Original Article

A Comparative Study for an Assessment of Arterial Stiffness with Cardio-Ankle Vascular Index and Clinical Determinants between those Individuals with and without Diabetes

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Background: Arterial stiffness and dysfunction are clinical determinants in predicting long-term cardiovascular risk in type 2 diabetes (T2DM). Cardio-ankle vascular index (CAVI) is a novel tool in detecting atherosclerosis by measuring arterial stiffness along the aorta to tibial arteries.

Objective: To compare clinical parameters between diabetes and non-diabetes groups. The present study explored clinical factors associated with CAVI of 8.0 or more in diabetes patients. Moreover, the study determined the correlation between CAVI and clinical predictors for long-term cardiovascular risk.

Materials and Methods: The present study was a retrospective, cross-sectional study. The controls or non-diabetes were matched with the cases or diabetes in ratio 2:1 and aged matched in two groups, 40 years and older and less than 40 years old.

Results: Two hundred fifty-two subjects were enrolled, 84 were diabetes and 168 were non-diabetes. The present study found those subjects with high body mass index (BMI) of 25.0 kg/m^2 or more and CAVI of 8.0 or more were the factors associated with greater risk of having diabetes than non-diabetes. Subjects with T2DM aged 40 years or older had 11.95 times greater risk of having CAVI of 8.0 or more than those younger than 40 years in T2DM ($p=0.002$). Known essential hypertension was another independent factor associated with 4.28 times greater risk of having CAVI of 8.0 or more than those without hypertension in T2DM ($p=0.010$). The present study found significant positive correlation between CAVI and the previously reported clinical markers, RAMA-EGAT score and the mean common carotid artery intima-media thickness, that predict long-term cardiovascular events in T2DM (Pearson's correlation coefficient; $r=0.6738$ and 0.4207, respectively, $p<0.05$).

Conclusion: Those subjects with CAVI of 8.0 or more and BMI of 25 kg/m^2 or more had significantly greater association with diabetes than non-diabetes. Age of 40 years or older and history of hypertension were independent risk of high CAVI of 8.0 or more in T2DM. CAVI also correlated with the previously reported clinical marker to predict long-term cardiovascular risk such as RAMA-EGAT score, the mean common carotid artery intima-media thickness in T2DM.

Keywords: Type 2 diabetes; Cardio-ankle vascular index (CAVI); Arterial stiffness

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Type 2 diabetes (T2DM) is a common chronic, non-communicable disease and associated with cardiovascular diseases (CVDs)[1]. CVD is the leading cause of death in patients with T2DM[2]. Moreover, the incidence of cardiovascular events, cerebrovascular disease, and arterial occlusion are more common in diabetic patients than in the normal population[3]. Chronic complications of T2DM are divided into macrovascular and microvascular complications. Diabetic patients with chronic complications have increased their mortality rate[4]. Therefore, the prevention of chronic complications and CVDs in diabetic patients is important, thus, diagnostic and therapeutic tools are urgently required for patients with T2DM.

Arterial stiffness and dysfunction are important determinants in predicting long-term CVD incidence in T2DM. Annual regular screening for the microvascular and macrovascular complications is recommended to help early detection and prompt treatment. Previous studies demonstrated some surrogate markers, such as ankle-brachial index (ABI), pulse wave velocity (PWV), and common carotid artery intima-media thickness (CCA-IMT)

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in diabetes, were capable of detecting asymptomatic arterial stiffness and atherosclerosis in diabetes[5].

Cardio-ankle vascular index (CAVI) is a novel marker in detecting atherosclerosis by measuring arterial stiffness along the aorta, femoral, and tibial arteries[6]. This parameter is not affected by blood pressure during measurements, which differs from the previous measuring tools such as PWV. Several reports have used a CAVI clinically to assess atherosclerotic disease and macro- and micro-vascular complications in patients with T2DM[7]. CAVI was demonstrated to be better than brachial ankle pulse wave velocity (BaPWV) and correlated with coronary atherosclerosis and carotid IMT[8,9].

The present study aimed to compare clinical demographics, blood chemistry profiles, anthropometric assessment, and cardiovascular measurements such as CAVI, ABI, and CCA-IMT, between diabetic and non-diabetic groups. The present study explored clinical and cardiovascular determinants associated with arterial stiffness marker such as high CAVI of 8.0 or more, in diabetes patients. The present study also determined the correlation between CAVI with long-term cardiovascular predictors such as RAMA-Electricity Generating Authority of Thailand (EGAT) heart score and CCA-IMT.

