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Relationship between arterial stiffness parameters and the extent and severity of coronary artery disease

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SOUHRN

Kontext: Souvislost mezi tuhostí tepen (arterial stiffness, AS) a ischemickou chorobou srdeční (ICHS) již byla prokázána. V popisované studii jsme se pokusili zjistit vztah mezi různými parametry AS a rozsahem a závažností ICHS.
Metody: Populaci ve studii tvořilo 411 pacientů s koronarograficky potvrzenou ICHS. Měřili jsme různé parametry AS včetně augmentačního indexu (augmentation index, AIx), augmentačního tlaku (augmentation pressure, AP), rychlosti pulsní vlny (pulse wave velocity, PWV), centrálního systolického tlaku (central systolic pressure, cSys), centrálního diastolického tlaku (central diastolic pressure, cDia) a centrálního pulsního tlaku (central pulse pressure, cPP); zároveň jsme provedli analýzu pulsní vlny. K výpočtu Gensiniho skóre a Syntax skóre jsme použili angiogramy. Parametry AS byly porovnány s Gensiniho skóre a se Syntax skóre.
Výsledky: Syntax skóre koreluje s věkem i s hodnotami cSys, cPP, PWV, AP, brachiálním pulsním tlakem (brachial pulse pressure, bPP), hemoglobinem, močovinou, přítomností diabetes mellitus, postižením kmene levé věnčité tepny (vždy $p < 0,10$). Gensiniho skóre však koreluje pouze s věkem, přítomností diabetes mellitus, postižením kmene levé věnčité tepny a bPP (vždy $p < 0,10$). Mnohorozměrová analýza prokázala, že věk, přítomnost diabetes mellitus, postižení kmene levé věnčité tepny a bPP významně predikují hodnotu Syntax skóre, zatímco v případě Gensiniho skóre byly za prediktory označeny věk, přítomnost diabetes mellitus, pohlaví, postižení kmene levé věnčité tepny a bPP.
Závěr: Parametry AS nijak nesouvisejí s hodnotami Gensiniho skóre ani Syntax skóre. Kromě tradičních rizikových faktorů se jediným významným prediktorem v případě Gensiniho skóre nebo Syntax skóre zdá být bPP.

ABSTRACT

Background: The association between arterial stiffness (AS) and coronary artery disease (CAD) has been previously demonstrated. In the present study, we aim to investigate the relationship between various AS parameters and the extent and severity of CAD.
Methods: The study population consisted of 411 patients with CAD documented by coronary angiography. We measured various AS parameters including augmentation index (AIx), augmentation pressure (AP), pulse wave velocity (PWV), central systolic pressure (cSys), central diastolic pressure (cDia) and central pulse pressure (cPP) with pulse wave analysis. Angiographic images were used to calculate Gensini score and Syntax score. AS parameters were compared using Gensini score and Syntax score.

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Results: Syntax score is correlated with age, cSys, cPP, PWV, AP, brachial pulse pressure (bPP), hemoglobin, urea, diabetes mellitus, left main coronary artery disease ($p < 0.10$ for each). However, Gensini score is correlated only with age, diabetes mellitus, left main coronary artery disease and bPP ($p < 0.10$ for each). Multivariate analysis revealed age, diabetes mellitus, left main coronary artery disease and bPP as significant predictors of Syntax score; however, for Gensini score, age, diabetes mellitus, gender, left main coronary artery disease, and bPP are determined as predictors.

Conclusion: AS parameters are not associated with Syntax score or Gensini score. Apart from traditional risk factors, bPP appears to be the only significant predictor for Syntax score and Gensini score.

Keywords:
Arterial stiffness
Central aortic pressure
Gensini score
Syntax score

Introduction

Coronary artery disease (CAD) is commonly associated with mortality and morbidity [1,2]. The gold standard technique used for the diagnosis of CAD is conventional invasive coronary angiography [3]. The extent, severity and complexity of CAD are assessed with Gensini score and Syntax score, both of which are associated with increased cardiovascular events [4,5]. Both scoring systems evaluate the anatomy, morphology and severity of coronary obstruction; however, Syntax score provides additional information about lesion complexity in terms of calcification, tortuosity, bifurcation or trifurcation localization, and thrombus burden in the context of guiding treatment strategy [6,7].

