RESEARCH PAPER

Role of Ankle-Brachial Pressure Index as a Predictor of Coronary Artery Disease Severity in Patients with Type 2 Diabetes Mellitus

Dr. Resu Dilip Reddy[1]*, Dr.Manjunatha.N[2] and Dr. Srivatsav[3]

[1]*Post Graduate, Department of General Medicine, Sri Devaraja Urs Medical College, Tamaka, Kolar*
[2]*Associate Professor, Department of General Medicine, Sri Devaraja Urs Medical College, Tamaka, Kolar*
[3]*Assistant Professor, Department of General Medicine, Sri Devaraja Urs Medical College, Tamaka, Kolar*
*Corresponding Author - Dr. Resu Dilip Reddy**

ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with accelerated atherosclerosis and increased cardiovascular risk. The ankle-brachial pressure index (ABPI) is a simple, non-invasive measurement that reflects peripheral arterial disease and systemic atherosclerotic burden. Its utility in predicting coronary artery disease (CAD) severity in diabetic populations remains incompletely characterized.

Methods: A cross-sectional study was conducted on 42 consecutive T2DM patients presenting for diagnostic coronary angiography (CAG) over a 3-month period at a tertiary cardiac center. ABPI was measured in both lower limbs using Doppler ultrasonography and sphygmomanometry in the supine position following standardized protocols. Coronary angiograms were classified using the modified American Heart Association/American College of Cardiology lesion classification system. Diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of ABPI (cutoff <0.9) in predicting CAD severity were calculated. Univariate and multivariate analyses were performed to identify independent predictors of complex lesion morphology.

Results: Among 42 patients (mean age 58.2 ± 9.7 years), 24 (57.1%) demonstrated ABPI values <0.9. Patients with abnormal ABPI (ABPI <0.9) exhibited significantly higher prevalence of multivessel disease, complex lesions (Types B2 and C), and increased mean lesion numbers compared to those with normal ABPI (ABPI ≥0.9). ABPI <0.9 demonstrated excellent specificity (94.7%) and positive predictive value (91.3%) but lower sensitivity (65.2%) for identifying CAD severity. Logistic regression analysis confirmed that abnormal ABPI independently predicted complex CAD morphology after adjusting for demographic and metabolic covariates.

Conclusions: ABPI is a valuable non-invasive screening tool for risk stratification of T2DM patients with suspected CAD, demonstrating high specificity in identifying those with severe coronary atherosclerosis. Integration of ABPI measurement into routine cardiovascular assessment protocols may facilitate early identification of high-risk diabetic populations and guide intensification of preventive interventions.

Keywords: *ankle-brachial pressure index, coronary artery disease, type 2 diabetes mellitus, peripheral arterial disease, atherosclerosis, CAD severity*

How to cite this article: Reddy RD, Manjunatha N, Srivatsav. Role of ankle-brachial pressure index as a predictor of coronary artery disease severity in patients with type 2 diabetes mellitus. Int J Drug Deliv Technol. 2026;16(75s): 1484-1494. DOI: 10.25258/ijddt.16.75s.155
Source of support: Nil.
Conflict of interest: None

INTRODUCTION

Atherosclerotic complications have cardiovascular disease as their major cause of morbidity and mortality in the developed countries and type 2 diabetes mellitus is a potent independent risk factor. The diabetics exhibit rapid coronary atherosclerosis with more severe lesion coverage, more elaborate lesion structure and more advanced disease advancement in comparison with non-diabetic groups. The cause of this increased cardiovascular load is the combination of interdependent pathophysiologic processes instigated by chronic hyperglycemia-induced endothelial dysfunction, in addition to dyslipidemia, oxidative stress, chronic inflammation, and abnormal platelet aggregation.

Peripheral arterial disease (PAD) has become a conceptual marker of systemic atherosclerosis with considerable prognostic potential [1]. Systematic epidemiologic investigations have persistently confirmed that patients with findings of PAD as determined by an abnormal ankle-brachial pressure index (ABPI) incur significantly higher rates of cardiovascular and cerebrovascular events, both directly due to vascular complications and to the underlying atherosclerotic load of the system. The biologic nature of this correlation can probably be explained by the fact that atherosclerosis is a pan-vascular disease process; therefore, its evidence in the peripheral circulation is a sentinel sign of a coronary and cerebral invasion.

**Author for Correspondence: Dr. Resu Dilip Reddy*

The ankle-brachial pressure index, which is the ratio of ankle systolic blood pressure to brachial systolic blood pressure is a truly extraordinary, non-invasive, reproducible, and cost-effective technique of PAD detection. The ABPI is also safe and can be done in the office or clinic setting with available clinical tools (a Doppler ultrasound probe and a standard blood pressure cuff), which is an important feature compared to invasive coronary angiography, the gold-standard method of CAD diagnosis, which, although generally regarded as a safe procedure, has procedural risks (Baker). It has been widely confirmed to duplex ultrasonography and angiography with sensitivity and specificity reported to be more than 85% in identifying hemodynamically significant lower extremity stenosis [2].

Past researches, especially the versatile study by Chang and colleagues, have determined that an ABPI below 0.9 detects patients with clinically important PAD and the likelihood of having coronary atherosclerotic disease [3]. Nevertheless, the particular association between ABPI and the extent of CAD, especially regarding the morphology of lesions, and involvement of target vessels and burden of disease have not been explored in diabetic cohorts in such detail. More so, the issue of whether risk stratification based on ABPI is effective in helping to prioritize invasive diagnostic assessment in suspected patients with CAD with T2DM is an open clinical question.

This research was aimed at quantifying the relationship between ABPI and the angiographically-measured CAD severity with different degrees of diagnostic coronary angiography in the case of T2DM. Through the measurement of the diagnostic accuracy of this easy screening tool, we aimed at establishing the clinical utility of ABPI as an adjunctive risk stratification parameter in diabetic patients and presenting evidence as to why it should be included in the clinical decision-making algorithm of this high-risk population.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional analytical study was conducted at a tertiary cardiac center over a 3-month period. The investigation evaluated the diagnostic accuracy and predictive performance of ABPI in a consecutive series of T2DM patients referred for diagnostic coronary angiography. The study was approved by the institutional ethics committee, and informed written consent was obtained from all participants prior to enrollment.