Materials and Methods

Study design and population

The present study was a retrospective, cross-sectional study. Inclusion criteria included male or female, age at least 18 years, that previously underwent cardiovascular risk and general health assessment at the Thai International Hospital, Samui district, Surat Thani Province and Mae Fah Luang University Hospital, Bangkok, Thailand between 1 July 2018 and 30 June 2020. Exclusion criteria were pregnant women, chronically infected with human immunodeficiency virus (HIV), chronic hepatitis B or C infection, malignancy with active treatment, or currently on medication that might affect arterial stiffness assessment such as pseudoephedrine or ephedrine. The present study was a rollover study from the previous study by Jularattanaporn et al (2019) entitled "Association of age with carotid IMT, arterial stiffness, and brachial artery systolic time intervals in Thai people undergoing a routine annual physical exam"[10]. Clinical data such as clinical demographics, medical history and illness, known underlying diseases, medication use, blood chemistry profiles, anthropometric assessment, and cardiovascular measurement including CAVI, ABI, and CCA-IMT, were collected and analyzed.

Five hundred seventy-nine individuals were included in this study and were divided into the cases or diabetic group by using the criteria of at least 8-hour fasting period, plasma glucose greater than or equal to 126 mg/dL, or glycated hemoglobin or hemoglobin A1C level at 6.5 gm% or greater, or known case of diabetes or currently taking anti-diabetes agents. The controls or non-diabetics were those without diabetes and matching the cases by principal investigator with 1:2 ratio basis, and by their age between 40 years and older versus younger than 40 years. If the total population size per group is greater than the number required, the investigator will use simple random sampling technique to select the samples as representative.

Data collection

All subjects gave signed consent prior to enrolling in the present study. The clinical measurement of arterial blood pressure, weight in kilogram, height in meter, body mass index (BMI) in kg/m^2, waist and hip circumference, CAVI, and CCA-IMT previously performed and recorded in source documents were collected. The laboratory results from the hospital's laboratory data archiving system included fasting plasma glucose, lipid profiles including total cholesterol, high density lipoprotein (HDL)-cholesterol, low density lipoprotein (LDL)-cholesterol, and triglyceride level were collected. History of general medical illness and CVD and current smoking status were recorded.

Cardio-ankle vascular index measurement

CAVI was measured using the vascular screening device, Fukuda VaSera, VS-1500 model. All subjects were advised to be in supine position with blood pressure cuffs on all four extremities. Electrocardigphic electrodes were applied. CAVI was calculated using the formula as $CAVI = 2\times(\text{Blood density}) / (Ps–Pd)\cdot(\ln Ps/Pd)\cdot PWV^2$; Ps and Pd=brachial systolic and diastolic pressure, PWV=pulse wave velocity calculated for the ratio of vascular distance from the heart to ankle divided by time duration of the blood circulating from the heart to ankle area[11]. According to Yingchoncharoen et al study, the best cutoff value of CAVI to predict coronary artery disease in Thais was 8.0 with 92% sensitivity and 63% specificity rate. Therefore, the present study selected CAVI at 8.0 as a cutoff point[12].

Common carotid artery intima-media thickness

The measurement of CCA-IMT was performed by using vascular ultrasound system device (Vivid-I, GE Healthcare, Chicago, Illinois, USA). CCA-IMT was measured at the distal part of the CCA near the bifurcation area. The measurement of the means, maximal, and minimal thickness of carotid intimal media were reported[10].

Operational definition

Metabolic syndrome was classified by the International Diabetes Federation Global Consensus, defined as those with one criteria of central obesity as waist circumference of 90 cm or more in male and 80 cm or more in female Asian population plus any two of the following four criteria, elevated triglycerides of 150 mg/dL or more, or low HDL-cholesterol of less than 40 mg/dL in male and less than 50 mg/dL in female, or abnormal blood pressure with systolic blood pressure (BP) greater than 130 mmHg or diastolic BP greater than 85 mmHg, or previously diagnosed with hypertension or raised fasting plasma glucose of 100 mg/dL or more, or previously diagnosed with diabetes[13].