Arterial stiffness (AS) is a parameter indicating the elasticity of vessel wall which can be measured with invasive and non-invasive methods. One of the methods, the ARCSolver method (Austrian Institute of Technology, Vienna, Austria), is a non-invasive pulse wave analysis method proven to be consistent with conventional invasive and non-invasive AS measuring methods (tonometric method) [8,9].

Several studies investigating AS parameters revealed an association between pulse wave velocity (PWV) and augmentation index (AIx) in CAD [10–13]. In a study, Syntax score was found to be associated with brachial-ankle PVV [10]; while another study reported that aortic wave reflection and pulse wave amplification were associated with Gensini score [11]. Previous reports provided both positive and negative results regarding the relationship between CAD and AIx [12–14]. In the present study, we aim to investigate the relationship between AS parameters measured with an oscillometric device using a pulse wave analysis method, the ARCSolver method (Austrian Institute of Technology, Vienna, Austria) and two scoring systems; namely Gensini score and Syntax score, which indicate the severity, extent and complexity of CAD.

Methods

Study population

The study population consisted of 512 patients with suspected CAD who underwent conventional coronary angiography during the period between April 2013 and May 2014 at Medipol University Cardiology Department. Of these patients, 111 had normal coronary arteries (0 point based on Gensini score) documented with coronary angiography, and were excluded from the study. Exclusion criteria included acute coronary syndrome, left ventricle dysfunction (ejection fraction < 50%), severe valvular disease, renal failure, malignancy, severe infection, peripheral artery disease, coronary artery bypass graft or percutaneous coronary intervention.

Hypertension was defined as the average of two or more properly measured arterial blood pressure > 140/90 mmHg at each of two or more office visits after an initial screening or already receiving antihypertensive treatment. Diabetes mellitus was defined as fasting plasma glucose level ≥ 126 mg/dL or random plasma glucose ≥ 200 mg/dL plus diabetic symptoms or 2-hour plasma glucose ≥ 200 mg/dL in oral glucose tolerance test or HbA_{1c} level ≥ 6.5%. Active smoking was defined as smoking at least one cigarette per day. Positive family history for CAD was defined as the presence of CAD in men younger than 55 years of age, and women younger than 65 years of age among at least one of first-degree family members.

Instrumentation

The ARCSolver method (Austrian Institute of Technology, Vienna, Austria) provides estimates of central systolic pressure (cSys) , central diastolic pressure (cDia), central pulse pressure (cPP), augmentation index (Aix), and pulse wave velocity (PWV) using a validated oscillometric device (Mobil-O-Graph NG 24 hour PWA: IEM, Germany) to record pressure waves and the application of a general transfer function. The device is approved by Food and Drug Administration and Conformité Européenne, and its BP detection unit is validated according to the recommendations of British Hypertension Society and European Society of Hypertension [15].

