kerala. Stethoscope-measured ABPI served as the index test, while Doppler ultrasonography was used as the reference standard. ABPI values were compared with Doppler findings to determine sensitivity, specificity, PPV (Positive Predictive Value), NPV (Negative Predictive Value), diagnostic accuracy, and area under the receiver operating characteristic curve.

Results: The mean age of participants was 61.8 ± 10.5 years, with an almost equal gender distribution. Doppler ultrasonography identified POVD in 48.1% of patients. Doppler waveforms were triphasic in 51.9%, biphasic in 26.4%, and monophasic in 21.7% of participants. Stethoscope-measured ABPI demonstrated excellent diagnostic performance with an AUC of 0.879 ($p < 0.01$). An optimal ABPI cut-off value of 0.94 yielded a sensitivity of 78.4%, specificity of 100%, PPV of 100%, NPV of 83.3%, and overall diagnostic accuracy of 89.6%. Longer duration of diabetes ($p = 0.005$) and smoking ($p = 0.003$) were significantly associated with POVD.

Conclusion: Nearly half of asymptomatic diabetic patients had subclinical POVD. Stethoscope-measured ABPI demonstrated high specificity and good overall diagnostic accuracy, making it a practical, cost-effective screening tool for early detection of POVD, particularly in resource-limited settings. Doppler confirmation is recommended for borderline or negative cases with high clinical suspicion.

Keywords: Peripheral Occlusive Vascular Disease, Ankle-Brachial Pressure Index, Doppler Ultrasonography, Diabetes Mellitus, Peripheral Arterial Disease, Diagnostic Accuracy, Screening, Vascular Disease.

INTRODUCTION

Peripheral occlusive vascular disease, a manifestation of systemic atherosclerosis affecting the arteries of the lower limbs, is a

significant yet underdiagnosed public health problem. Globally, an estimated 236.62 million individuals aged over 25 years were affected by POVD in 2015, with nearly one-third of

cases occurring in low- and middle-income countries.^[1] Despite its high prevalence, the disease remains under-recognized and undertreated, resulting in considerable morbidity and mortality.^[2] In India, where the burden of diabetes and cardiovascular disease is rapidly increasing, POVD is expected to emerge as a major healthcare challenge.^[3]

POVD shares common risk factors with atherosclerotic cardiovascular disease, including advancing age, male gender, smoking, diabetes mellitus, hypertension, and hyperlipidemia.^[2,4] It is strongly associated with systemic atherosclerosis and is considered a coronary artery disease equivalent. Patients with peripheral arterial occlusive disease have a threefold higher risk of all-cause mortality and a sixfold higher risk of cardiovascular mortality compared to unaffected individuals.^[5-7]

The diagnosis of POVD is often delayed because clinical manifestations vary widely. Intermittent claudication, the classical symptom, occurs in only 10% of patients, while nearly 40% remain asymptomatic.^[8,9] Consequently, only about one-quarter of affected individuals receive timely diagnosis and treatment.^[10] This challenge is particularly important in patients with type 2 diabetes mellitus, who have up to a 20-fold increased risk of developing lower extremity POVD and experience higher rates of amputation and mortality.^[11] Early detection is therefore essential, as 40–50% of diabetes-related amputations may be preventable.

The ABPI (Ankle–Brachial Pressure Index) is a simple, reliable, and non-invasive tool for diagnosing POVD and assessing cardiovascular risk.^[8] Traditionally, ABPI measurement requires Doppler ultrasonography, which may not be readily available in primary care and resource-limited settings. A stethoscope-based method offers a potentially accessible and cost-effective alternative; however, evidence regarding its diagnostic accuracy remains limited.

AIMS AND OBJECTIVES

The present study aims to evaluate the diagnostic accuracy of stethoscope-measured ABPI for the identification of POVD in diabetic patients without clinical features of the disease, using Doppler ultrasonography as the reference standard in a tertiary care center in Kerala. Additionally, the study seeks to estimate the prevalence of peripheral occlusive

vascular disease among the diabetic population and assess the potential utility of stethoscope-measured ABPI as a simple, cost-effective, and non-invasive screening tool for early detection of POVD.

MATERIALS AND METHODS

Study Design

This study was conducted as a cross-sectional diagnostic test evaluation in the Department of General Surgery, Government Medical College Hospital, Thiruvananthapuram, Kerala. The study was carried out over a period of 18 months following approval from the HEC (Human Ethics Committee). The study population comprised diabetic patients attending the inpatient and outpatient services of the Department of General Surgery. Eligible participants were recruited consecutively and evaluated to determine the diagnostic accuracy of stethoscope-measured ABPI for the detection of POVD, using Doppler ultrasonography as the reference standard.