The RAMA-EGAT heart score can be rated from factors loading including age, gender, total cholesterol level, cigarette smoking status, history of diabetes and hypertension, and excess waist circumference, which were used as predictor of long-term cardiovascular risks[14].

Statistical analysis

Descriptive data were reported with mean and standard deviation for numeric data and frequency and percentage for grouped data. Independent t-test if normal distributed data, and Wilcoxon rank-sum test if non-normal distributed data for continuous data were tested. In case of grouped data, Pearson's chi-square or Fisher' exact test was tested.

Univariate and multivariate analysis to compare between CAVI of 8.0 or more or less than 8.0 in diabetes, simple and multiple backward stepwise, binary logistic regression model was used. The factors with p-value less than 0.05 in univariate analysis were entered into the final analysis. Crude and adjusted odds ratio (OR) with 95% confidence intervals (CI) were reported. A p-value less than 0.05 represented statistical significance.

Pearson's correlation coefficient or Spearman's correlation coefficient was used to determine the strength of association between CAVI and the previous clinical markers such as ABI, RAMA-EGAT heart score and CCA-IMT.

The IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA) was used for data analyses.

The present study was approved by the Ethical Committee of Mae Fah Luang University on August 17, 2020 with EC number 20060-20.

Results

Five hundred seventy-nine individuals attending annual check-up visit at check-up clinic of the hospital were screened. Eighty-four participants with diabetes were age-matched with the participants without diabetes in the ratio of 1:2 categorizing into two groups, less than 40 years of age and 40 years or older. Two hundred fifty-two subjects met the study criteria and enrolled, 84 were diabetic and 168 were non-diabetic.

Comparison of clinical parameters between diabetes and non-diabetes group

The means of 8-hour fasting period, plasma glucose was significantly higher in diabetic group as compared to non-diabetic group ($p<0.0001$). Triglyceride level was higher in diabetic group compared to non-diabetic group ($p=0.0061$). Serum HDL-cholesterol level was significantly lower in diabetic group as compared to non-diabetic group ($p=0.0316$). Diabetic group had significantly greater BMI than non-diabetic group ($p=0.0087$).

Diabetic group had greater length of waist circumference than non-diabetic ($p=0.0002$) and greater waist-hip ratio (WHR) (p=0.000.1) (Table 1).

Diabetic group had significantly higher the mean (±SD) of CAVI at 7.83±1.48, than the non-diabetes group at 7.33±1.24 ($p=0.005$). The mean, CCA-IMT was significantly greater in diabetic group than the non-diabetic group at 0.64±0.13 cm versus 0.57±0.12 mm, respectively ($p=0.004$). Diabetic group had significantly greater maximal and minimal thickness of CCA-IMT than non-diabetic group ($p=0.0003$ and 0.0004, respectively).

For predictive long-term cardiovascular risk, the present study found the diabetic group had higher RAMA-EGAT heart score than the non-diabetics, at 16.2±7.7 versus 9.6±6.3, respectively, $p<0.0001$ (Table 1).

From the final analysis with the fitted model, significant factors included BMI of 25 kg/m^2 or greater and CAVI of 8.0 or more independently associated with diabetic than non-diabetic group by controlling for age factor. The present study found

Table 1. To compare clinical and laboratory measurements between the T2DM and non-T2DM group