Blood pressure measurements – pulse wave analysis

All recordings and measurements were performed by physicians with experience of the ARCSolver method and standard oscillometric blood pressure measurement procedures. Written informed consents were obtained from all patients. Patients were instructed to sit on a chair with legs uncrossed and feet flat on the floor, and their back resting against the chair backrest. A blood pressure cuff was then attached to the patient's left or right arm. The patient's arm was then rested on a table placing the cuff at approximately heart level. Patients were allowed to rest for approximately 5 minutes before blood pressure measurements, and resting heart rates were obtained. Systolic and diastolic blood pressure measurements were recorded by brachial measurements with the Mobil-O-Graph. Then the cuff was inflated at the diastolic blood pressure level and 10-second pulse wave analysis was recorded. A cut-off of 120 mmHg was chosen in order to determine erroneous peripheral diastolic blood pressure measurements. An algorithm consisting of 3 stages was applied following digitization. First step was verification of the single pressure waves by testing minimal position and corresponding wavelengths. Assessment of higher order time derivatives of the pressure signal in a repetitive way was utilized to detect minimum values. The second stage was comparison of all single pressure waves with one another to detect and avoid artifacts. Thereafter, aortic pulse waves were generated via transfer function. This would allow to modify a certain frequency range within the acquired pulse signal for derivation of the aortic pressure wave. The phase characteristics and modulus of the ARCSolver transfer function are described elsewhere in details [8,16,17]. The last stage was the verification of consistency among the measured parameters within the Mobil-O-Graph NG software package. This package provides visual inspection facility and uncovers consistently recorded intrinsic waveform distortion manually. Total duration for all of these processes was approximately 3 min.

Hemodynamic parameters

Brachial pulse pressure (bPP) was calculated as the difference between brachial systolic pressure (Sys) and brachial diastolic pressure (Dia) (bPP = Sys – Dia).

Central pulse pressure (cPP) was calculated as the difference between central systolic pressure (cSys) and central diastolic pressure (cDia) (cPP = cSys – cDia).

AP was calculated as the pressure difference between the second inflection point of systolic pressure wave and first inflection point. First inflection point is the arrival point of the wave spreading through ascending aorta and the pressure at this point is the inflection pressure [8].

AIx refers to the increase in aortic systolic blood pressure due to wave reflection in two forms, which are uncorrected and corrected for heart rate. AIx is defined as the ratio of AP to PP [16].

PWV is directly related to AS. It was calculated indirectly by a previously defined mathematical model utilizing parameters obtained with The Mobil-O-Graph system, pulse wave analysis and wave separation analysis [17].

Angiographic variables

Conventional coronary angiography was performed via percutaneous femoral artery access using the standard technique. Angiograms were analyzed by two experienced cardiologists blinded to the study. Normal coronary angiograms demonstrated by coronary angiography were considered as normal coronary arteries (0 point based on GS), and were excluded from the study. Gensini score and Syntax score were calculated on the remaining angiograms.

Gensini Score

Gensini score was calculated for each patient in order to reveal the extent and severity of atherosclerotic lesions angiographically [18]. This scoring system grades the narrowing of the lumen of coronary arteries (1 for 1–25% stenosis, 2 for 26–50% stenosis, 4 for 51–75% stenosis, 8 for 76–90% stenosis, 16 for 91–99% stenosis, 32 for total occlusion). This score is then multiplied by a factor that takes into account the importance of the lesion's position in the coronary arterial vasculature; for example: 5 for the left main coronary artery, 2.5 for the proximal left anterior descending coronary artery or proximal left circumflex coronary artery, 1.5 for the midregion of left anterior descending coronary artery, and 1 for the distal left anterior descending coronary artery or mid-distal region of the left circumflex. Gensini score was expressed as the total of the scores for all coronary arteries.

Syntax score

Syntax score is an anatomical scoring system to grade the complexity of CAD. All coronary lesions resulting in luminal narrowing ≥ 50% in vessels ≥ 1,5 mm were considered significant stenosis and calculated by online calculator version 2.1 at www.syntax-score.com [19].

Statistical analysis

Continuous variables are expressed as mean ± standard deviation and geometric mean. Categorical data are shown as frequencies and percentages. Continuous variables were tested by the Kolmogorov-Smirnov test. Logarithmic transformation was performed for some variables such as cSys, cDia, cPP, AP, PWV, PP, Ax, urea, hemoglobin, Gensini score and Syntax score due to their skewed distribution. The correlation coefficients are presented by Pearson's correlation analysis. Our multivariate analysis uses the significant independent variables at 10% level from this univariate analysis as covariates.