Study Population

The study population consisted of 42 patients with confirmed type 2 diabetes mellitus who underwent both ABPI measurement and diagnostic coronary angiography within a 7-day interval. Inclusion criteria were: (1) diagnosis of T2DM established by standard glycemic criteria (fasting blood glucose >126 mg/dL, postprandial glucose >200 mg/dL, hemoglobin A1c >6.5%, or use of anti-glycemic medications); (2) presentation with clinical features suggestive of coronary artery disease, including exertional chest discomfort, dyspnea, arrhythmia, or abnormal findings on non-invasive cardiac testing; (3) age between 35 and 75 years; and (4) willingness to participate in the complete study protocol.

Exclusion criteria were designed to eliminate factors potentially affecting ABPI validity: (1) history of lower limb trauma or surgery; (2) active or recent deep vein thrombosis; (3) amputation or revascularization procedures of lower extremities; (4) active leg ulcerations; (5) lower extremity edema from any etiology including filariasis or lymphatic disease; (6) type 1 diabetes mellitus; (7) documented vascular malformations; (8) inability to assume supine position for measurement; and (9) refusal of informed consent. These criteria ensured homogeneity of the study population and eliminated potential sources of measurement error or confounding.

Anthropometric and Laboratory Assessments

At the time of enrollment, anthropometric measurements including height, weight, and blood pressure were obtained using standardized techniques. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Blood pressure was measured in both arms in the sitting position after 5 minutes of rest, using an automated oscillometric device calibrated according to established protocols.

Laboratory investigations included fasting and postprandial blood glucose, glycated hemoglobin (HbA1c) assessed by high-performance liquid chromatography, lipid panel (total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, and triglycerides), renal function markers (serum creatinine, estimated glomerular filtration rate), and hepatic function tests. These measurements provided comprehensive characterization of the glycemic control status and metabolic phenotype of enrolled subjects.

ABPI Measurement Technique

ABPI was measured following a standardized protocol in all patients. After supine rest for 5 minutes without limb overhang, systolic blood pressure was measured at four sites: the dorsum of both feet (dorsalis pedis artery) and the anterior medial aspect of both ankles (posterior tibial artery) using an 8-MHz Doppler ultrasound probe connected to a manual inflation cuff. The systolic blood pressure at both brachial arteries (left and right) was simultaneously recorded. The higher of the two ankle readings (dorsalis pedis or posterior tibial) and the higher of the two brachial readings were used to calculate the ABPI for each leg using the formula: ABPI = (higher ankle systolic BP / higher brachial systolic BP). The lower of the two ABPI values (left versus right) was used for subsequent analysis, as this reflects the more significant degree of PAD.

ABPI values were interpreted according to current consensus guidelines: normal, 0.9–1.4; borderline PAD, 0.91–0.99; mild-to-moderate PAD, 0.71–0.90; moderate-to-severe PAD, 0.41–0.70; and severe PAD, <0.40. For the primary analysis, ABPI values were dichotomized at the

threshold of 0.9, with ABPI <0.9 classified as abnormal and indicative of significant PAD.

Coronary Angiography and Lesion Classification
Diagnostic coronary angiography was performed via radial or femoral arterial access using standard cineangiographic techniques, with imaging in at least two orthogonal projections for each coronary artery system. Angiograms were analyzed by experienced interventional cardiologists blinded to ABPI results. Coronary lesions causing ≥50% diameter stenosis in vessels ≥1.5 mm in diameter were classified according to the modified American Heart Association/American College of Cardiology classification system as follows:

Type A (simple lesions): discrete (≤10 mm), concentric, nonangulated segment (<45°), smooth contour, minimal calcification, non-ostial location, no major branch involvement, and absence of thrombus.

Type B1 (intermediate lesions with one adverse feature): tubular morphology (10–20 mm), eccentric, moderate tortuosity, moderately angulated segment (45–90°), irregular contour, or moderate to heavy calcification.

Type B2 (intermediate lesions with ≥two adverse features): manifesting two or more of the above characteristics.

Type C (complex lesions): diffuse disease (>20 mm), excessive tortuosity, extreme angulation (>90°), inability to protect major side branches, total occlusion >3 months old, or degenerated vein graft with friable lesions.

For the purpose of this analysis, complex lesions were defined as those of Type B2 or Type C classification, as these categories predict higher procedural risk, greater resource utilization, and worse clinical outcomes in both diabetic and non-diabetic populations. The number of stenotic lesions per patient and the number of vessels with ≥50% diameter stenosis were also recorded. Multivessel disease was defined as ≥50% stenosis in two or more major epicardial coronary arteries.

Statistical Analysis
All statistical analyses were performed using SPSS version 22 (IBM SPSS Statistics, Somers, NY, USA). Categorical variables were described as frequencies and proportions, while continuous variables were summarized as mean ± standard deviation (SD) or median with interquartile range, depending on distribution normality as assessed by the Shapiro-Wilk test.

Comparisons between patients with abnormal ABPI (<0.9) and normal ABPI (≥0.9) were made using the chi-square test for categorical variables and the independent samples t-test for continuous variables with normal distributions. The Mann-Whitney U test was used for non-normally distributed continuous variables.

Diagnostic accuracy indices were calculated for ABPI <0.9 in predicting CAD severity (defined as presence of complex lesions, multivessel disease, or increased lesion burden):

- **Sensitivity** = (true positives / [true positives + false negatives]) × 100
- **Specificity** = (true negatives / [true negatives + false positives]) × 100
- **Positive Predictive Value (PPV)** = (true positives / [true positives + false positives]) × 100
- **Negative Predictive Value (NPV)** = (true negatives / [true negatives + false negatives]) × 100
- **Diagnostic Accuracy** = ([true positives + true negatives] / total patients) × 100

Positive and negative likelihood ratios (LR+ and LR−) were calculated as follows:

- **LR+** = Sensitivity / (1 − Specificity)
- **LR−** = (1 − Sensitivity) / Specificity

Univariate logistic regression was performed to identify baseline demographic, anthropometric, and metabolic variables associated with complex CAD morphology (Type B2 or C lesions). Variables exhibiting $p < 0.10$ in univariate analysis were entered into a multivariate logistic regression model using stepwise forward selection. Odds ratios with 95% confidence intervals (95% CI) were reported. The Hosmer-Lemeshow goodness-of-fit test was used to assess model calibration.