Variables	Total		T2DM		Non-T2DM		p-value*
	n	Mean±SD	n	Mean±SD	n	Mean±SD	
Creatinine (mg/dL)	179	1.06±0.78	45	0.87±0.24	134	1.13±0.88	0.05
FPG (mg/dL)	182	116.1±50.3	65	158.6±57.1	117	92.5±24.1	<0.0001
Total cholesterol (mg/dL)	196	214.8±43.0	47	206.8±49.0	149	217.3±40.7	0.9292
Triglyceride (mg/dL)	191	144.4±97.9	46	175.8±111.3	145	134.4±91.4	0.0061
HDL-cholesterol (mg/dL)	100	54.8±20.1	40	50.3±21.7	60	57.9±18.7	0.0316
LDL-cholesterol (mg/dL)	99	126.6±38.7	39	122.7±36.2	60	129.1±40.4	0.7889
Waist circumference (cm)	252	34.5±4.3	84	35.9±4.3	168	33.8±4.2	0.0002
BMI (kg/m^2)	252	25.4±4.5	84	26.4±4.6	168	24.9±4.4	0.0087
Waist-hip ratio	221	0.88±0.70	67	0.91±0.08	154	0.87±0.07	0.0001
Systolic blood pressure (mmHg)	251	136.9±19.1	83	138.6±18.8	168	136.1±19.2	0.3191
Diastolic blood pressure (mmHg)	251	85.3±12.0	83	85.6±11.2	168	85.2±12.4	0.8044
Mean arterial pressure (mmHg)	251	102.5±13.5	83	103.0±13.1	168	102.2±13.8	0.6546
CAVI	252	7.50±1.35	84	7.83±1.48	168	7.33±1.24	0.005
ABI	252	1.03±0.15	84	1.04±0.07	168	1.03±0.18	0.558
CCA-IMT, maximal thickness (mm)	249	0.78±0.29	84	0.84±0.23	165	0.75±0.18	0.0003
CCA-IMT, mean thickness (mm)	249	0.59±0.13	84	0.64±0.13	165	0.57±0.12	0.004
CCA-IMT, minimal thickness (mm)	249	0.48±0.16	84	0.49±0.16	165	0.42±0.13	0.0004
RAMA-EGAT score	252	11.8±7.4	84	16.2±7.7	168	9.6±6.3	<0.0001

T2DM=type 2 diabetes; SD=standard deviation; FPG=fasting plasma glucose; HDL=high density lipoprotein; LDL=low density lipoprotein; BMI=body mass index; CAVI=cardio-ankle vascular index; ABI=ankle-brachial index; CCA-IMT=common carotid artery intima-media thickness

* Independent student t-test and Wilcoxon rank-sum test was applied to determine the difference between T2DM and non-T2DM group

Table 2. Univariate and multivariate analysis to determine clinical factors associated with T2DM

Variables	Total (n=252); n (%)	T2DM (n=84); n (%)	Non-T2DM (n=168); n (%)	Univariate analysis		Multivariate analysis	
				Crude OR (95% CI)	p-value*	Adjusted OR (95% CI)	p-value*
Male sex	97 (38.5)	33 (39.3)	64 (38.1)	1.05 (0.62 to 1.76)	0.859		
Cigarette smoking	37 (14.7)	9 (10.7)	28 (16.7)	0.59 (0.26 to 1.33)	0.205		
Known hypertension	116 (46)	49 (58.3)	67 (39.9)	2.34 (1.32 to 4.16)	0.004		
Known CVDs	4 (1.6)	2 (2.4)	2 (1.2)	3.43 (0.21 to 56.7)	0.390		
Known dyslipidemia	174 (69.1)	52 (61.9)	122 (72.6)	0.60 (0.34 to 1.06)	0.082		
BMI ≥25 kg/m^2	117 (46.4)	48 (57.1)	69 (41.1)	1.93 (1.12 to 3.33)	0.017	1.82 (1.05 to 3.15)	0.034
Excess waist circumference	146 (57.9)	56 (66.7)	90 (53.6)	1.74 (1.006 to 3.021)	0.048		
Metabolic syndrome	78 (30.9)	49 (58.3)	29 (17.3)	6.96 (3.64 to 13.3)	<0.001		
CAVI ≥8.0	89 (35.3)	42 (50.0)	47 (28.0)	2.95 (1.62 to 5.37)	<0.001	2.85 (1.55 to 5.22)	0.001

T2DM=type 2 diabetes; OR=odds ratio; CI=confidence interval; CVDs=cardiovascular diseases; BMI=body mass index; CAVI=cardio-ankle vascular index

* Backward stepwise, simple/multiple, conditional logistic regression was tested

diabetic group had 1.82 times greater association with high BMI of 25.0 kg/m^2 or more than those with non-diabetes, adjusted OR 1.82 (95% CI 1.05 to 3.15, p=0.034). Importantly, diabetic group had 2.85 times greater association with CAVI of 8.0 or more than non-diabetic group, adjusted OR 2.85 (95% CI 1.55 to 5.22, p=0.001) (Table 2).