A linear regression analysis was performed to capture the effects of arterial stiffness measurements on Syntax score and Gensini score. Clinical and laboratory variables were used in the regression analysis to provide the control of individual differences. We performed the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity, and the normality/independence of regression disturbances. We also tested for Ramsey regression specification-error test for omitted variables. Multicollinearity was checked for the variables used in the regression analysis since the stiffness parameters were correlated with each other – which may cause bias in a multivariate setting. Accordingly, the variance inflation factor and tolerance values were used after the regression analysis to check for multicollinearity. Since the variance inflation factor and the tolerance values in our model were at acceptable levels (individual variance inflation factors less than 10 and average variance inflation factor less than 5), we ignored the multicollinearity in our analysis.

Table 1 presents the multivariate analysis for our model. The coefficients for each independent variable and the standard errors (in parenthesis) are presented in the table, and we show the independent variables significant at 1%, 5% and 10% with asterisks (***, **, and *), respectively. We used Stata 13 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP) for our statistical analysis.

Results

The present study analyzes the relationship between the AS measures and the Syntax score and Gensini score. The baseline demographic characteristics of the study sample are shown in Table 2. In Table 3, we present the correlati-

Table 1 – Multivariate linear regression (OLS) results.

	LogSyntax	LogGensini
Age	0.02*	0.01*
	(0.01)	(0.005)
DM	0.18*	0.25**
	(0.10)	(0.12)
Gender		0.37***
		(0.13)
Loghb	–0.27	
	(0.40)	
Logurea	0.05	
	(0.16)	
LMCA+	1.01***	1.29***
	(0.28)	(0.35)
LogcSys	0.26	
	(0.54)	
LogcPP	–0.26	
	(0.32)	
LogAP	–0.04	
	(0.07)	
Logpwv	–0.22	
	(0.67)	
LogPP	0.97***	0.37*
	(0.36)	(0.22)
Constant	–2.18	0.56
	(2.19)	(0.87)
R^2	0.15	0.08
N	411	411

Standard deviations in parenthesis * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
AP – augmentation pressure; cPP – central pulse pressure; cSys – central systolic pressure; DM – diabetes mellitus; Hb – hemoglobine; HT – hypertension; LMCA+ – left main coronary artery disease; Lg – logarithmic transformed; PP – pulse pressure; PWV – pulse wave velocity.

on coefficients using Pearson's correlation analysis. It shows that Syntax score is correlated with age, cSys, cPP, PWV, bPP hemoglobin, urea. However, Gensini score is correlated only with age and bPP. And finally, we present a linear regression analysis to capture the effects of AS measurements on Syntax score and Gensini score in Table 1. The AS measures are used in their logarithmic format due to non-normal distribution. Moreover, clinical variables are used in the regression analysis to control for the individual differences.

The results of the multivariate analysis (by using Ordinary Least Squares method, OLS) are presented in Table 1. Syntax score is the dependent variable in the first column and Gensini score is the dependent variable in the second column in Table 1. The results in the first column show that age, diabetes mellitus, left main coronary artery disease and bPP positively correlated with Syntax score.

Table 2 – Baseline demographic and laboratory characteristics for the patients.

	Patients n: 411
Age (years)	56 ± 10
Gender, n (male %)	288 (71)
Hypertension, n (%)	264 (65)
Diabetes mellitus, n (%)	147 (36)
Current smoking, n (%)	140 (34)
BMI (kg/m^2)	30 ± 4.7
SBP (mmHg)	127 ± 17
DBP (mmHg)	81 ± 11
Heart rate (bpm)	71 ± 11
PP (mmHg)[a]	45
Laboratory	
White blood cells (μl)	6.9 ± 1.9
Hemoglobine (g/dL)[a]	13.04
Platelet (μl)	231 ± 53
Urea (mg/dL)[a]	33
Creatinine (mg/dL)	0.7 ± 0.1
Arterial stiffness	
cSys (mmHg)[a]	117
cDia (mmHg)[a]	82
cPP (mmHg)[a]	35
AP (mmHg)[a]	7
PWV (m/s)[a]	8
AIx	20.6
Drugs	
ACEIs, n (%)	102 (25)
ARBs, n (%)	98 (24)
ß-blockers, n (%)	199 (49)
CCB, n (%)	67 (16)
Statins, n (%)	119 (29)
OADs, n (%)	112 (27)
ASA, n (%)	106 (26)
Clopidogrel, n (%)	38 (9.5)