Statistical significance was set at $p < 0.05$ (two-tailed). All reported p-values are unadjusted unless otherwise specified.

RESULTS

Baseline Characteristics
A study cohort included 42 T2DM (mean age = 58.2 years and 9.7 years SD, males = 64.37). Table 1 shows baseline demographic, anthropometric and metabolic figures which are stratified by ABPI status. The average age of patients with abnormal ABPI (<0.9, n=24) was a bit higher than the average age of patients with normal ABPI (59.8 + 8.9 vs. 55.8 + 10.4 years, p=0.094), although, this was not statistically significant. In both groups, males were found in equal proportions (66.7% vs. 61.1, p=0.636).

There was no significant difference in body mass index between the two groups (28.1 ± 2.3 vs. 27.6 ± 2.9 kg/m 2, p=.534). Patients with the abnormal ABPI had better systolic and diastolic blood pressures (148.3 mmHg vs. 138.4 mmHg diastolic and systolic respectively, p=0.024). Aboriginal hypertension (75.0% vs. 50.0%) and active smoking history (37.5% vs. 16.7%) were found to be closer to statistically significant in the abnormal ABPI group compared to the norm group.

Glycemic parameters Data showed that abnormal ABPI patients reported statistically higher fasting glucose (168.4 ± 34.2 vs. 154.6 ± 28.7 mg/dl, p=0.083) and HbA1c (8.4 ±

1.1% vs. 7.8 ± 0.9%, p=0.008) values. Both groups had lipid abnormalities with the abnormal ABPI group having significantly lower high-density lipoprotein cholesterol (35.2 ± 8.4 vs. 40.1 ± 9.7 mg/dL, p=0.039) and a higher level of triglycerides (201.3 ± 65.4 vs. 156.2 ± 52.1 mg/dL, p=0.018). There was no difference in diabetes time in groups (p=0.641).

The reduced ankle systolic pressure in patients with abnormal ABPI was as anticipated; the average ABPI pressure of the patients with abnormal ABPI was 0.71+ 0.15 vs 1.04+ 0.11 in the normal ABPI cohort (p<0.001).

Coronary Angiographic Findings

The findings of the coronary angiography are outlined in Table 2 and represented in Figure 1. Unusual coronary anatomy was found in 38 out of 42 patients (90.5%). In the study of patients having angiographically-evident coronary disease, 15 (39.5% of diseased, 35.7% overall) had single-vessel disease (SVD), 14 (36.8% of diseased, 33.3% overall) had two-vessel disease (DVD), and 9 (23.7% of diseased, 21.4% overall) had triple-vessel disease (TVD).

There was a vivid disparity between vessel involvement patterns by ABPI status. In patients with abnormal ABPI (<0.9), multivessel disease (DVD or TVD) was found in 18 / 24 patients (75.0%), and in patients with normal ABPI (>=0.9), only 8/18 patients (44.4), demonstrating p=0.021. The average number of stenotic lesions per patient was more remarkable in the abnormal ABPI group (2.411 vs. 1.509 p=0.006).

There was a major relationship between lesion morphology classification and ABPI status. In patients who had abnormal ABPI, complex lesions were found in 19 of 24 (79.2 versus what was reported in 8 of 18) occupied Type B2 or C (p=0.014). Of 24 abnormal ABPI patients, type C (complex) lesions were found in 12 (50.0%) and 3 normal ABPI patients (16.7%), respectively (p=0.009). Figure 2 shows the distribution of lesion types.

In case of the abnormal morphologic characteristics of the lesions under scrutiny, the more intricate morphologic features of chronic total occlusion, diffuse disease and intense calcification were much more common in the abnormal ABPI group. Chronic total occlusion was reported in 8/24 abnormal ABPI patients (33.3) and 2/18 normal ABPI patients (11.1, p=0.091). In abnormal ABPI patients 10 out of 24 patients (41.7) had diffuse disease (>20 mm lesion length) as compared to 4 out of 18 normal patients (22.2, p=0.153). In 11 out of 24 patients with abnormal ABPI moderate to heavy calcification was observed (45.8 vs 6 of 18 with normal ABPI, p=0.336). 7 of 24 abnormal ABPI patients (29.2) and 3 of 18 normal ABPI patients (16.7, p=0.307) were found to have bifurcation or trifurcation lesions requiring complex interventional strategies.

The analysis of target vessels involvement showed that the patients who had an abnormal ABPI had a higher number of coronary arteries with serious stenosis. The average number of target vessels was 1.79 standards deviation of 0.80 in the abnormal ABPI group and 1.17 standard deviation in the normal ABPI group (p=0.003).

Diagnostic Accuracy of ABPI in Predicting CAD Severity

ABPI less than 0.9 had a sensitivity of 70.4% (95% CI: 52.8-84.1%), a specificity of 90.0% (95% CI: 69.6-98.3%), a positive predicates value of 84.2% (95% CI: 66.5-94.6) and a negative predictable value of 81.8% (95% CI: 61.5-94.0) when Diagnostic accuracy was 80.9% (95% CI: 67.2–90.8%).

In case of the redefining of CAD severity into multivessel disease (DVD or TVD), ABPI <0.9 gave a sensitivity of 69.2% (95% CI: 50.683.6%), specificity of 77.8% (95% CI: 52.493.3%), positive predictive value 81.8% (95% CI: 62.693.7%), and negative predictive value 63.2 (95% Diagnostic accuracy was 71.4% (95% CI: 56.9–83.5%).

ABPI <0.9 had sensitivity of 65.2% (95% CI: 48.379.4), specificity of 94.7% (95% CI: 74.099.9), positive predictive value of 91.3 (95% CI: 71.987.9) and negative predictive value of 74.2 (95% CI: 55.487.9) when CAD severity was defined as the presence of complex lesions (Diagnostic accuracy was 78.6% (95% CI: 64.5–88.8%).

The combined definition positive likelihood ratio was 12.32 (95% CI: 1.78 85.3), which means that an abnormal ABPI significantly elevated the risks of having severe CAD. The negative likelihood ratio was 0.37 (95% CI: 0.2359), which is moderate and means that a normal ABPI cannot rule out disease severity.