Comparison of clinical and cardiovascular factors between CAVI of 8.0 or more and less than 8.0 in diabetic patients

The mean (±SD) age of those with CAVI of 8.0 or more was 58.7±9.3 years significantly higher than those with CAVI of less than 8.0 with 41.2±11.9 years (p<0.0001). The present study found that the CAVI

Table 3. To compare clinical and laboratory measurements between CAVI ≥8.0 versus CAVI <8.0 in T2DM patients (n=84)

Variables	Total		CAVI ≥8.0		CAVI <8.0		p-value*
	n	Mean±SD	n	Mean±SD	n	Mean±SD	
Age (years)	84	49.9±13.8	42	58.7±9.3	42	41.2±11.9	<0.0001
Creatinine (mg/dL)	45	0.87±0.24	30	0.89±0.25	15	0.82±0.23	0.4118
FPG (mg/dL)	65	158.6±57.1	30	154.8±59.6	35	161.8±55.5	0.6869
Total cholesterol (mg/dL)	47	206.8±49.0	29	207.1±53.6	18	206.2±42.2	0.4765
Triglyceride (mg/dL)	46	175.8±111.3	29	156.2±116.6	17	209.2±95.9	0.9401
HDL-cholesterol (mg/dL)	40	50.3±21.7	28	54.1±24.2	12	41.3±10.3	0.9556
LDL-cholesterol (mg/dL)	39	112.7±36.2	27	125.5±39.9	12	116.3±26.4	0.2338
Waist circumference (cm)	84	35.9±4.3	42	36.6±4.0	42	35.3±4.6	0.1614
BMI (kg/m^2)	84	26.4±4.6	42	26.7±4.5	42	26.2±4.7	0.6148
Waist-hip ratio	47	0.90±0.07	14	0.93±0.08	33	0.88±0.07	0.0347
Systolic blood pressure (mmHg)	84	138.6±18.8	42	146.5±9.9	42	130.9±14.3	0.0001
Diastolic blood pressure (mmHg)	84	85.6±11.2	42	90.5±10.3	42	80.7±10.0	<0.0001
Mean arterial pressure (mmHg)	84	103.0±13.1	42	109.1±12.7	42	97.3±10.9	<0.0001

T2DM=type 2 diabetes; SD=standard deviation; FPG=fasting plasma glucose; HDL=high density lipoprotein; LDL=low density lipoprotein; BMI=body mass index; CAVI=cardio ankle vascular index

* Independent student t-test and Wilcoxon rank-sum test was tested

Table 4. Univariate and multivariate analysis to determine clinical factors associated with CAVI ≥8.0 in T2DM patients

Variables	Total (n=84); n (%)	CAVI ≥8.0 (n=42); n (%)	CAVI <8.0 (n=42); n (%)	Univariate analysis		Multivariate analysis	
				Crude OR (95% CI)	p-value*	Adjusted OR (95% CI)	p-value*
Age≥40 vs. <40 years	61 (71.6)	40 (95.2)	21 (50.0)	20.0 (4.3 to 93.6)	<0.0001	11.95 (2.4 to 59.3)	0.002
Known hypertension	49 (58.3)	34 (80.9)	15 (35.7)	7.65 (2.83 to 20.71)	<0.0001	4.28 (1.43 to 12.88)	0.010
Sex: male	33 (39.3)	20 (47.6)	13 (30.9)	2.02 (0.83 to 4.94)	0.120		
Cigarette smoking	9 (10.7)	3 (7.1)	6 (14.3)	0.64 (0.11 to 1.98)	0.291		
BMI >25 kg/m^2	48 (57.1)	23 (54.8)	25 (59.5)	0.82 (0.35 to 1.96)	0.659		
Excess waist circumference	56 (66.7)	30 (71.4)	26 (61.9)	1.54 (0.62 to 3.84)	0.356		
known dyslipidemia	52 (61.9)	33 (78.6)	19 (45.2)	4.44 (1.7 to 11.54)	0.002		
Metabolic syndrome	49 (58.3)	30 (71.4)	19 (45.2)	3.03 (1.22 to 7.47)	0.016		

CAVI=Cardio-ankle vascular index; OR=odds ratio; CI=confidence interval; BMI=body mass index

* Backward stepwise, simple/ multiple binary logistic regression model was tested

of 8.0 or more group was significantly higher WHR than CAVI of less than 8.0 group (p=0.0347). CAVI of 8.0 or more group had significantly greater systolic and diastolic blood pressure than CAVI of less than 8.0 group (p<0.0001) (Table 3).