Inclusion and Exclusion Criteria

The study included known diabetic patients attending the Department of General Surgery who had no clinical signs or symptoms suggestive of PAOD (Peripheral Arterial Occlusive Disease). Patients were excluded if they had symptomatic POVD, including intermittent claudication, rest pain, or absent distal pulses on clinical examination. Patients presenting with foot ulcers, gangrenous changes of the lower limbs, or those unwilling to provide informed consent for participation in the study were also excluded.

Sample Size Calculation

The sample size was calculated using the formula

$$n = (Z_{1-\alpha/2})^2 pq/d^2$$

$$Z_{1-\alpha/2} = 1.96$$

$$n \approx 4pq/d^2$$

p = sensitivity of ABPI measurement by stethoscope in diagnosing POVD (by reference study^[12])

$$p = 71.4^{[12]}$$

$$q = 100 - p$$

d = Relative precision

$$20\% \text{ of } p = 20/100 \times 71.4$$

$$= 14.2$$

$$n = (1.96)^2 \times 71.4 \times (100 - 71.4) \div (20/100 \times 71.4)^2$$

$$= 38.4$$

Since diabetic patients were taken as the study population

Sample size $N = n \div \text{prevalence of POVD in diabetic population in the geographical region of study (according to reference study}^{[13]} \times 100$

$N = 38.4 \times 100 \div 36^{13}$

$= 105.556$

$= 106$

Data Collection Procedure

Data was collected using a pretested proforma, stethoscope, and sphygmomanometer. After explaining the purpose and rationale of the study, written informed consent was obtained from all eligible participants. The study included diabetic patients without clinical features of POVD who had undergone Doppler ultrasonography of the lower limb arteries as part of their routine evaluation. Doppler findings were obtained from the Department of Radiodiagnosis, Government Medical College, Thiruvananthapuram, and served as the reference (gold standard) test, while stethoscope-measured ABPI was used as the index test. ABPI measurements were performed by an investigator blinded to the Doppler results, with the patient in the supine position. Blood pressure cuffs were placed above the antecubital fossa and medial malleolus for brachial and ankle pressure measurements, respectively. Using a stethoscope, systolic pressures were recorded

based on Korotkoff sounds, and the ankle systolic pressure at the posterior tibial artery was divided by the brachial systolic pressure to calculate the ABPI. For increased accuracy, the highest systolic pressure obtained from the posterior tibial and dorsalis pedis arteries in both lower limbs was divided by the highest brachial systolic pressure, and the lowest resulting value was considered the patient's overall ABPI. An ABPI value of less than 0.9 was considered indicative of peripheral arterial disease.

Statistical Analysis

Categorical variables were expressed as frequency and percentage, while quantitative variables were presented as mean $\pm$ standard deviation (SD). Descriptive statistics including mean $\pm$ SD, median with IQR (Interquartile Range), minimum, and maximum values were used to summarize ABPI measurements. ROC (Receiver Operating Characteristic) curve analysis was performed to evaluate the diagnostic accuracy of ABPI in detecting POVD, and the area under the curve was calculated. Sensitivity, specificity, PPV (Positive Predictive Value), NPV (Negative Predictive Value), and overall accuracy were determined. Associations between categorical variables were assessed using the chi-square test. A p-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS software version 20.0.

RESULTS

Variable	Category	n (%)
Age	<50 years	15 (14.2)
	50–59 years	31 (29.2)
	60–69 years	39 (36.8)
	≥ 70 years	21 (19.8)
Sex	Male	52 (49.1)
	Female	54 (50.9)
Family History of Diabetes	Present	54 (50.9)
	Absent	52 (49.1)
Duration of Diabetes	1–5 years	27 (25.5)
	6–10 years	37 (34.9)
	11–15 years	24 (22.6)
	15–20 years	10 (9.4)
	>20 years	8 (7.5)

Table 1: Baseline Characteristics of Study Participants (n=106)

Table 1 presents the baseline demographic and diabetic characteristics of the study population. The mean age was 61.8 ± 10.5 years, with most participants belonging to the 60–69-year age group. Gender distribution was nearly equal. Approximately

half of the participants had a positive family history of diabetes. The majority had diabetes for 6–10 years, while nearly 40% had diabetes for more than 10 years, indicating a population at high risk for vascular complications.