Univariate and Multivariate Analyses

Univariate logistic regression analysis revealed the following variables that are significantly related to complex CAD morphology (Type B2 or C lesions): abnormal ABPI (p=0.009), age (p=0.034), systolic blood pressure (p=0.018) as well as history of smoking (p=0.042), HbA1c (p=0.011), triglyceride (p=0.023) and HDL cholesterol (p=0.031). Complex lesion morphology did not have significant associations with gender, body mass index, fasting glucose, diabetes duration and LDL cholesterol through univariate analysis.

The final multivariate logistic regression model adopted a stepwise selection process (p<0.10 based on entry criterion) which conserved five variables in the final model (Table 3). The abnormal ABPI was independent of complex CAD morphology after correction by other variables (adjusted odds ratio 4.28; 95% CI: 1.18 sixteenteens 15.51; p=0.027). Other independent predictors of the final model were HbA1c (adjusted OR 1.89 per 10 mg/dL increase; 95% CI: 1.083.31; p=0.026), systolic blood pressure (adjusted OR 1.06 per 10 mmHg increase; 95% CI: 1.011.11), smoking status (adjusted OR 3.15; 95% CI: 0.9210.78), and The goodness-of-fit test: Hosmer-Lemeshow test showed that the model is calibrated reasonably (p=0.647).

Safety and Feasibility

All 42 enrolled patients without any adverse events successfully underwent ABPI measurement. The average ABPI measurement time was 8.31 x -21-21-21/3. There were no complications related to the measurement procedure in the patients, and no patient dropped out because of discomfort associated with measurement. The reproducibility was determined by measuring a subset of 15 randomly selected patients who had repeat ABPI measure in the next 2 hours; intraclass correlation coefficient of measures was 0.94 (95% CI: 0.86, 0.98) which showed that the reproducibility was excellent.

Tables

Table 1. Baseline Demographic, Anthropometric, and Metabolic Characteristics by ABPI Status

Variable	ABPI <0.9 (n=24)	ABPI ≥0.9 (n=18)	p-value
Age (years)	59.8 ± 8.9	55.8 ± 10.4	0.094
Male gender, n (%)	16 (66.7)	11 (61.1)	0.636
BMI (kg/m²)	28.1 ± 2.3	27.6 ± 2.9	0.534
Systolic BP (mmHg)	148.3 ± 11.5	138.4 ± 9.2	0.003
Diastolic BP (mmHg)	92.1 ± 8.7	87.2 ± 7.4	0.024
Hypertension, n (%)	18 (75.0)	9 (50.0)	0.048
Smoking, n (%)	9 (37.5)	3 (16.7)	0.077
Diabetes duration (years)	8.4 ± 5.2	7.8 ± 4.6	0.641
Fasting glucose (mg/dL)	168.4 ± 34.2	154.6 ± 28.7	0.083
HbA1c (%)	8.4 ± 1.1	7.8 ± 0.9	0.008
Total cholesterol (mg/dL)	194.2 ± 35.1	186.3 ± 32.4	0.351
LDL-C (mg/dL)	112.3 ± 28.6	108.4 ± 26.7	0.624
HDL-C (mg/dL)	35.2 ± 8.4	40.1 ± 9.7	0.039
Triglycerides (mg/dL)	201.3 ± 65.4	156.2 ± 52.1	0.018
Mean ABPI	0.71 ± 0.15	1.04 ± 0.11	<0.001

Patients with reduced ankle-brachial pressure index (ABPI <0.9) demonstrated significantly elevated systolic and diastolic blood pressure compared to those with normal ABPI (≥0.9), with mean values of 148.3 versus 138.4 mmHg and 92.1 versus 87.2 mmHg, respectively (p=0.003 and p=0.024). Hypertension prevalence was substantially higher in the reduced ABPI group (75.0% versus 50.0%, p=0.048). Metabolic profile was notably worse in patients with reduced ABPI, evidenced by higher HbA1c levels (8.4% versus 7.8%, p=0.008), elevated triglycerides (201.3 versus 156.2 mg/dL, p=0.018), and reduced protective HDL cholesterol (35.2 versus 40.1 mg/dL, p=0.039). Age, gender, BMI, and diabetes duration showed no significant differences between groups, suggesting reduced ABPI primarily reflects hemodynamic and metabolic dysfunction rather than baseline demographics.

Table 2. Coronary Angiographic Findings by ABPI Status

Variable	ABPI <0.9 (n=24)	ABPI ≥0.9 (n=18)	p-value
Vessel Involvement			
No coronary disease, n (%)	2 (8.3)	2 (11.1)	0.724
Single-vessel disease, n (%)	4 (16.7)	8 (44.4)	0.021
Double-vessel disease, n (%)	9 (37.5)	5 (27.8)	0.439
Triple-vessel disease, n (%)	9 (37.5)	3 (16.7)	0.142
Multivessel disease, n (%)	18 (75.0)	8 (44.4)	0.021
Mean # stenotic lesions/patient	2.4 ± 1.1	1.5 ± 0.9	0.006
Mean # target vessels/patient	1.79 ± 0.80	1.17 ± 0.51	0.003
Lesion Morphology			
Type A lesions, n (%)	1 (4.2)	3 (16.7)	0.167
Type B1 lesions, n (%)	4 (16.7)	7 (38.9)	0.083
Type B2 lesions, n (%)	7 (29.2)	5 (27.8)	0.915
Type C lesions, n (%)	12 (50.0)	3 (16.7)	0.009
Complex lesions (B2 or C), n (%)	19 (79.2)	8 (44.4)	0.014
Morphologic Features			
Chronic total occlusion, n (%)	8 (33.3)	2 (11.1)	0.091
Diffuse disease (>20 mm), n (%)	10 (41.7)	4 (22.2)	0.153
Heavy calcification, n (%)	11 (45.8)	6 (33.3)	0.336
Bifurcation/trifurcation lesions, n (%)	7 (29.2)	3 (16.7)	0.307

Patients with reduced ABPI (<0.9) exhibited more severe coronary artery disease patterns. Multivessel disease affected 75.0% of the reduced ABPI group versus 44.4% with normal ABPI (p=0.021), with significantly higher mean stenotic lesions (2.4 versus 1.5, p=0.006) and target vessels (1.79 versus 1.17, p=0.003). Complex lesion morphology was markedly predominant in reduced ABPI patients, with Type C lesions in 50.0% versus 16.7% (p=0.009), and combined complex lesions (Type B2 or C) present in 79.2% versus 44.4% (p=0.014). Morphologic features showed trends toward greater disease severity in the reduced ABPI group, including higher prevalence of chronic total occlusions (33.3% versus 11.1%) and diffuse disease (41.7% versus 22.2%), though these differences did not reach statistical significance. These findings demonstrate reduced ABPI is strongly associated with anatomically severe, diffuse coronary pathology.