Clinical factors with p<0.05 in univariate analysis, included age of 40 years or older, known of hypertension, dyslipidemia, and metabolic syndrome were entered into the model for final analysis. From the best fitted model, the presented study found those subjects with age of 40 years or older and history of hypertension were the independent risks of high value of CAVI of 8.0 or more as the surrogate maker for arterial stiffness and long-term cardiovascular risk in T2DM. Those subjects whose CAVI of 8.0 or more had 11.95 times greater risk to be 40 years or older than those with CAVI of less than 8.0 in T2DM (adjusted OR 11.95, 95% CI 2.4 to 59.3, p=0.002). Those subjects with CAVI of 8.0 or more had 4.28 times greater risk of having a known of essential hypertension than those with CAVI of less than 8.0 in T2DM (adjusted OR 4.28, 95% CI 1.43 to 12.88, p=0.010). Concurrent older age of 40 years or older and essential hypertension was 13.6 times more likely to have CAVI of 8.0 or more (AOR 13.6, 95% CI 4.77 to 38.7) than those with less than 40 years of age and

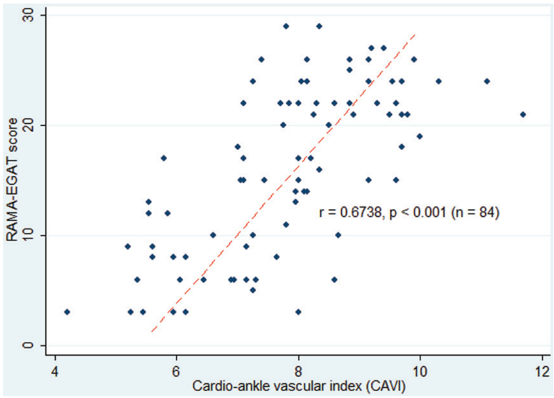

Figure 1. Scatter plot, correlation between CAVI and RAMA-EGAT heart score in type 2 diabetes.

without hypertension in T2DM ($p<0.0001$) (Table 4).

Correlation between CAVI with clinical parameters for long-term cardiovascular predictors

The present study found the significant positive correlation of CAVI and the previously reported long-term cardiovascular predictors such as RAMA-EGAT heart score, the mean, maximal, and minimal CCA-IMT in T2DM (Pearson's correlation coefficient, r=0.6738, 0.4207, 0.2345, and 0.4716, respectively; $p<0.05$) (Figure 1).

Discussion

Diabetes mellitus is a chronic disease that leads to multiple organ complications. CVDs are the major cause of mortality in diabetic patients[2]. Cardiovascular involvement in diabetic patients includes abnormal ventricular myocardium or large and small arteries dysfunction. Previous study addressed the benefit of intensive glycemic control in prevention of microvascular complications and cardiovascular events[15]. According to the cardiovascular risk classification from European Society of Cardiology guidelines in 2019, the cardiovascular involvements and clinical presentations differ remarkably in term of their disease severity among those patients in T2DM[16]. Therefore, annual screening for arterial stiffness is recommended as a risk modifier in asymptomatic patients with diabetes[16].

The present study found those subjects with high BMI of 25.0 kg/m² or more have higher risk of diabetes than those with normal BMI (p=0.034). High CAVI with greater than 8.0 was an independent factor for an association with diabetes. Age at 40 years or over and known hypertension were the independent factors of high CAVI in T2DM. Those subjects whose age are 40 years or older and had known essential hypertension with other independent factors had greater risk of having CAVI of 8.0 or more than those without hypertension in T2DM. The current study also found significant positive correlation between CAVI and the previously reported clinical markers that predict long-term cardiovascular events, RAMA-EGAT heart score, and the mean CCA-IMT in T2DM.