Variable	Category	n (%)
Medication Type	OHA	50 (47.2)
	Insulin	25 (23.6)
	Both	19 (17.9)
	Diet only	12 (11.3)
Medication Adherence	Regular	59 (55.7)
	Irregular	36 (34.0)
	Nil	11 (10.4)
Hypertension	Present	64 (60.4)
Dyslipidemia	Present	41 (38.7)
CAD	Present	17 (16.0)
Smoking	Yes	26 (24.5)
Alcohol Consumption	Yes	15 (14.2)

Table 2: Treatment Profile, Comorbidities and Lifestyle Factors

Table 2 summarizes treatment patterns, comorbid conditions, and lifestyle factors among diabetic patients. Oral hypoglycemic agents were the most commonly used treatment. Hypertension was the

predominant co-morbidity, followed by dyslipidemia. Nearly one-fourth of participants were smokers, representing an important modifiable risk factor for peripheral vascular disease.

Parameter	Lower Limb SBP	Upper Limb SBP
Mean $\pm$ SD	141.1 $\pm$ 10.1	146.3 $\pm$ 10.1
Median (IQR)	140 (135–150)	145 (140–155)
Minimum	110	120
Maximum	165	170

Table 3: Stethoscope-Measured Systolic Blood Pressure Parameters

Table 3 describes systolic blood pressure measurements used for ABPI calculation. Upper limb systolic pressures were

slightly higher than lower limb pressures, forming the basis for ABPI determination.

Parameter	Value
Mean $\pm$ SD	0.94 $\pm$ 0.14
Median (IQR)	0.96 (0.85–0.97)
Minimum	0.68
Maximum	1.30

Table 4: Distribution of Ankle-Brachial Pressure Index

Table 4 presents the descriptive statistics of ABPI values. The mean ABPI was 0.94 $\pm$ 0.14. ROC analysis identified an ABPI

value of 0.94 as the optimal threshold for identifying peripheral occlusive vascular disease.

Doppler Waveform	n	%
Monophasic	23	21.7
Biphasic	28	26.4
Triphasic	55	51.9

Table 5: Doppler Ultrasonography Findings

Table 5 demonstrates Doppler waveform characteristics among the study participants. Triphasic flow was observed in approximately half of the patients, whereas

monophasic and biphasic waveforms, indicative of arterial disease, were present in 48.1% of participants.

POVD Status	n	%
Present	51	48.1
Absent	55	51.9

Table 6: Prevalence of Peripheral Occlusive Vascular Disease

Table 6 depicts the prevalence of peripheral occlusive vascular disease among asymptomatic diabetic patients. Nearly half of

the participants were diagnosed with POVD, emphasizing the substantial burden of subclinical vascular disease in this population.

Parameter	Value
Sensitivity (%)	78.4
Specificity (%)	100.0
Positive Predictive Value (%)	100.0
Negative Predictive Value (%)	83.3
False Positive Rate (%)	0.0
False Negative Rate (%)	21.6
Negative Likelihood Ratio	0.2
Accuracy (%)	89.6
AUC (ROC)	0.879
Optimal Cut-off	0.94

Table 7: Diagnostic Accuracy of Stethoscope-Measured ABPI

Table 7 highlights the diagnostic performance of stethoscope-measured ABPI when compared with Doppler ultrasonography. The test demonstrated excellent specificity and

high overall accuracy. The area under the ROC curve of 0.879 indicates good discriminatory ability, supporting the usefulness of ABPI as a screening tool for POVD in diabetic patients.

Variable	POVD Present n (%)	χ^2	p-value
Age $\geq$ 60 years	33 (55.0)	2.63	0.105
Diabetes Duration >10 years	26 (61.9)	10.61	0.005*
Family History Present	27 (50.0)	0.16	0.692
Smoking Present	19 (73.1)	8.60	0.003*

Table 8: Association of Peripheral Occlusive Vascular Disease with Selected Variables

*Statistically Significant ($p < 0.05$)

Table 8 evaluates factors associated with peripheral occlusive vascular disease. A significant association was observed between POVD and the longer duration of diabetes as well as smoking status. Although older age showed a higher prevalence of disease, the association was not statistically significant. Family history of diabetes was not associated with the occurrence of POVD.

DISCUSSION

The present study was conducted to evaluate the diagnostic accuracy of stethoscope-measured ABPI for identifying POVD in diabetic patients without clinical features of the disease, using Doppler ultrasonography as the reference standard. In addition, the prevalence of subclinical POVD and its associated risk factors were assessed.