[a] Values are expressed as geometric mean
ACEIs – angiotensin converting enzyme inhibitors; AIx – augmentation index; AP – augmentation pressure; ARBs – angiotensin receptor blockers; BMI – body mass index; CCB – calcium chanel blockers; cPP – central pulse pressure; cSys – csystolic, DBP – diastolic blood pressure; OAD – oral antidiabetic; PWV – pulse wave velocity; SBP – systolic blood pressure.

The syntax score will be 19.7% higher for the patients who have diabetes compared to those who do not have diabetes, 175% higher for the patients with left main coronary artery disease than those without left main coronary artery disease, when all other independent variables are held at a certain fixed value. With a one-unit increase in the age variable, we expect to see an increase

Table 3 – Univariate analysis using Pearson's correlation coefficients (*p*-values reported under correlation coefficients [* denotes a significance level of 0.10 or less; ** denotes a significance level of 0.05 or less].)

	LgSyntax	LgGensini	Age	Lghb	Lgurea	LgcSys	LgcPP	LgAP	Lgpwv	LgPP	LgAIx	Gender	HT	DM	LMCA+
LgSyntax	1														
LgGensini	0.7*	1													
	0.00														
Age	0.25*	0.09*	1												
	0.00	0.05													
Lghb	–0.13*	–0.05	–0.23*	1											
	0.01	0.28	0.00												
Lgurea	0.10*	0.03	0.30*	–0.04	1										
	0.03	0.29	0.00	0.34											
LgcSys	0.15*	–0.02	0.13*	0.00	0.00	1									
	0.00	0.70	0.00	0.97	0.99										
LgccPP	0.21*	0.03	0.18*	–0.14*	0.03	0.67*	1								
	0.00	0.61	0.00	0.00	0.50	0.00									
LgAP	0.17*	–0.02	0.30*	–0.22*	0.05	0.41*	0.56*	1							
	0.00	0.72	0.00	0.00	0.23	0.00	0.00								
Lgpwv	0.25*	0.07	0.87*	–0.16*	0.24*	0.47*	0.4*	0.41*	1						
	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00							
LgPP	0.27*	0.09*	0.28*	–0.18*	0.07*	0.63*	0.88*	0.60*	0.49*	1					
	0.00	0.05	0.00	0.00	0.09	0.00	0.00	0.00	0.00						
LgAIx	0.048	–0.069	0.183(**)	–0.179(**)	–0.028	0.266(**)	0.270(**)	0.809(**)	0.270(**)	0.299(**)	1				
	0.351	0.176	0.000	0.000	0.497	0.000	0.000	0.000	0.000	0.000					
Gender	–0.074	0.081	–0.136(**)	0.402(**)	0.026	–0.143(**)	–0.284(**)	–0.335(**)	–0.179(**)	–0.284(**)	–0.272(**)	1			
	0.140	0.104	0.001	0.000	0.515	0.000	0.000	0.000	0.000	0.000	0.000				
HT	0.046	–0.020	0.207(**)	–0.134(**)	0.176(**)	0.080(*)	0.088(*)	0.128(**)	0.204(**)	0.143(**)	0.059	–0.135(**)	1		
	0.357	0.688	0.000	0.001	0.000	0.049	0.029	0.002	0.000	0.000	0.159	0.001			
DM	0.169(**)	0.132(**)	0.086(*)	–0.129(**)	0.138(**)	0.074	0.154(**)	0.079	0.074	0.188(**)	0.024	–0.069	0.245(**)	1	
	0.001	0.008	0.034	0.001	0.001	0.069	0.000	0.052	0.067	0.000	0.567	0.089	0.000		
LMCA+	0.192(**)	0.192(**)	0.044	–0.006	0.070	–0.008	0.000	0.026	0.005	0.001	0.008	–0.031	0.024	0.126(*)	1
	0.000	0.000	0.382	0.903	0.159	0.868	0.994	0.608	0.924	0.985	0.883	0.542	0.626	0.012	

