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ORIGINAL RESEARCH

Color M-mode echocardiography-derived propagation velocity of descending aorta decreases with aging

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Background: Arterial stiffness (AS) can be determined by some noninvasive tests such as pulse wave velocity (PWV). Atherosclerosis is also detectable by some ultrasonographic techniques such as color M-mode-derived propagation velocity measured along the origin of the descending aorta (AVP).

Aim: The aim of the study was to find out a possible relationship between atherosclerosis and AVP and whether AVP can be used as a parameter of AS.

Materials and methods: The study group was composed of 134 people from routine screening examination who were ≥40 years old, completely healthy, and without any known disease and use of any drug. PWV has been determined to show aortic stiffness, and carotid artery intima–media thickness (CIMT) was measured for subclinical atherosclerosis. AVP values were obtained from all participants, and correlations were calculated between these parameters and age.

Results: AVP decreased ($r=-0.902$, $P<0.001$) and PWV increased ($r=0.854$, $P<0.001$) significantly with increasing age. CIMT also increased with aging ($r=0.518$, $P<0.001$). There were significant correlations between AVP and PWV ($r=-0.832$, $P<0.001$) and AVP and CIMT ($r=-0.345$, $P<0.001$).

Conclusion: Transthoracic echocardiographic determination of AVP can be used as a simple measurement of AS and correlates well with PWV, age, and CIMT in healthy people.

Keywords: color M-mode, pulse wave velocity, elderly, aortic propagation velocity, carotid intima–media thickness

Introduction

Cardiovascular diseases (CVD) are the main cause of morbidity and mortality in many countries.[1] Life expectancy has been increased, and as such, increasing age has become a major problem in the recent decades because advancing age has been found to be one of the most important risk factors for CVD.[1] Aging may increase the risk of developing CVD causing arterial dysfunction.[2]

Pulse wave velocity (PWV) is used as a gold-standard noninvasive measurement of arterial stiffness (AS). It has been proved to be independently related to mortality in normal population[3–5] and several diseases such as essential hypertension,[6] type 2 diabetes,[7] and end-stage renal disease (ESRD).[8–10] Other measurements for AS, including aortic distensibility, aortic strain, and carotid femoral[11] or aortofemoral PWV,[12] are not routinely used in clinical practice since they are difficult to perform and time consuming.

The carotid artery intima–media thickness (CIMT) is strongly correlated with the presence and extent of CVD[13,14] and associated with cardiovascular and

cerebrovascular events.[15] Besides, aortic PWV and CIMT have found to be significantly correlated with each other in several studies.[16,17]

Color M-mode-derived propagation velocity measured along the origin of the descending aorta (AVP) has been also shown to be associated with presence and severity of atherosclerosis in patients with coronary artery disease,[12] type 2 diabetes mellitus,[18] and coronary slow flow.[19] It has been thought in these studies that a decrease in the flow propagation speed within the arterial lumen may reflect the increased aortic resistance due to atherosclerosis.

The aim of this study was to investigate the relationship between AVP and subclinical atherosclerosis and whether AVP can be used as a parameter of aortic stiffness.

Materials and methods

The study group was composed of 134 people from routine screening examination who were ≥40 years old, completely healthy, non-smoker, and without any known disease and use of any drug. Four participants were excluded due to imaging problems. All the 130 participants included in our study had normal sinus rhythm ECG, and echocardiographic images were of sufficient quality. The study was approved by the local ethics committee of Ordu University Medical School. All participants were informed about the study and provided their written consents. Complete blood count and some biochemical markers have been obtained from patients. Peripheral blood was drawn from a vein into sterile tubes, one of which was containing ethylenediamine tetra-acetic acid,[20,21] and these samples underwent glucose, creatinine, and lipid profile measured by standard methods. Complete blood counts were measured by an automated hematology analyzer.

Transthoracic echocardiographic examination

Echocardiographic examination was performed by two experienced echocardiographers who were blinded to the clinical data. Three measures by each observer in each of 10 randomly selected patients were used to calculate inter-observer variability and 3 measures by the same observer from the same 10 randomly selected patients were used to calculate intra-observer variability.

The patients were at rest and in the left lateral decubitus position. A commercially available echocardiographic device (Vivid 5S; General Electric, Chicago, IL, USA) with a 3.0 MHz rectangular (linear-array) transducer was used for echocardiographic examinations. Color M-mode Doppler measurements from suprasternal window at supine position

were recorded with the cursor parallel to main flow of direction in descending aorta. Color Doppler Nyquist limit was set at 30–50 cm/s, and an M-mode spatio-temporal velocity map similar to the flame shape was obtained switching to M-mode with recorder sweep rate of 200 mm/s (Figure 1). If the slope of flame was not clear, the aliasing velocity was changed using baseline shifting until isovelocity slope was clearly delineated. Dividing the distance between points corresponding to the beginning and end of the propagation slope by the duration between corresponding time points, aortic flow propagation velocity was calculated. As a result, velocity at which the flow is propagating down the artery was measured as AVP. Mean of at least three measurements was recorded as AVP value.

