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Original Article

Lower Limb Peripheral Artery Disease Assessment via Ankle Brachial Index and CT Angiography

Shiza Hussain[2], Waleed Abdullah[2], Shaher Bano[2], Syeda Tazmeen Batool[2], Ushna Gul[2], Maham Khalid[3], Tamsal Hameed[1]*, Qurat ul Ain[1]

[1] Department of Medical Imaging, University of Management and Technology, Lahore, Pakistan
[2] BS in Medical Imaging and Ultrasonography, University of Management and Technology, Lahore, Pakistan
[3] Department of Clinical Services, University of Management and Technology, Lahore, Pakistan

*Corresponding author: Tamsal Hameed, tamsalhameed979@gmail.com

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ABSTRACT

Background: Peripheral arterial disease is common among patients with type 2 diabetes mellitus and may be difficult to assess because arterial calcification can alter ankle-brachial index interpretation. Objective: To determine the association between ankle-brachial index categories and CT angiographic findings in patients with suspected lower-limb peripheral arterial disease. Methods: This single-center cross-sectional observational study included 45 patients with type 2 diabetes mellitus and suspected lower-limb peripheral arterial disease. Demographic characteristics, cardiovascular risk factors, symptoms, limb involvement, ABI values, and CTA findings were recorded. CTA findings included arterial segment involvement, stenosis severity, and calcification. Associations between ABI category and CTA findings were analyzed using chi-square testing. Results: The study included 25 males and 20 females, with 62.2% aged 60 years or above. Bilateral limb involvement was present in 18 patients. Peroneal artery involvement was the most frequent CTA finding (44.4%), followed by tibial artery involvement (42.2%). ABI-defined PAD was significantly associated with CTA stenosis severity; 7 patients had mild stenosis, 15 had moderate stenosis, and 19 had severe or occlusive disease, while all 4 patients with ABI 0.90–1.30 had mild stenosis only (χ^2=13.570, p=0.001). Non-compressible ABI was strongly associated with CTA-detected calcification (χ^2=35.837, p<0.001). Conclusion: ABI is useful for functional screening of lower-limb PAD, but CTA provides essential anatomical confirmation, particularly in diabetic patients with non-compressible ABI and suspected calcification. Keywords: Peripheral arterial disease; ankle-brachial index; CT angiography; type 2 diabetes mellitus; arterial calcification; lower-limb ischemia.

INTRODUCTION

Peripheral arterial disease is a progressive atherosclerotic disorder characterized by partial or complete obstruction of peripheral arteries, most commonly affecting the lower limbs. Reduced arterial perfusion may remain clinically silent in early stages, but progressive disease can lead to intermittent claudication, rest pain, tissue loss, ulceration, gangrene, impaired mobility, and increased cardiovascular morbidity. The global burden of peripheral arterial disease has increased substantially, particularly among older adults and individuals with cardiometabolic risk factors. Diabetes mellitus, hypertension, dyslipidemia, smoking, chronic kidney disease, and generalized atherosclerotic disease are among the principal contributors to lower-limb arterial narrowing and occlusion. In patients with type 2 diabetes mellitus, peripheral arterial disease is especially important because vascular dysfunction, neuropathy, endothelial injury, and accelerated atherosclerosis may delay symptom recognition while increasing the risk of severe limb-threatening complications (1–4).

Early diagnosis of peripheral arterial disease is clinically important because timely identification allows risk-factor modification, pharmacological management, structured exercise therapy, vascular referral, and revascularization planning where indicated. However, diagnosis in diabetic patients can be challenging. Many patients remain asymptomatic or present with atypical symptoms, while coexisting neuropathy may reduce pain perception and delay clinical suspicion. Physical examination and pulse assessment alone may miss disease, particularly in patients with multilevel arterial involvement. Therefore, objective vascular assessment is required to determine the presence and severity of disease and to guide further imaging or intervention (5–7).

The ankle-brachial index is widely used as a simple, inexpensive, and non-invasive first-line test for suspected lower-limb peripheral arterial disease. It compares systolic ankle pressure with brachial systolic pressure, and values below 0.90 are generally considered suggestive of peripheral arterial disease. Lower values usually indicate more severe impairment of limb perfusion. Nevertheless, ABI has important limitations in diabetic and elderly populations because medial arterial calcification can make arteries poorly compressible, producing falsely elevated or non-compressible readings. As a result, patients with diabetes may have significant arterial stenosis or calcification despite apparently normal or high ABI values. This diagnostic limitation supports the need to interpret ABI in relation to anatomical imaging findings, especially when clinical suspicion remains high or ABI values are non-compressible (8–11).

