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Ultrasound Evaluation of Lower Limb Arteries in Non-Diabetic Controls and Diabetic Patients

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Abstract

Background: Diabetes mellitus is associated with an increased risk of lower extremity arterial disease. Ultrasound imaging enables non-invasive assessment of both arterial morphology and hemodynamics. This study aimed to compare lower limb arterial morphology and hemodynamic characteristics assessed using ultrasound between asymptomatic diabetic patients and non-diabetic controls.

Methods and Results: This study included 71 participants comprising 38 diabetic patients and 33 non-diabetic controls. Duplex ultrasound examinations of the popliteal, anterior, and posterior tibial arteries were performed using a high-resolution ultrasound system. B-mode ultrasound was used to measure wall thickness, and Doppler imaging was used to assess flow velocity (FV), resistive index (RI), and acceleration time (AT). Comparisons between groups were performed using the Mann–Whitney U test, with statistical significance set at $P \leq 0.05$.

A total of 406 arterial segments were evaluated. Diabetic patients demonstrated significantly greater wall thickness compared with controls (median 0.71 mm [IQR 0.33] vs. 0.62 mm [IQR 0.30]; $P < 0.001$). Doppler ultrasound revealed significantly higher RI values in diabetic patients (median 0.98 [IQR 0.03] vs. 0.94 [IQR 0.07]; $P = 0.008$) and prolonged AT (median 110 ms [IQR 37] vs. 103 ms [IQR 33.75]; $P = 0.04$). No significant difference in FV was observed between groups ($P = 0.76$).

Conclusion: Diabetic patients exhibit structural and hemodynamic alterations in lower limb arteries, characterized by increased arterial wall thickness, elevated vascular resistance, and prolonged systolic acceleration time. These findings suggest that triplex ultrasound-derived parameters may be useful pre-clinical markers of diabetes-associated vascular impairment and could facilitate earlier identification of lower extremity arterial disease.(**International Journal of Biomedicine. 2026;16(3):352-356.**)

Keywords: diabetes mellitus • peripheral artery disease • hemodynamics • vascular imaging • ultrasound

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Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder that has emerged as one of the leading global health challenges due to its increasing prevalence and its profound impact on morbidity and mortality.[1] The disease is characterized by persistent hyperglycemia causing metabolic and vascular dysfunction.[2] Vascular complications remain a major cause of disability and death among diabetic patients, accounting for a substantial proportion of hospitalizations and reduced quality of life. [3,4]

Diabetes-related vascular complications arise from chronic hyperglycemia-induced endothelial dysfunction and oxidative stress, with advanced glycation end-products and inflammation accelerating atherosclerosis and vascular damage.[5,6] Peripheral artery disease (PAD) is a major macrovascular complication of diabetes and a manifestation of systemic atherosclerosis, leading to partial or complete occlusion of lower-extremity arteries and impaired tissue perfusion. [7] PAD is associated with impaired wound healing and diabetic foot ulceration, and it increases the risk of chronic limb-threatening ischemia, lower extremity amputation, and mortality.[8,9] Vascular alteration, including increased arterial stiffness and impaired arterial compliance, may develop early in the course of dysglycaemia and may precede the clinical manifestation of diabetes and its vascular complications.[10,11] Therefore, early detection of these subclinical vascular alterations is essential for timely intervention, risk stratification, and prevention of disease progression and its associated complications.

Duplex ultrasound is a non-invasive imaging modality for PAD, offering non-invasive assessment of lower limb arterial circulation.[12] B-mode ultrasound enables measurement of intima–media thickness (IMT), a recognized marker of subclinical atherosclerosis and vascular remodeling. In contrast, Doppler ultrasound provides quantitative hemodynamic parameters such as blood flow velocity and volume, resistive index (RI), and acceleration time (AT), allowing for the assessment of both structural and functional vascular abnormalities.[13,14] The present study aimed to investigate structural and hemodynamic differences in the lower limb arteries of patients with diabetes mellitus compared with non-diabetic controls using B-mode and Doppler ultrasound imaging, through measuring intima-media thickness, flow volume, RI, and AT in the popliteal, anterior tibial, and posterior tibial arteries.

Methods

Study Design and Participants

This observational pilot study was ethically approved on 10.12.2023 by the Institute Review Board of Research Ethics Committee at King Abdullah Medical City (IRB No 23-1177). The study design adhered to the principles outlined in the Declaration of Helsinki and the International Conference of Harmonization of Good Clinical Practice. Adult participants referred to the ultrasound department for lower limb arterial assessment were prospectively recruited. The diabetic group comprised asymptomatic patients with type 2 diabetes mellitus (T2DM) of ≤5 years duration and without clinical evidence or a history of diabetes-related vascular complications or peripheral arterial disease. Healthy age- and BMI-matched non-diabetic volunteers served as controls. Ultrasound assessment of the lower limb arteries was performed by an experienced vascular sonographer.