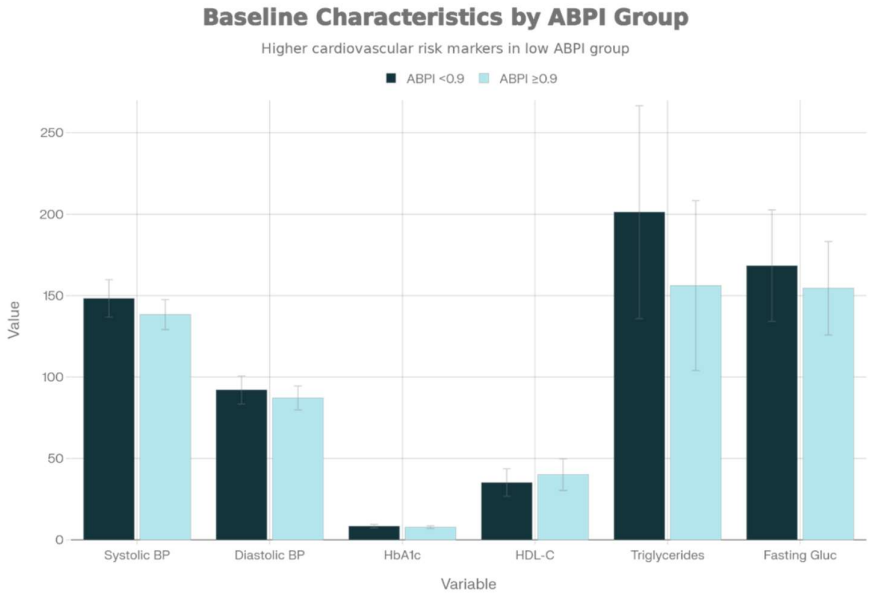
Table 3. Multivariate Logistic Regression Model for Complex CAD Morphology (Type B2 or C Lesions)

Variable	Adjusted OR	95% CI	p-value
ABPI <0.9	4.28	1.18–15.51	0.027
HbA1c (per 1% increase)	1.89	1.08–3.31	0.026
Systolic BP (per 10 mmHg increase)	1.06	1.01–1.11	0.019
Smoking status	3.15	0.92–10.78	0.066
Triglycerides (per 10 mg/dL increase)	1.01	1.00–1.02	0.043

Multiple independent factors were identified as significant predictors of complex coronary artery disease morphology (Type B2 or C lesions) after multivariate adjustment. Reduced ABPI (<0.9) demonstrated a 4.28-fold increased odds of complex lesion morphology (95% CI: 1.18–15.51, p=0.027). Each 1% increase in HbA1c elevated odds by 1.89 times (95% CI: 1.08–3.31, p=0.026), while each 10 mmHg systolic blood pressure elevation increased odds by 1.06 times (95% CI: 1.01–1.11, p=0.019). Triglycerides independently predicted complex morphology with an adjusted OR of 1.01 per 10 mg/dL increase (p=0.043). The model demonstrated good discriminatory ability (R^2=0.487) and excellent calibration (Hosmer-Lemeshow p=0.647), indicating reduced ABPI, glycemic control, hypertension, and triglyceridemia collectively identify patients at heightened risk for anatomically challenging coronary disease.

Figures

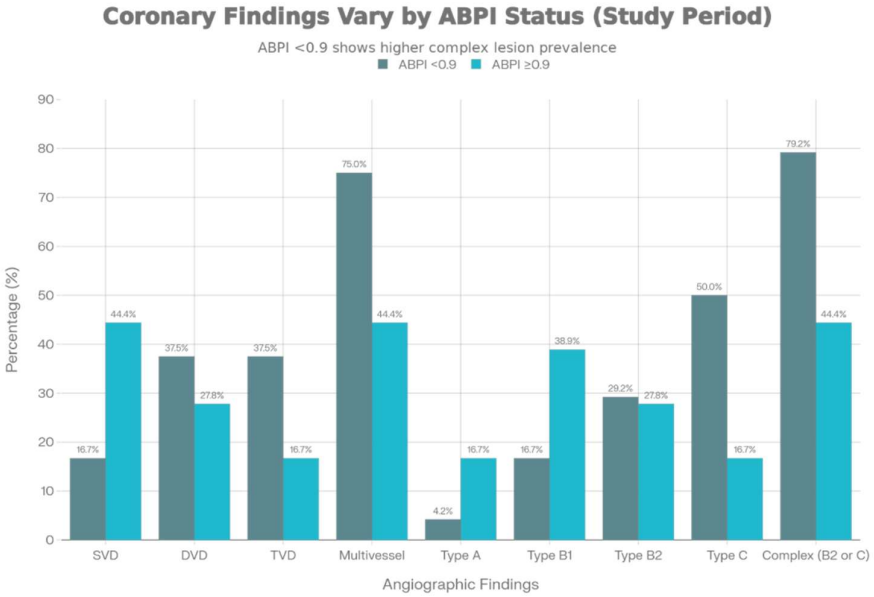
Figure 1. Distribution of Coronary Vessel Involvement by ABPI Status



[Descriptive caption: Bar chart showing the proportion of patients with single-vessel disease (SVD), double-vessel disease (DVD), triple-vessel disease (TVD), and multivessel disease (MVD) among those with abnormal ABPI (<0.9) versus normal ABPI (≥0.9). The chart clearly demonstrates the significantly higher prevalence of multivessel disease in the abnormal ABPI group (75.0%) compared to the normal ABPI group (44.4%, p=0.021).]

**Author for Correspondence: Dr. Resu Dilip Reddy*

Figure 2. Distribution of Coronary Lesion Morphology by ABPI Status



[Descriptive caption: Stacked bar chart displaying the frequency distribution of ACC/AHA lesion classifications (Type A, Type B1, Type B2, and Type C) among patients with abnormal versus normal ABPI. The chart illustrates the substantially higher prevalence of complex lesions (Type B2 and C combined) in the abnormal ABPI group (79.2%) compared to the normal ABPI group (44.4%, p=0.014), with Type C lesions alone being significantly more common in the abnormal ABPI cohort.]