Computed tomography angiography provides detailed anatomical visualization of the lower-limb arterial tree and can identify the location, extent, severity, and distribution of stenosis, occlusion, and calcification. Unlike ABI, which reflects the functional hemodynamic effect of arterial disease, CTA directly demonstrates vascular morphology and is useful for treatment planning, particularly when endovascular or surgical intervention is being considered. However, CTA involves contrast exposure and radiation, and therefore it is not usually used as a universal screening tool. A clinically relevant diagnostic approach is to use ABI for initial functional assessment and CTA for anatomical confirmation, severity grading, and evaluation of calcified or multisegment disease (12–14).

Despite the established role of ABI and CTA in peripheral arterial disease assessment, limited local data are available on how ABI categories correspond with CTA-detected stenosis severity and arterial calcification among type 2 diabetic patients with suspected lower-limb peripheral arterial disease. This gap is clinically relevant because diabetic patients may show discordance between functional ABI results and anatomical disease due to vascular calcification. Establishing the relationship between ABI and CTA findings may help clinicians identify patients who require advanced imaging, improve interpretation of abnormal or falsely elevated ABI values, and support more accurate assessment of disease severity. Therefore, this study aimed to determine the association between ABI categories and CT angiographic findings, including degree of stenosis, arterial calcification, and segmental arterial involvement, among patients with type 2 diabetes mellitus and suspected lower-limb peripheral arterial disease.

MATERIALS AND METHODS

This study was conducted as a single-center cross-sectional observational study among patients with type 2 diabetes mellitus who presented with clinical suspicion of lower-limb peripheral arterial disease at the Radiology Department of Pakistan Kidney and Liver Institute. The study included 45 participants, comprising 25 males and 20 females, aged 30–80 years. Eligible participants were adults with type 2 diabetes mellitus who had suspected lower-limb peripheral arterial disease based on symptoms such as intermittent claudication, rest pain, ulceration, gangrene, or clinical referral for vascular assessment. Hypertension, hyperlipidemia, and smoking history were recorded as cardiovascular risk factors rather than mandatory eligibility requirements. Patients were excluded if they were pregnant, had non-measurable ABI, known allergy to iodinated contrast, previous lower-limb arterial stenting or surgery, connective tissue disorders, renal impairment, or any condition that could interfere with safe contrast-enhanced CT angiography or reliable vascular assessment.

Participants were enrolled after clinical evaluation and written informed consent. Demographic data, relevant medical history, cardiovascular risk factors, laterality of limb involvement, and peripheral arterial disease symptoms were recorded using a structured data collection sheet. Symptoms included intermittent claudication, anatomical site of claudication, rest pain, ulcer or gangrene, and ulcer location where applicable. Smoking status was categorized as current, former, or never smoker. Hypertension and hyperlipidemia were recorded according to documented clinical history or available medical records.

Ankle-brachial index was measured as a non-invasive functional assessment of lower-limb perfusion. Systolic blood pressure readings were obtained from the brachial artery and ankle arteries, and ABI was calculated as the ratio of ankle systolic pressure to brachial systolic pressure for each limb. ABI values below 0.90 were categorized as suggestive of peripheral arterial disease, values from 0.90 to 1.30 were considered within the compressible or non-PAD range, and values above 1.30 were categorized as non-compressible or falsely elevated, suggesting possible arterial calcification. Right and left ABI values were recorded separately, and the clinically relevant abnormal ABI category was used for association with CT angiographic findings.

All included participants underwent CT angiography of the lower limbs for anatomical assessment of peripheral arterial disease. CT angiographic images and corresponding radiological reports were reviewed for arterial involvement, degree of stenosis or occlusion, laterality, and calcification. The arterial segments assessed included iliac, femoral, popliteal, peroneal, and tibial arteries. Segmental involvement was recorded as present or absent for each arterial territory. Stenosis severity was categorized according to CTA findings as mild, moderate, severe, or occlusion, and calcification was recorded as present when arterial calcification was reported on CTA. To reduce information bias, data were extracted from structured imaging reports and cross-checked with the recorded data collection sheet for completeness and consistency.

The primary study outcome was the association between ABI category and CT angiographic findings of lower-limb peripheral arterial disease. The main CTA outcomes were degree of stenosis and presence of arterial calcification. Secondary outcomes included the distribution of involved arterial segments and the association between gender and arterial segment involvement. Potential confounding variables, including age, sex, diabetes status, hypertension, hyperlipidemia, smoking history, symptoms, and laterality, were documented to describe the clinical profile of the study population. Because all participants had type 2 diabetes mellitus, diabetes was treated as a defining population characteristic rather than a comparative exposure variable.