Ultrasound Assessment and Data Acquisition

Lower limb ultrasound examinations were performed on all participants to evaluate the popliteal, anterior tibial, and posterior tibial arteries using a high-resolution EPIQ ultrasound imaging system (Philips Healthcare, Andover, MA, USA) equipped with a high-frequency linear transducer. Image quality was optimized by adjusting key parameters, including depth, focus point, overall gain, time-gain compensation, and dynamic range, to achieve high-resolution B-mode images. Longitudinal views of all arteries were acquired for comprehensive assessment. B-mode and Doppler ultrasound imaging were used to measure intima-media thickness, flow velocity, resistive index (RI), and acceleration time (AT) for all arteries depicted via ultrasound with Doppler angle correction of 60° (Figure 1). During ultrasound imaging, participants were positioned supine. A sufficient amount of gel was applied, and the transducer was placed on the artery to be assessed.

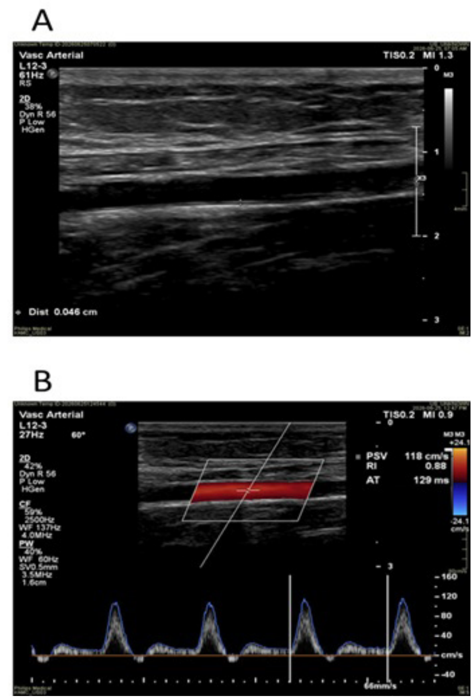

Figure 1. *Ultrasound measurement of lower limb arterial parameters. B-mode measurement of wall thickness (A). Doppler measurements of peak systolic velocity (PSV), resistive index (RI), and acceleration time (AT).*

Statistical Analysis

Statistical analysis was conducted using SPSS Statistics (Version 21.0, IBM Corp., Armonk, NY, USA). The Mann–Whitney U test was employed to assess differences in intima–media thickness, flow velocity, RI and AT of the lower limb arteries between non-diabetic controls and diabetic patients. Statistical significance was defined as a P-value ≤ 0.05.

Results

A total of 406 lower limb arteries from 71 participants were evaluated using duplex ultrasound, comprising 33 non-diabetic controls and 38 patients with T2DM. Overall, the cohort had a mean age of 61.4 ± 16.0 years and a mean BMI of 29.6 ± 7.3 kg/m². The control group included 23 females and 10 males, with a mean age of 60.0 years and a mean BMI of 29.2 kg/m². The diabetic group consisted of 12 females and 26 males, with a mean age of 62.7 years and a mean BMI of 29.7 kg/m². Of the 71 patients included in this study, 36 were male (10 control and 26 diabetic), and 35 were female (23 control and 12 diabetic). Lower limb arterial wall thickness measured by B-mode ultrasound was significantly greater in the diabetic group compared with the control group (control: median 0.62 mm, interquartile range [IQR] 0.30 mm; diabetic: median 0.71 mm, IQR 0.33 mm; Z = −4.20, $P < 0.001$, n=383; Figure 2A). RI and AT assessed using Doppler ultrasound, also differed significantly between groups, with diabetic patients demonstrating higher RI and delayed AT values than controls (RI, control: median 0.94, IQR 0.07; diabetic: median 0.98, IQR 0.03; Z = −2.65, $P = 0.008$, n=405, Figure 2B; AT, control: median 103 ms, IQR 33.75 ms; diabetic: median 110 ms, IQR 37 ms; Z = −2.02, $P = 0.04$, n=405, Figure 2C). No significant difference in flow velocity was observed between the control and diabetic groups (Z = −0.30, $P = 0.76$, n=406, Figure 2D).

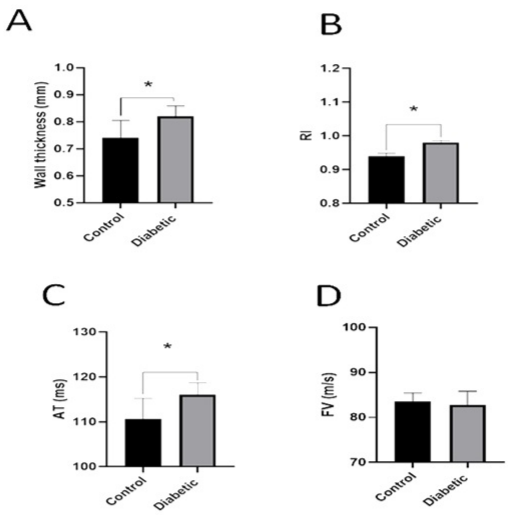

*Figure 2. Comparison of lower limb arterial intima–media thickness (IMT, A), resistive index (RI, B), acceleration time (AT, C), and flow velocity (FV, D) between control and diabetic groups. Data are presented as median and interquartile range (IQR). *P ≤ 0.05 using the Mann–Whitney U test.*