Demographic Characteristics

The mean age of participants in the present study was 61.8 ± 10.5 years, and the majority (36.8%) belonged to the 60–69-year age group. This finding is comparable to the study

by Premalatha et al.,^[14] who reported a higher prevalence of peripheral arterial disease among older diabetic patients. Similarly, Gupta et al.,^[15] observed that increasing age was associated with a greater burden of peripheral vascular disease among diabetic individuals. The predominance of older age groups in the present study may be explained by the progressive nature of atherosclerosis and the cumulative vascular damage caused by long-standing diabetes.

The gender distribution in the present study was nearly equal, with 49.1% males and 50.9% females. This differs from several previous studies where male predominance was observed. Gupta et al.,^[15] reported a higher proportion of male participants, while Premalatha et al.,^[14] also found a greater prevalence of peripheral vascular disease among males. The balanced gender representation in the present study improves the generalizability of the findings across both sexes.

Duration of Diabetes Mellitus

The mean duration of diabetes was 10.3 ± 6.7 years, and nearly 40% of participants had diabetes for more than 10 years. This finding is clinically important because prolonged exposure to hyperglycemia contributes to endothelial dysfunction, vascular inflammation, and accelerated atherosclerosis.

A statistically significant association was observed between diabetes duration and POVD ($p = 0.005$). Patients with diabetes duration greater than 10 years had a markedly higher prevalence of POVD (61.9%) compared with those having diabetes for less than five years (22.2%). Similar findings were reported by Premalatha et al.,^[14] who demonstrated that longer duration of diabetes was associated with increased peripheral arterial disease. Thulasikumaret al.,^[16] also reported that diabetic patients with disease duration exceeding ten years had significantly higher rates of peripheral arterial disease.

Family History of Diabetes

In the present study, 50.9% of participants had a positive family history of diabetes. However, family history was not significantly associated with POVD ($p=0.692$). This finding suggests that while genetic predisposition contributes to the development of diabetes mellitus, the occurrence of vascular complications appears to be more strongly influenced by acquired risk factors such as smoking, hypertension, dyslipidemia, and duration of diabetes. Similar observations have been reported in previous studies where family history influenced diabetes occurrence but not peripheral vascular complications.^[15]

Medication Profile and Adherence

Oral hypoglycemic agents constituted the most common treatment modality (47.2%), followed by insulin therapy (23.6%). More than half of the participants (55.7%) reported regular medication adherence. Adequate glycemic control has been shown to reduce the progression of microvascular and macrovascular complications in diabetic patients. Poor adherence observed among a significant proportion of participants may contribute to the development of vascular complications, including POVD.

Comorbidities

Hypertension was the most common comorbidity in the present study (60.4%), followed by dyslipidemia (38.7%) and coronary artery disease (16%). These findings

are consistent with those reported by Gupta et al.,^[15] who identified hypertension and dyslipidemia as the most prevalent comorbid conditions among diabetic patients with peripheral arterial disease.

The coexistence of hypertension and diabetes accelerates endothelial injury and promotes atherosclerotic plaque formation. Dyslipidemia further contributes to vascular narrowing through lipid deposition within arterial walls. These mechanisms explain the high prevalence of vascular disease observed in diabetic populations.

Lifestyle Factors

Smoking was reported by 24.5% of participants. A highly significant association was observed between smoking and POVD ($p = 0.003$). Among smokers, 73.1% had POVD compared to only 40% of non-smokers. This finding strongly supports the established role of smoking as an independent risk factor for peripheral arterial disease.

The present findings are consistent with those of Premalatha et al.,^[14] who also reported significantly higher rates of peripheral arterial disease among smokers. Smoking contributes to endothelial dysfunction, oxidative stress, platelet aggregation, and reduced nitric oxide availability, thereby accelerating arterial occlusion.

Alcohol consumption was reported by 14.2% of participants. Although alcohol intake was documented, its association with POVD was not specifically analyzed in the present study.

Stethoscope-Measured ABPI

The mean ABPI observed in the present study was 0.94 ± 0.14 . ROC (Receiver Operating Characteristic) analysis identified an optimal cut-off value of 0.94 for detecting POVD. Traditionally, an ABPI value below 0.90 is considered diagnostic of peripheral arterial disease. However, diabetic patients frequently exhibit arterial calcification and reduced arterial compressibility, which may lead to falsely elevated ABPI values. Therefore, the slightly higher cut-off identified in the present study appears reasonable in this diabetic population.