Data were entered in Microsoft Excel and analyzed using IBM SPSS Statistics version 25. Categorical variables were summarized as frequencies and percentages, while continuous variables such as ABI values were summarized using mean, standard deviation, minimum, and maximum values. Chi-square tests were used to evaluate associations between categorical variables, including ABI category and stenosis severity, ABI compressibility status and CTA-detected calcification, and gender with arterial segment involvement. Fisher's exact test was considered where expected cell counts were small. A p-value of less than 0.05 was considered statistically significant. Missing or incomplete entries were checked against source records before analysis, and only valid cases were included in the relevant statistical tests.

The study was conducted in accordance with ethical principles for human research. Approval was obtained from the relevant institutional and hospital authority, and written informed consent was obtained from all participants before data collection. Participation was voluntary, confidentiality was maintained throughout the study, and all collected data were anonymized before analysis. No personal identifiers were disclosed in the manuscript or resulting publication.

RESULTS

A total of 45 patients with type 2 diabetes mellitus and suspected lower-limb peripheral arterial disease were included. The study population comprised 25 males (55.6%) and 20 females (44.4%). Most participants were older adults, with the highest representation in the 70–80-year age group (n=15, 33.3%), followed by the 60–69-year age group (n=13, 28.9%). This indicates that 62.2% of the study population was aged 60 years or above.

Table 1. Demographic Characteristics of Study Participants

Variable	Category	Frequency	Percentage
Gender	Male	25	55.6
	Female	20	44.4
Age group	30–39 years	2	4.4
	40–49 years	6	13.3
	50–59 years	9	20.0
	60–69 years	13	28.9
	70–80 years	15	33.3

All participants had type 2 diabetes mellitus. Hypertension was present in 33 participants, while hyperlipidemia was documented in 31 participants. Regarding smoking status, 10 participants were current smokers, 12 were former smokers, and 23 had never smoked. Intermittent claudication was reported by 26 participants, rest pain by 19 participants, and ulcer or gangrene by 15 participants. The calf was the most frequently reported claudication site, while toe involvement was the most common ulcer/gangrene location.

Table 2. Clinical Risk Factors and Symptom Profile

Variable	Category	Frequency	Percentage
Type 2 diabetes mellitus	Yes	45	100.0
Hypertension	Yes	33	73.3
	No	11	24.4
Hyperlipidemia	Yes	31	68.9
	No	14	31.1
Smoking history	Current	10	22.2
	Former	12	26.7
	Never	23	51.1
Intermittent claudication	Yes	26	57.8
	No	19	42.2
Claudication site	Calf	11	24.4
	Thigh	10	22.2
	Buttock	5	11.1
Rest pain	Yes	19	42.2
	No	26	57.8
Ulcer/gangrene	Yes	15	33.3
	No	30	66.7
Ulcer/gangrene site	Toes	8	17.8
	Foot	5	11.1
	Leg	2	4.4

Lower-limb involvement was bilateral in 18 participants (40.0%), left-sided in 15 participants (33.3%), and right-sided in 12 participants (26.7%). ABI values showed wide variation, with right ABI ranging from 0.30 to 1.41 and left ABI ranging from 0.32 to 1.41. The mean right ABI was 0.86±0.34, while the mean left ABI was 0.80±0.37.

Table 3. Limb Involvement and ABI Values

Variable	Category / Statistic	Value
Limb involvement	Bilateral	18 (40.0%)
	Left	15 (33.3%)
	Right	12 (26.7%)
Right ABI	Mean ± SD	0.86 ± 0.34

Variable	Category / Statistic	Value
	Minimum–maximum	0.30–1.41
Left ABI	Mean ± SD	0.80 ± 0.37
	Minimum–maximum	0.32–1.41

CT angiography demonstrated involvement of multiple lower-limb arterial segments. The most frequently affected arteries were the peroneal artery (n=20, 44.4%) and tibial artery (n=19, 42.2%), followed by femoral artery involvement in 16 participants (35.6%). Iliac and popliteal artery involvement were each observed in 14 participants (31.1%).

Table 4. CT Angiographic Arterial Segment Involvement

Arterial Segment	Involved, n (%)	Not Involved, n (%)
Iliac artery	14 (31.1)	31 (68.9)
Femoral artery	16 (35.6)	29 (64.4)
Popliteal artery	14 (31.1)	31 (68.9)
Peroneal artery	20 (44.4)	25 (55.6)
Tibial artery	19 (42.2)	26 (57.8)

Gender-based analysis showed no statistically significant association between gender and involvement of any arterial segment. Femoral artery involvement was observed in 10 males and 6 females, while iliac artery involvement was seen in 6 males and 8 females. Peroneal artery involvement was equally distributed between males and females. All p-values were greater than 0.05, indicating that arterial segment involvement did not significantly differ by gender in this sample.