Discussion

This study investigated the structural and hemodynamic characteristics of lower limb arteries in diabetic patients compared with non-diabetic controls using ultrasound imaging, encompassing B-mode imaging and Doppler spectral analysis. Our findings demonstrate that diabetic patients exhibit significantly increased IMT, higher RI, and prolonged systolic AT, with no significant difference in mean flow volume was identified between groups. These findings indicate that DM is associated with morphological and hemodynamic alterations in the lower limb arteries, and support the utility of ultrasound as a useful modality for detecting subclinical arterial abnormalities in diabetic patients.

The increased arterial wall thickness observed in the present study is consistent with the progressive vascular remodeling associated with hyperglycemia, which promotes oxidative stress and inflammation, increases advanced glycation end-product formation, and impairs endothelial function, thereby stimulating smooth muscle cell proliferation and extracellular matrix accumulation, which contribute to arterial wall thickening and stiffening.[15–17] These extend previous observations to the lower limb arteries, which are particularly susceptible to diabetic macroangiopathy and play a central role in the development of peripheral arterial disease, critical limb ischemia, and diabetic foot complications.[18,19] Similar findings have been reported, with progressive increases in the wall thickness of the dorsalis pedis and posterior tibial arteries with increasing duration of T2DM, and a significant positive association between diabetes duration and artery wall thickness.[20] The greater wall thickness identified across multiple arterial segments, despite the relatively short duration of diabetes and absence of overt vascular complications in our cohort, suggests that diabetes-related macrovascular changes are diffuse in nature and may be detectable even in asymptomatic individuals. Collectively, these findings underscore the potential role of duplex ultrasound as a sensitive, non-invasive tool for the early identification of subclinical diabetic vasculopathy.

The significantly higher RI and prolonged AT observed in diabetic patients indicate the presence of early hemodynamic alterations associated with diabetic vasculopathy. RI is a Doppler-derived parameter reflecting downstream vascular resistance and vascular compliance, and elevated RI in diabetic patients is consistent with increased peripheral vascular impedance.[21] Several studies reported a progressive increase in the pulsatility index (PI) and RI of the peripheral arteries with increasing diabetes duration.[20,22,23] In addition, the significantly prolonged AT observed in the present study provides complementary evidence of impaired arterial hemodynamics. AT represents the interval between the onset of systolic flow and the attainment of peak systolic velocity on spectral Doppler waveform analysis, thereby serving as an indirect marker of arterial compliance, proximal flow impedance, and downstream vascular resistance.[24] The clinical utility of AT has been established across multiple vascular territories, where pedal acceleration time has emerged as a reliable Doppler parameter for assessing lower limb ischemia and peripheral arterial disease.[25–27] The prolonged AT identified in the diabetic cohort supports the presence of early functional vascular abnormalities and highlights the potential value of Doppler waveform analysis for detecting subclinical lower extremity vascular impairment. Together, RI and AT appear to be sensitive for detecting early lower limb vascular dysfunction and may represent practical quantitative markers for incorporation into routine duplex ultrasound surveillance of diabetic patients.

Several limitations of the present study should be acknowledged. The relatively small sample size and single-center design may have limited the generalizability of the findings. The cross-sectional nature of the study and the need for a longitudinal study are warranted to characterize further and assess vascular alterations associated with diabetes. In addition, incorporating clinical variables such as glycemic control, medication use, and the presence of microvascular complications in future studies would provide a more comprehensive understanding of the factors influencing lower limb vascular remodeling and hemodynamic impairment.

Conclusion

Diabetes mellitus is associated with early structural and hemodynamic alterations of the lower limb arteries, even in the absence of clinically evident peripheral arterial disease. Compared with non-diabetic controls, diabetic patients demonstrated increased arterial wall thickness, elevated resistive index, and prolonged acceleration time, indicating subclinical vascular remodeling and increased peripheral vascular resistance. These findings highlight the ability of duplex ultrasound to provide comprehensive assessment of both arterial morphology and hemodynamics and support its potential role as a non-invasive tool for the early detection of diabetes-associated vascular impairment. Further large-scale longitudinal studies are warranted to establish the prognostic significance of these ultrasound-derived markers and to clarify their relationship with disease duration, glycemic control, and the development of vascular complications.

Author Contributions

Adel Alzahrani: Writing - review & editing, Supervision
Omar Alserihy, Asma Alkhaldi, Khadijah Alshogaifi, Ahmed Monis, Yaser Khojah, Nawaf Alsaedi, Reem T Alturki: Data curation, Investigation
Salahaden R Sultan: Data analysis, Writing - original draft

Conflict of Interest

The authors declare that they have no competing interests.

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