AIx – augmentation index; AP – augmentation pressure; cPP – central pulse pressure; cSys – central systolic pressure; DM – diabetes mellitus; Hb – hemoglobine; HT – hypertension; LMCA+ – left main coronary artery disease; Lg – logaritmic transformed; PP – pulse pressure; PWV – pulse wave velocity.

of approximately 2% in the Syntax score, since exp(0.02) = 1.02. When we look at the effect of PP, we can say that for any 10% increase in bPP, we expect an increase of about 9.7% in the Syntax score, while everything else remains constant.

Our second column in Table 1 shows that Gensini score is positively associated with age, diabetes mellitus, gender, left main coronary artery disease, and bPP. Thus, the Gensini score will be 28% higher for the patients who have diabetes compared to those without diabetes, and will be 45% higher for males than females when all other independent variables remain constant. As for the left main coronary artery disease variable; the Gensini score will be 263% higher for the patients with left main coronary artery disease than for those without left main coronary artery disease. With a one-unit increase in the age variable, we expect to see an increase of approximately 1% in the Gensini score, and for a 10% increase in bPP score, we expect about a 4% increase in the Gensini score, provided that everything else remains constant.

The R^2 shows that 15% of the variation in the Syntax score and 8% of the variation in the Gensini score is explained by all the independent variables included in the models.

Discussion

In the present study, we evaluated the relationship between AS parameters and Syntax score and Gensini score. When both clinical and stiffness parameters were assessed; age, DM, LMCA disease and bPP were found to be significant predictors for Syntax score; while age, DM, male gender, LMCA disease, and bPP were found to be predictors for Gensini score.

Gensini score has been used as a scoring system for the assessment of CAD extent and severity for a long time [18]. On the other hand, Syntax score is a more recent scoring system the use of which has become more and more common, providing additional information on lesion complexity and offering prognostic value within the context of death, myocardial infarction and revascularization [19]. In the present study, we found age, diabetes mellitus, left main coronary artery disease and bPP as significant predictors for both scoring systems and male gender as a significant predictor for Gensini score. Since age, diabetes mellitus and male gender are among traditional risk factors for CAD, and due to inclusion of left main coronary artery disease as a parameter in the scoring systems, the association between these factors is an expected finding.

Several studies have revealed the association between AS and CAD [1,11,12]. In a study which investigated the association between Syntax score and brachial-ankle PWV measured with volume-plethysmographic device, PWV was related to Syntax score [10]. Another study which excluded patients with peripheral artery disease revealed a significant association between CAD extent defined as 1-, 2- or 3-vessel disease and brachial-ankle PWV measured with volume-plethysmographic device [20]. To the best of our knowledge, the relationship between PWV and Gensini score has not been investigated to date. In addition to the current literature, we compared various AS parameters with both Gensini score and Syntax score. We found that PWV was not a predictor for Syntax score or Gensini score.

Composure of a more homogenous group by excluding patients with acute coronary syndrome, renal failure or heart failure, and measurement of PWV with an oscillometric device may have been the determinants of the inconsistency between our findings and the literature. AIx, a common AS parameter, is a hemodynamic index measured with pulse wave analysis. AIx is defined as the ratio of AP to PP [16]. AIx increases with advanced age until 60 years; however, after the age of 60, this increase diminishes [21]. Prior studies evaluating the relationship between AS and CAD provided different results according to the mean age of patients. In a study including 80 patients AIx was measured with an oscillometric device, and there was a significant association between the Gensini score and AIx in patients younger than 65 years, but not in patients aged ≥ 65 years [11]. Another study which graded CAD according to the number of diseased arteries showed no association between AIx and CAD in patients with an average age of 63 years [11]. Tanindi et al. demonstrated that AIx was associated with both Syntax score and Gensini score in145 patients with stable angina pectoris, unstable angina pectoris or acute MI who were divided into 3 groups according to AIx [22]. In our study population, the mean age was 56 years, and the different findings from other patient group under 65 years of age may be explained with the interaction between AIx measurement and several factors such as gender, heart rate and antihypertensive drugs. The impact of hemodynamic status on AS measurements is the main reason of the currently vague knowledge about AS parameters. Heterogeneity in selected patient groups and sample size may cause diversity among study findings.