Table 5. Association Between Gender and Arterial Segment Involvement

Arterial Segment	Female Involved, n (%)	Male Involved, n (%)	χ^2	df	p-value
Femoral artery	6 (37.5)	10 (62.5)	0.485	1	0.486
Popliteal artery	6 (42.9)	8 (57.1)	0.021	1	0.885
Peroneal artery	10 (50.0)	10 (50.0)	0.450	1	0.502
Tibial artery	9 (47.4)	10 (52.6)	0.114	1	0.736
Iliac artery	8 (57.1)	6 (42.9)	1.327	1	0.249

The relationship between ABI category and CTA-detected stenosis severity was statistically significant. Among participants with ABI-defined PAD, 7 had mild stenosis, 15 had moderate stenosis, and 19 had severe stenosis or occlusive disease. In contrast, all 4 participants categorized as no PAD by ABI had only mild stenosis on CTA. The association between ABI category and stenosis severity was significant, χ^2=13.570, df=2, p=0.001, indicating that abnormal ABI values were associated with greater CTA-detected stenosis severity.

Table 6. Association Between ABI Category and CTA-Detected Stenosis Severity

CTA Stenosis Severity	ABI <0.90 / PAD, n	ABI 0.90–1.30 / No PAD, n	Total, n	χ^2	df	p-value
Mild	7	4	11	13.570	2	0.001
Moderate	15	0	15			
Severe / occlusive disease	19	0	19			
Total	41	4	45			

CTA-detected arterial calcification was strongly associated with non-compressible ABI. Among participants with compressible ABI values below 1.30, 32 had no calcification and 2 had calcification on CTA. In contrast, all 11 participants with non-compressible ABI values above 1.30 had CTA-detected calcification. This association was highly statistically significant, χ^2=35.837, df=1, p<0.001. Fisher's exact test also showed statistical significance, supporting the robustness of this association despite the small sample size.

Table 7. Association Between ABI Compressibility Status and CTA-Detected Arterial Calcification

CTA Calcification Status	Compressible ABI <1.30, n	Non-Compressible ABI >1.30, n	Total, n	χ^2	df	p-value	Fisher's Exact p-value
No calcification	32	0	32	35.837	1	<0.001	<0.001
Calcification present	2	11	13				
Total	34	11	45				

Overall, ABI categories showed clinically meaningful correspondence with CTA findings. Low ABI values were associated with greater stenosis severity, while non-compressible ABI values were strongly associated with arterial calcification on CTA. These findings support the complementary role of ABI and CTA in evaluating lower-limb peripheral arterial disease among patients with type 2 diabetes mellitus.

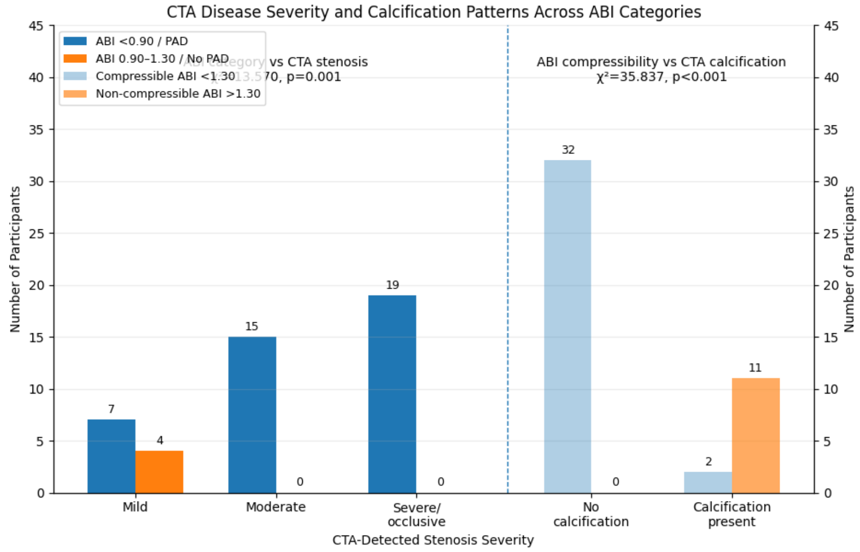

Figure 1 CTA Disease Severity and Calcification Patterns Across ABI Categories

The integrated distribution demonstrates that ABI-defined PAD was concentrated in higher CTA severity categories, with 7 mild, 15 moderate, and 19 severe/occlusive cases, whereas all 4 participants with ABI 0.90–1.30 had only mild stenosis. This association was statistically significant (χ^2=13.570, p=0.001). ABI non-compressibility showed an even stronger relationship with CTA-detected calcification: all 11 participants with ABI >1.30 had calcification, while 32 of 34 participants with compressible ABI had no calcification (χ^2=35.837, p<0.001). These findings support ABI as a useful functional screening measure while emphasizing CTA's value for identifying calcification and anatomical disease severity in diabetic lower-limb PAD.