DISCUSSION

This paper offers evidence that ankle-brachial pressure index which is a simple and easily available non-invasive measure has great diagnostic value in determining T2DM patients with severe coronary artery disease. The main result, including the fact that, when accounting for demographic and metabolic confounders, ABPI <0.9 is an independent predictor of complex CAD lesion morphology and multivessel involvement, comes to extend the prior results and provide implication to medical practice: it may be used as a predictive factor in patients with diabetes who are suspected of having CAD.

Our results are in line with the classical study conducted by Chang and others, who proved that low ABPI is a predictor of the existence of CAD in diabetics [3]. Thanks to their study sample of 155 patients with T2DM, ABPI below 0.9 showed an odds ratio of 8.45 to predict CAD when compared to patients without diabetes (and no odds ratio of 3.91 to predict CAD), the value of abnormal ABPI in predicting CAD in the diabetic setting was particularly strong. Our work goes further to provide meaning, illustrating that ABPI-defined PAD does not not only detect CAD but also specifically predicts its severity both in complexity of the lesion morphology and the amount of vessels involved.

In the present analysis, 79.2% of patients with T2DM with ABPI under 0.9 had complex coronary lesions (Type B2 or C) whereas only 44.4% of patients with normal ABPI had complex coronary lesions. This dramatic disparity remained even following the adjustment of age, blood pressure, glycemic control, and lipid parameters, and made ABPI an independent factor in the phenotype of CAD severity. Further, the positive likelihood ratio value (12.32) is very high, which implies that the detection of low ABPI in a diabetic patient in fact changes the post-test probability of severe CAD; a negative likelihood ratio value of 0.37 suggests that a normal ABPI value fails to reliably rule out the severe CAD, thus; further clinical attention is necessary even where the ABPI value is favorable.

The mechanism underlying the connection between the ABPI-CAD severity and the severity of CAD is probably multiple and connected pathophysiologic pathways. On the most general level, both PAD and CAD are expressions of systemic atherosclerosis that is provoked by such common risk factors as hypertension, dyslipidemia, smoking, and diabetes per se. The high total atherosclerotic burden, such as coronary involvement, is, therefore, a proxy of the presence of significant PAD as indicated by low ABPI. Alongside this general principle, however, there has been also emerging evidence to indicate more specific mechanistic correlations between the severity of PAD and CAD.

Recent studies have shed light on a putatively causal interdependence amid peripheral vascular disease and the extent of coronary atherosclerosis mediated by systemic inflammation and endothelial malfunction. In a study conducted by Holubkov et al., it was found that myeloperoxidase and interleukin-6 levels were higher in the femoral circulation of patients who had PAD together

with CAD, compared with the patients who had CAD alone, and these inflammatory mediators had a positive correlation with impaired assessment of coronary endothelial functions with cold pressor test [4]. These results indicate the possibility of systemic effects of inflammation that starts in ischemic peripheral tissues and promotes the further development of coronary atherosclerosis and destabilized pre-existing plaques.

The dysfunctional endothelial cell that is characteristic of both PAD and CAD includes adhesion molecules (ICAM-1, VCAM-1, E-selectin, P-selectin) upgrading, increased leukocyte recruitment and transmigration, enhanced secretion of inflammatory cytokines into the blood (TNF-alpha, IL-6), and dysregulation of platelet activation processes. These inflammatory processes are especially strong in diabetic patients whose hyperglycemia accumulates advanced glycation end products, promotes oxidative stress in a variety of pathways such as the polyol pathway or increasing the activity of protein kinase C, and has a direct and deleterious effect on endothelial functioning by uncoupling endothelial nitric oxide synthase. The existence of PAD in a diabetic patient therefore determines a person with an extremely high amount of inflammatory loads and with grossly impaired endothelial protective systems, which clarifies a much more assaultive atherosclerotic phenotype in an angiographically.

It is also known that type 2 diabetes encourages the formation of atherosclerotic plaques with specifically undesired features such as increased lipid content, increased necrotic core volume, pre-eminent thin-cap fibroatheroma morphology, increased calcium deposition. Increased dense calcium and necrotic core, more frequent thin-cap fibroatheroma and fibrocalcific atheroma have been reported in diabetic patients compared to non-diabetic individuals through virtual histology intravascular ultrasound studies. These characteristics are directly related with ACC/AHA Type B2 and Type C of lesions applied in the present study which entails heavy calcification, diffuse disease, tortuosity that are used to describe the complexity of diabetic atherosclerotic lesion.

The finding that the power of ABPI-defined PAD is a highly predictive parameter of this extreme that manifests as plaque, points to the fact that those individuals who have evidence of severe peripheral vascular disease have reached a critical threshold of systemic atherosclerotic burden at which coronary plaques have assumed particularly adverse structural and compositional features. This observation has significant prognostic implications, with poorer post percutaneous coronary intervention outcomes signaled by complicated lesion morphology (Type C lesions specifically) being associated with increased incidences of restenosis, no-reflow phenomena, target lesion revascularization, and major adverse cardiac events.

The high specificity of ABPI (94.7) and the positive predictive value of ABPI (91.3) in the present context indicate that ABPI measurement has the potential to be a useful tool to risk sort T2DM patients with suspected CAD. Abnormal ABPI patients should be vigorously pursued to determine their definitive diagnosis through coronary angiography and other potentially more intensive preventive treatment as they by far have a significantly high risk of developing complex atherosclerotic disease with its resultant morbidity and mortality.

On the other hand, the average sensitivity (65.2%), and negative ratio of 0.37 serves as an indication that normal ABPI is not a certain indicator that the CAD is not significant especially in diabetic patients. This restriction indicates the already reported process of arterial stiffening and medial calcification in diabetes that may lead to artificially normal or even increased ABPI, despite the presence of a large stenosis in the calcified arteries. The ABPI might not reduce accordingly when there is medial arterial calcifying despite the functional impairment of blood flow. In these cases, alternative testing modalities such as toe-brachial index, carotid intima-media thickness or the direct non-invasive imaging of coronary atherosclerosis may be used as complementary diagnostic data.