Prior studies clearly demonstrated an association between central aortic pressure and cardiovascular mortality and morbidity [23]. In a study consisting of only male patients, invasively measured cPP was associated with CAD extent which was defined as 1, 2 or 3 vessel-disease [24]. Similarly, PP amplification which was defined as cPP/bPP was shown to be associated with Gensini score in patients < 65 years of age while no such association was observed in patients ≥ 65 years. Although we could not show an association between CAD and central aortic pressure, bPP was an important predictor for both risk scores. In this context, although bPP was defined as the arithmetic difference between systolic and diastolic blood pressure, it is affected by several mechanisms such as aortic elasticity, cardiac output, and peripheral vascular resistance. The association between CAD and cardiovascular mortality has been well established with large randomized trials [25]. In the Framingham Heart Study, each 10 mmHg increase in bPP was associated with 23% increased CAD risk [25]. In a study which included normotensive patients, bPP was shown to be associated with cardiovascular mortality in a patient group younger than 55 years age [26]. Another study including both normotensive and hypertensive patients aged 40–69 years, bPP was found to be associated with cardiovascular mortality in hypertensive and normotensive males, and hypertensive females [27]. Madhavan et al. reported increased cardiovascular complications in hypertensive patients receiving no antihypertensive treatment with PP > 63 mmHg [28]. However, the relationship between bPP and CAD has not been studied to date. The increase in PP with aging depends on the change of systolic and diastolic blood pressures over time. Diastolic pressure peaks around the age of 55 years, and afterwards, it progressively decreases whereas systolic pressure tracks a progressive increase through all decades. Therefore, there is a more close correlation between PP and significant predictor compared to that between diastolic pressure and advanced age. Increased systolic pressure is mainly associated with increased AS with aging [29]. The relationship between PP and CAD can be explained with several mechanisms; increased PP leads to greater stress on arteries and defragmentation in elastic components of vessel wall. Vascular intima becomes damaged and results in increased risk of atherosclerosis and thrombosis. In addition, increased PP causes increased stress over left ventricle which may lead to left ventricle hypertrophy and failure [30]. Increased systolic pressure increases myocardial oxygen consumption while decreased diastolic pressure limits coronary perfusion, resulting in ischemia. Therefore, bPP may be a more effective parameter during CAD development than others owing to all aforementioned characteristics, especially in younger patients. Moreover, bPP may be a more practical parameter due to having less interaction with central aortic pressure and a standard measurement method. Moreover, bPP measurement offers practical convenience without pulse wave analysis requirement. Several studies have investigated the association between CAD and cPP; however, further studies are required to better clarify the relationship between bPP and CAD extent and severity.

Study limitation

The study population is relatively young with an average age of 56 years. Patients were not grouped according to age and gender. Although the percentage of male patients in the present study was 70, we attempted to eliminate this factor by adding gender in the multivariate analysis. Antihypertensive treatment may affect blood pressure and subsequently various AS parameters.

Conclusion

AS parameters are not associated with Syntax score or Gensini score. The only significant predictor for Syntax score and Gensini score apart from traditional risk factors is bPP. When compared with AS parameters measured with pulse wave analysis, bPP may be a more practical and effective parameter to predict CAD development. Further studies are required to investigate the relationship between bPP and CAD extent and severity.

Conflict of interest
None declared.

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Authors state that the research was conducted according to ethical standards.

Informed consent
Informed consent was obtained from all patients.

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