The findings are supported by the recommendations of Aboyans et al.,^[17] who emphasized that interpretation of ABPI in diabetic individuals requires caution because medial arterial calcification may affect diagnostic accuracy.

Doppler Ultrasonography Findings

Doppler ultrasonography demonstrated triphasic waveforms in 51.9% of participants, biphasic waveforms in 26.4%, and monophasic waveforms in 21.7%. Monophasic and biphasic waveforms are generally considered indicative of arterial disease.

These findings indicate that almost half of the study population exhibited abnormal arterial flow patterns despite the absence of clinical symptoms. This observation highlights the importance of screening asymptomatic diabetic individuals for peripheral vascular disease.

Prevalence of Peripheral Occlusive Vascular Disease

The prevalence of POVD in the present study was 48.1%. This prevalence is higher than the 10–42% prevalence range reported in many diabetic populations and reflects the substantial burden of subclinical disease among asymptomatic diabetic patients.

Premalatha et al.,^[14] reported a prevalence of approximately 36% among diabetic patients using ABI and duplex ultrasound. Similarly, Gupta et al.,^[15] demonstrated a significant prevalence of peripheral arterial disease among diabetic individuals. The higher prevalence observed in the present study may be due to the inclusion of older patients with longer duration of diabetes and multiple cardiovascular risk factors.

Diagnostic Accuracy of Stethoscope-Measured ABPI

The most important finding of the present study is the demonstration of good diagnostic accuracy of stethoscope-measured ABPI.

The ROC analysis showed an AUC of 0.879 (95% CI: 0.805–0.953; $p < 0.01$), indicating good discriminatory ability. The sensitivity was 78.4%, specificity was 100%, positive predictive value was 100%, negative predictive value was 83.3%, and overall accuracy was 89.6%.

These findings compare favourably with the pilot study conducted by Carmo et al.,^[12] who reported a sensitivity of 71.4%, specificity of 91%, PPV of 62.5%, and NPV of 93.8% for stethoscope-measured ABI. The present study demonstrated higher specificity and overall accuracy, suggesting that stethoscope-based ABPI measurement can serve as an effective screening tool in resource-limited settings.

Takahashi et al.,^[18] reported that the auscultatory method was useful for excluding peripheral arterial disease but had limitations in confirming disease presence. In contrast, the present study demonstrated excellent specificity and PPV, indicating that a positive test result strongly predicts true disease.

Similarly, Gupta et al.,^[15] reported sensitivity and specificity values of 92.5% and 88.3%, respectively, for ABI compared with Doppler ultrasonography. Although the sensitivity observed in the present study was lower, the specificity was substantially higher, resulting in excellent overall diagnostic performance.

Factors Associated with POVD

Age showed a higher prevalence of POVD among participants aged 60 years or older; however, the association was not statistically significant ($p = 0.105$). Similar observations have been reported by previous studies where age acted as a contributory rather than an independent predictor of peripheral arterial disease.

The strongest predictors of POVD in the present study were longer duration of diabetes and smoking. These findings are biologically plausible and consistent with existing literature, which identifies chronic hyperglycaemia and tobacco exposure as major contributors to vascular damage and atherosclerosis.

The findings of the present study support the use of stethoscope-measured ABPI as a simple, inexpensive, and reliable screening tool for identifying asymptomatic peripheral occlusive vascular disease among diabetic patients, particularly in primary care and resource-constrained settings where Doppler ultrasonography may not be readily available.

LIMITATIONS

This study was conducted in a single tertiary care center with a relatively limited sample size, which may restrict the generalizability of the findings. ABPI measurement using a stethoscope is operator-dependent and may be affected by interobserver variability. Although ABPI demonstrated high specificity and overall accuracy, its moderate negative predictive value suggests that some cases of POVD may be missed, warranting Doppler confirmation in selected patients. Further multicenter studies with larger and more

diverse populations are needed to validate these findings.

CONCLUSION

The present study demonstrated that stethoscope-measured ABPI is a simple, cost-effective, and reliable screening tool for detecting POVD in diabetic patients without clinical symptoms. With high specificity (100%) and good overall diagnostic accuracy (89.6%), ABPI can be effectively utilized in primary care and resource-limited settings for early identification of POVD. The high prevalence of subclinical POVD (48.1%) observed in this study highlights the importance of routine screening among diabetic patients, particularly those with prolonged duration of diabetes and a history of smoking. However, Doppler ultrasonography remains essential for confirmation in selected cases, and further large-scale multicentric studies are recommended to validate these findings.

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