Alternative non-invasive surrogate markers of coronary atherosclerotic burden in diabetic populations have come to be known as Carotid intima-media thickness (CIMT). A recent report by Prashanth and colleagues has directly compared ABPI with CIMT with respect to its predictive capabilities regarding the severity of CAD among diabetic patients [5]. In circumstances where CIMT and ABPI were tested independently, CIMT had better sensitivity (83.7% vs. 65.2% in the present study) at the expense of specificity relative to ABPI of severe CAD. When CIMT and ABPI however were used as parallel methods (there had to be abnormality in either) the combination of both yielded a sensitivity of 83.7 and a specificity of 83.8; indicating that possibly concomitant application of the two measurements could maximize diagnostic accuracy.

The other more recent study by Reda and colleagues in an Egyptian diabetic group explored the association between ABPI and the severity of CAD measured using angiography, which is analogous to the present study [6]. They make reports that ABPI less than 0.9 detected CAD with a sensitivity of 84% and specificity of 91% which are a little higher than those found in the present cohort but their study never specified the analysis of lesion morphology classification and odds ratio adjusted.

Another significant clinical consideration that was emphasized in the Prashanth study is that the traditional ABPI cutoff value of 0.9 should be changed based on diabetic populations [5]. They observed that ABPI ranges of 0.9 1.1 often ruled angiographically-confirmed CAD in diabetic individuals, and higher cutoffs (e.g., less than 1.0 or less than 1.1) may be superior in this patient group. This is currently a fascinating observation that should be furthered into research since there is a possibility that this observation could significantly add to the level of

sensitizing the standard of ABPI-based screening of diabetic cohort at the expense of its specificity.

The multivariate analysis established that in addition to ABPI, many other variables could predict complex coronary lesion morphology independently in this cohort of T2DM patients. Glycemic control status, measured by HbA1c became a strong independent predictor (adjusted OR 1.89 per 1% increment) as previously observed that chronic hyperglycemia has an oncolytic effect of promoting atherosclerosis progression, and plaque composition. Equally, a high systolic blood pressure, a high level of triglycerides and active smoking status were independent risk factors to complex CAD, findings that are consistent with cardiovascular epidemiology and highlight the multifactorial aspect of atherosclerotic disease in diabetes.

This fact suggests that ABPI is a stronger predictor which remains after controlling such variables (adjusted OR 4.28) suggesting that ABPI has the capacity to represent atherosclerotic burden not detailed by standard risk factors and glycemic control parameters. This is probably also an indication that ABPI is the combined hemodynamic impact of atherosclerosis across the entire lower extremity vascular bed and could be a more comprehensive measure of systemic atherosclerotic disease than any single metabolic or hemodynamic marker.

A number of the methodologic limitations is worth mentioning. To start with, the sample size (n=42) is relatively small, which limits the statistical power and extrapolation of results. The study had power to identify significant variations in prevalence of ABPI and severity of CAD, but might lack adequate power to identify minor variations in other subgroup analyses. Secondly, cross-sectional cannot be used to estimate how things change over time or even draw causal conclusions. Even though PAD, as defined by ABPI alone, is an independent predictor of CAD severity at one time, the research does not determine whether PAD goes before or after the onset of the development of coronary atherosclerosis, or whether interventions to achieve improvement of ABPI are followed by decreases in the severity of CAD complications.

Third, ABPI measurement under arterial calcification conditions with specific references to T2DM may provide inaccurate high values, which might underestimate the real PAD rates among diabetic patients. Medial arterial calcification occurs in about 3040 percent of T2DM patients, leading to augmented arterial rigidity and potentially to ABPI greater than 1.4 with a lot of significant functional vascular disease. The present study did not specifically measure the burden of arterial calcification or focused attention on the subgroup of patients with high ABPI per se; it is an essential shortcoming of further work.

Fourth, the study sample was selected at a single tertiary center and presumably enriched with more severe CAD (as indicated by the 90.5 percent angiographic disease prevalence), which may be unrepresentative of a primary care or general population. Fifth, we have simply used the standard ABPI cutoff of 0.9 instead of discussing what might be the utility of higher cutoffs in the diabetic populations.

Lastly, they failed to include direct measures of systemic inflammation (e.g., high-sensitivity C-reactive protein, interleukin-6) or endothelial functional assessment, which means that we could not test directly proposed mechanistic pathways between PAD severity and coronary atherosclerosis.

Such results indicate some directions to be pursued in the future. The generalizability of the research finding to other ethnic groups, geographic areas, and health care settings would be formed by multi-center, prospective cohort studies with bigger samples and more varied population. The prospective (long follow-up) observation of enrolled patients to determine whether ABPI-identified high-risk subjects have an elevated event rate of major adverse cardiovascular events would prove the value of ABPI as a prognostic variable and support its inclusion in risk prediction models. The use of different ABPI cutoffs specifically designed to perform optimally in diabetic populations, possibly with age, arterial calcification load or complementary measurements like toe-brachial index included, may also improve diagnostic accuracy.

Mechanistic studies that involve ABPI evaluation with the direct measurement of parameters of inflammatory biomarkers (TNF-, interleukins, myeloperoxidase) and endothelial functional evaluation (flow-mediated dilation, reactive hyperemia index) and non-invasive imaging of coronary atherosclerosis (coronary calcium scoring, coronary CT angiography) would help to understand the precise pathophysiologic pathways connecting peripheral and coronary atherosclerosis in diabetic populations. Lastly, randomized trials examining the hypothesis that intensive ABPI-based risk stratification and selective aggressive treatments in identified high-risk individuals have better outcomes than traditional risk assessment would determine clinical utility and inform a transition to practice.

CONCLUSION

The ankle-brachial pressure index is an easy, non-invasive, cheap, and easily reproducible technique of identifying type 2 diabetes mellitus patients in high risk of severe coronary artery disease. This paper has shown that ABPIs values below 0.9 are independent predictors of the complex coronary lesion morphology and multivessel disease on the basis of the outcome after the consideration of pre-existing demographic and metabolic risk factors. The specificity (94.7) and positive predictive value (91.3) imply that the ABPI measurement may complement existing risk stratification strategies among diabetic groups in the community, enabling clinicians to focus on invasive diagnostic testing and escalate preventive measures among those with abnormal ABPI. The implementation of ABPI evaluation into the standard cardiovascular evaluation

protocols attending T2DM patients exhibiting symptoms of chest pain, dyspnea, or objective ischemia would help in the timely identification of at-risk patients and possibly increase the outcome through the implementation of specific therapeutic interventions. Yet, the intermediate sensitivity and the known shortcomings of ABPI in the environment of extensive arterial calcification requires that normal ABPI values cannot be used to rule out CAD in diabetic individuals. Prospective studies involving bigger sample sizes, varied populations, mechanistic research, and long-term outcome results are all further likely to illuminate the clinical applicability of ABPI in the risk stratification of diabetic CAD.