BaPWV was previously a standard tool for arterial stiffness screening and a marker for cardiovascular risk and atherosclerosis[5]. A study by Antonopoulos et al, which enrolled 414 subjects in T2DM, reported that those subjects with T2DM presenting with microvascular complication had high BaPWV and associated with higher incidence rate of cardiovascular death and cerebral stroke. However, BaPWV is affected by arterial blood pressure during the measurement[3]. The CAVI is a new index of the overall stiffness of the artery from the aorta to the ankle, and independent of blood pressure during measurement[6]. CAVI increases with age and associated with many arteriosclerotic diseases, such as coronary artery disease and common cardiovascular risk factors such as essential hypertension, diabetes mellitus and dyslipidemia[6]. Moreover, a previous study reported high CAVI correlated with left ventricular diastolic dysfunction from echocardiography[8]. Previous systematic review from an Asian cohort study, enrolling 5,217 subjects assessed the association between CAVI and CVD. It confirmed an association between high CAVI with incident risk of CVD[17]. In addition, a retrospective, cross-sectional study by Kim et al that enrolled 340 Korean T2DM patients aimed to determine the associations between the CAVI, which assessed arterial stiffness, CCA-IMT, and diabetic microvascular complications in Korean T2DM patients[7]. The present study found that CAVI was correlated with systolic blood pressure and IMT. Moreover, the mean IMT and the presence of carotid plaque were independently associated with increased CAVI greater than 9.0[7]. Furthermore, another study found the CAVI was positively correlated with CIMT[9].

A retrospective cross-sectional study was conducted in 23,257 healthy Japanese subjects that underwent health screening by Nagayama et al. It aimed to investigate the association of BMI with arterial stiffness assessed by CAVI. It found that high CAVI was associated with older age and male gender, essential hypertension, and impaired fasting glucose, but inverse relationship with high BMI in healthy Japanese subjects[18]. This finding differed from the present study which did not demonstrate any association between high BMI of 25 kg/m² or more and high CAVI. In the study by Tian et al conducted to investigate the relationship between arterial stiffness by using the CAVI measurement in T2DM, they found significantly higher CAVIs observed in patients with T2DM compared with non-T2DM patients, and age was the only significant factor affecting the CAVI, in patients with T2DM[19]. A study by Gomez et al aimed to identify an association between CAVI and target organ damages such as vascular structure and function, and cardiovascular risk in patients with T2DM and metabolic syndrome, the present study found those patients with any target organ damage or cardiovascular risks had high CAVI values. The CAVI score had a positive correlation with glycated hemoglobin level, systolic and diastolic blood pressure, and IMT. However, the present study did not demonstrate the correlation between CAVI value and waist circumference or BMI[20].

The present study had some limitations. Firstly, some confounding factors that might influence the results of the study such as medical treatment, personal behavior and lifestyle, cigarette smoking, and alcohol consumption were not analyzed. The present study was a cross-sectional study, which limited the capability to show the causal effect from these results. Additional prospective cohort study required to determine the clinical benefits of CAVI reduction or minimizing the risk of arterial stiffness and cardiovascular long-term risk in T2DM is warranted.

In conclusion, CAVI score of 8.0 or more and BMI of 25 kg/m² or more were the independent factors associated with diabetes. Those subjects with CAVI of 8.0 or more and BMI of 25 kg/m² or more were significantly more associated with diabetes than non-diabetes. Individuals with age of 40 years or older and history of hypertension were the independent risk of high CAVI score of 8.0 or more in T2DM. CAVI score also correlated with previously reported clinical marker to predict long-term cardiovascular events such as RAMA-EGAT heart score, the mean-, maximal-, and minimal- CCA-IMT in T2DM.

What is already known on this topic?

CAVI is a novel marker in detecting arterial stiffness and atherosclerosis. Several reports have used CAVI clinically to assess atherosclerotic disease and macro- and micro-vascular complications in patients with T2DM. Little is known about clinical determinants associated with arterial stiffness measuring by CAVI in diabetes patients. There is limited data to evaluate an association between CAVI and long-term cardiovascular risk predictors in Thais.

What this study adds?

The presented study found that individuals with age 40 years or older and history of hypertension were the independent risk of high CAVI score of 8.0 or more in T2DM. CAVI score also correlated with previously reported clinical markers to predict long-term cardiovascular events such as RAMA-EGAT heart score, the mean-, maximal-, and minimal- CCA-IMT in T2DM.

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Authors' contributions

Chalermchai T and Jularattanaporn V prepared the research project, recruited and enrolled the study subjects, and prepared the manuscript.

Conflicts of interest

All authors declare no conflict of interest.

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