DISCUSSION

This study demonstrated a clinically meaningful association between ABI categories and CTA-detected lower-limb arterial disease among patients with type 2 diabetes mellitus and suspected peripheral arterial disease. The findings showed that participants with ABI-defined PAD were more likely to have moderate to severe or occlusive stenosis on CTA, while participants with ABI values within the non-PAD range showed only mild stenosis. This supports the role of ABI as a useful first-line functional screening tool for detecting hemodynamically relevant lower-limb arterial disease. However, the presence of mild CTA-detected stenosis in participants with ABI values between 0.90 and 1.30 also highlights an important limitation: ABI may not identify early or anatomically mild disease when arterial narrowing has not yet produced a measurable reduction in ankle systolic pressure.

The strongest finding of this study was the highly significant association between non-compressible ABI and CTA-detected arterial calcification. All participants with ABI values above 1.30 had calcification on CTA, while calcification was uncommon among those with compressible ABI values. This is particularly important in diabetic populations, where medial arterial calcification can reduce arterial compressibility and produce falsely elevated ABI values. Therefore, a high ABI should not be interpreted as normal in patients with diabetes; rather, it should raise suspicion for calcified arterial disease and prompt further anatomical or alternative physiological assessment. These findings are consistent with existing evidence that ABI is useful for PAD screening but has reduced diagnostic reliability in patients with diabetes, especially when arterial calcification is present (8–11).

CTA provided additional anatomical information that ABI alone could not provide, including the affected arterial segments, distribution of disease, stenosis severity, occlusion, and calcification. In this study, peroneal and tibial arteries were the most frequently involved segments, suggesting a predominance of distal lower-limb arterial disease. This pattern is clinically plausible in diabetic PAD, where infrapopliteal and distal vessel involvement is commonly observed and may contribute to rest pain, ulceration, gangrene, and impaired wound healing. The absence of a statistically significant association between gender and arterial segment involvement indicates that, within this sample, the anatomical distribution of disease was not meaningfully different between males and females. However, this finding should be interpreted cautiously because the sample size was small and the study was not powered for gender-based subgroup analysis.

The findings support a complementary diagnostic model in which ABI and CTA serve different but clinically connected purposes. ABI reflects the hemodynamic impact of arterial obstruction and is appropriate for initial evaluation because it is inexpensive, non-invasive, and easy to perform. CTA, in contrast, provides detailed anatomical characterization and is particularly valuable when ABI is abnormal, non-compressible, or discordant with clinical symptoms. This distinction is important for diabetic patients because both falsely elevated ABI and multilevel disease can complicate interpretation. Combining ABI with CTA may therefore improve clinical decision-making by identifying patients who require vascular referral, further imaging, or intervention planning.

Several limitations should be considered. The study was conducted at a single center with a relatively small sample size of 45 participants, limiting generalizability and reducing the precision of subgroup comparisons. The sample included symptomatic or clinically suspected PAD patients with type 2 diabetes mellitus, so the findings cannot be directly extended to asymptomatic diabetic populations or the general population. The cross-sectional design also prevents assessment of disease progression, treatment response, or clinical outcomes such as amputation, revascularization, or wound healing. In addition, the study did not include toe-brachial index, duplex ultrasound comparison, interobserver agreement for CTA interpretation, or multivariable adjustment for potential confounders such as age, smoking, hypertension, and hyperlipidemia. Future multicenter studies with larger samples, standardized CTA grading, and longitudinal follow-up are needed to validate these findings and clarify how ABI-CTA correlation predicts clinical outcomes.

CONCLUSION

This study showed that ABI categories were significantly associated with CTA-detected lower-limb arterial disease among patients with type 2 diabetes mellitus and suspected peripheral arterial disease. Low ABI values were associated with greater stenosis severity, while non-compressible ABI values were strongly associated with CTA-detected arterial calcification. These findings support ABI as a useful first-line functional screening tool but emphasize that CTA provides essential anatomical information, particularly in diabetic patients with suspected calcification or discordant ABI findings. Combined interpretation of ABI and CTA may improve assessment of disease severity and guide more appropriate clinical management.

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