REFERENCES

1. Einarson TR, Acs A, Ludwig C, Panton UH. Prevalence of cardiovascular disease in type 2 diabetes: a systematic literature review of observational studies. Cardiovasc Diabetol. 2018;17(1):21.
2. Emerging Risk Factors Collaboration. Diabetes mellitus, fasting glucose, and risk of cause-specific death. N Engl J Med. 2011;364(9):829-841.
3. Dangas GD, Farkouh ME, Sleeper LA, et al. Angiographic findings and clinical outcomes in diabetic patients with acute myocardial infarction: the NHLBI Dynamic Registry. Catheter Cardiovasc Interv. 2003;60(4):508-513.
4. Weyer C, Funahashi T, Tanaka S, et al. Hypoadiponectinemia in obesity and type 2 diabetes: close association with insulin resistance and hyperinsulinemia. J Clin Endocrinol Metab. 2001;86(5):1930-1935.
5. Morrish NJ, Stevens LK, Fuller JH, Keen H, Jarrett RJ. Mortality and causes of death in the WHO Multinational Study of Vascular Disease in Diabetes. Diabetologia. 2001;44 Suppl 2:S14-S21.
6. Hirsch AT, Criqui MH, Treat-Jacobson D, et al. Peripheral arterial disease detection, awareness, and treatment in primary care. JAMA. 2001;286(11):1317-1324.
7. Criqui MH, Langer RD, Fronek A, et al. Mortality over a period of 10 years in patients with peripheral arterial disease. N Engl J Med. 1992;326(6):381-386.
8. Newman AB, Sutton-Tyrrell K, Vogt MT, Kuller LH. Morbidity and mortality in hypertensive adults with a low ankle/arm blood pressure index. JAMA. 1993;270(4):487-489.
9. Fowkes FG, Murray GD, Butcher I, et al. Ankle brachial index combined with Framingham risk score to predict cardiovascular events and mortality: a meta-analysis. JAMA. 2008;300(2):197-208.
10. Aboyans V, Criqui MH, Abraham P, et al. Measurement and interpretation of the ankle-brachial index: a scientific statement from the American Heart Association. Circulation. 2012;126(24):2890-2909.
11. Baker JD, Dix D. Variability of Doppler ankle pressures with arterial occlusive disease: an evaluation of ankle index and stroke risk. Surgery. 1981;89(1):134-137.
12. Lijmer JG, Hunink MG, van den Dungen JJ, Loonstra J, Smit AJ. ROC characteristics of noninvasive tests for peripheral arterial disease. J Clin Epidemiol. 1996;49(12):1491-1498.
13. Chang ST, Chu CM, Hsu JT, Pan KL, Lin PG, Chung CM. Role of ankle-brachial pressure index as a predictor of coronary artery disease severity in patients with diabetes mellitus. Can J Cardiol. 2009;25(9):e301-e305.
14. Aboyans V, Ricco JB, Bartelink MEL, et al. 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for Vascular Surgery (ESVS). Eur Heart J. 2018;39(9):763-816.
15. Prashanth GR, Radhakrishnan K, Sethumadhavan R, Ponnuswamy SK. Utility of Ankle Brachial Pressure Index (ABPI) and Carotid Intima Media Thickness (CIMT) in predicting coronary artery disease severity among diabetic patients. J Evid Based Med Healthc. 2022;9(30):2290-2295.
16. Reda AA, El-Kersh AM, El-Habashy EM. Ankle brachial index in patients with type II diabetes mellitus undergoing coronary angiography. Menoufia Med J. 2021;34(1):32.
17. Chang ST, Chu CM, Hsu JT, Pan KL, Lin PG, Chung CM. Role of ankle-brachial pressure index as a predictor of coronary artery disease severity in patients with diabetes mellitus. Can J Cardiol. 2009;25(9):e301-e305.
18. Holubkov R, Kazmier FJ, Coffman JD. Abnormal endothelial-dependent vascular relaxation in peripheral vascular disease is not limited to the involved limb. Circulation. 1992;86(3):1099-1106.
19. Endemann DH, Schiffrin EL. Endothelial dysfunction. J Am Soc Nephrol. 2004;15(8):1983-1992.
20. Ceriello A. Acute hyperglycaemia: a 'new' risk factor for cardiovascular syndromes. Heart. 2005;91(2):145-147.
21. Hong YJ, Jeong MH, Choi RK, et al. Plaque rupture and intact fibrous cap in acute coronary syndrome: a study with intravascular ultrasound at culprit lesion. Int J Cardiol. 2004;96(1):47-53.
22. Mintz GS, Nissen SE, Anderson WD, et al. American College of Cardiology Clinical Expert Consensus Document on Standards for Acquisition, Measurement and Reporting of Intravascular

Ultrasound Studies (IVUS): A Report of the American College of Cardiology Task Force on Clinical Expert Consensus Documents. J Am Coll Cardiol. 2001;37(5):1478-1492.

23. Aboyans V, Criqui MH, Abraham P, et al. Measurement and interpretation of the ankle-brachial index: a scientific statement from the American Heart Association. Circulation. 2012;126(24):2890-2909.
24. Emdin CA, Anderson SG, Woodward M, Rahimi K. Usual blood pressure and risk of new-onset diabetes: a systematic review and meta-analysis of prospective cohort studies. J Am Coll Cardiol. 2015;66(14):1552-1562.
25. Prashanth GR, Radhakrishnan K, Sethumadhavan R, Ponnuswamy SK. Utility of Ankle Brachial Pressure Index (ABPI) and Carotid Intima Media Thickness (CIMT) in predicting coronary artery disease severity among diabetic patients. J Evid Based Med Healthc. 2022;9(30):2290-2295.
26. Reda AA, El-Kersh AM, El-Habashy EM. Ankle brachial index in patients with type II diabetes mellitus undergoing coronary angiography. Menoufia Med J. 2021;34(1):32.
27. Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. BMJ. 2000;321(7273):405-412.