PWV

Carotid femoral PWV was measured according to current guidelines[22] using the Complior device (Alam Medical, Vincennes, France). Pulsed-wave Doppler recordings were obtained from the descending thoracic artery at the origin of the subclavian artery and the left common femoral artery in supine position. Wavefront arrival at each location was defined by extrapolation of the ascending Doppler flow profile to the baseline using the electrocardiographic R wave as a time reference. Dividing the distance (measured on the body surface using a tape measure) by the time delay between two points, the descending aortofemoral PWV was
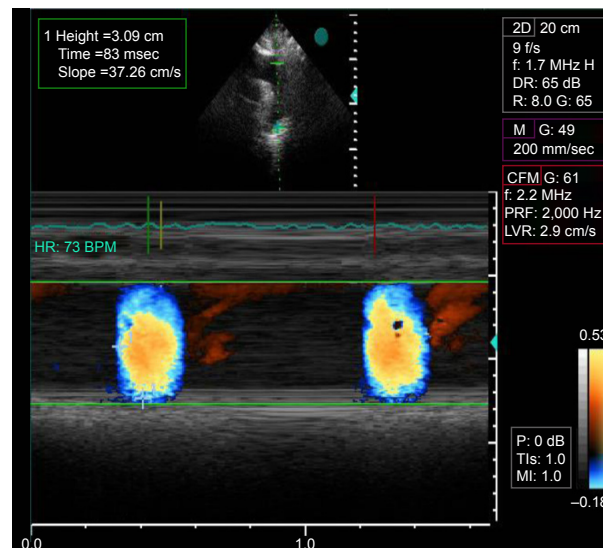

Figure 1 Measurement of color M-mode derived propagation velocity measured along the origin of the descending aorta (AVP).
Notes: The AVP was calculated by dividing the distance between points corresponding to the beginning and end of the propagation slope by the duration between corresponding time points.
Abbreviations: DR, deceleration rate; CFM, color flow mapping; PRF, pulse repetition velocity; LVR, left ventricular remodeling.

calculated.[23] To cover a complete respiratory cycle, the mean of five successive readings was used in the analysis.

CIMT measurements

The subjects' bilateral common carotid arteries were scanned longitudinally with a 7 MHz transducer attached to an available machine (Vivid 5S; General Electric). Indicating the border between the distal common carotid artery and the carotid bulb, the bulb dilation served as a landmark. Distal segment of the common carotid artery, 1–2 cm proximal to the carotid bulb, was used to obtain images. Intima and media lines were identified as two bright echogenic lines in the arterial wall. The intima–media thickness was measured as the distance between these lines. Images showing the maximum intima–media thickness were stored in a digitized fashion, and CIMT measurements were obtained offline. The mean of the measurements from both common carotid arteries was used for analysis. CIMT measurements did not include the plaques, defined as an endoluminal protrusion of the arterial lumen of ≥0.5 mm or localized ≥50% thickening of the intima compared to the rest of the wall.

Statistical analysis

Quantitative variables are expressed as mean ± standard deviation and qualitative variables as numbers and percentages. Pearson's correlation analysis was used for correlation measurements where necessary. SPSS for Windows, version IBM 22.0, was used for the statistical tests. Statistically significance was considered if $P<0.05$ was found.

Results

The baseline characteristics of the patients are summarized in Table 1.

Both the inter-observer variability and intra-observer variability for all the echocardiographic measurements were measured $<10\%$.

With increasing age, early diastolic flow (E), E/A ratio, and atrial contraction signal (A) decreased significantly ($r=-0.293$, $P=0.001$; $r=-0.239$, $P=0.006$; and $r=187$, $P=0.033$). Deceleration time (DT) and isovolumetric relaxation time (IVRT) significantly increased with increasing age ($r=0.232$, $P=0.008$ and $r=0.339$, $P<0.001$).

AVP decreased ($r=-0.902$, $P<0.001$) and PWV increased ($r=0.854$, $P<0.001$) significantly with increasing age. CIMT also increased with aging ($r=0.518$, $P<0.001$).

There were significant correlations between AVP and PWV ($r=-0.832$, $P<0.001$) (Figure 2), AVP and age ($r=-0.902$, $P<0.001$) (Figure 3), AVP and CIMT ($r=-0.345$,

Table 1 Clinical and echocardiographic characteristics of study population

Characteristics	Study group
Age, years	63.2±10.6
Men, n	78 (60%)
BMI, kg/m²	26.9±4.1
SBP, mmHg	121.7±13.6
DBP, mmHg	74.6±8.0
Pulse pressure, mmHg	47.1±10.2
Heart rate, beats per minute	73.1±9.9
White blood cell, k/μL	6.8±1.3
Hemoglobin, g/dL	13.8±1.1
Hematocrit, %	42.3±4.0
Platelet, k/mL	235.8±67.7
Fasting glucose, mg/dL	92.0±7.2
Aspartate transaminase, U/L	29.1±11.1
Alanine transaminase, U/L	23.4±11.6
CRP	3.2±0.6
Total cholesterol, mg/dL	187.6±24.4
LDL cholesterol, mg/dL	113.1±18.9
HDL cholesterol, mg/dL	44.1±10.2
Triglyceride, mg/dL	169.6±66.5
Creatinine, mg/dL	0.85±0.15
Left atrial diameter, cm	3.80±0.43
Aortic diameter, cm	3.01±0.29
LVDD, cm	4.70±0.36
LVSD, cm	3.05±0.44
IVS, cm	0.97±0.12
PW, cm	0.93±0.12
LVEF, %	62.13±2.47
E_{max}, m/s	0.64±0.12
A_{max}, m/s	0.60±0.14
E/A ratio	1.14±0.39
DT, ms	235.88±46.77
IVRT, ms	88.21±25.20
PWV, m/s	8.85±1.48
AVP, cm/s	54.36±8.81
CIMT, mm	0.80±0.11

Note: Data presented as mean ± SD or n (%).
Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; LDL, low-density lipoprotein; HDL, high-density lipoprotein; LVDD, left ventricular diastolic diameter; LVSD, left ventricular systolic diameter; IVS, interventricular septum thickness; PW, posterior wall thickness; LVEF, left ventricular ejection fraction; max, maximum; E, early diastolic flow; A, atrial contraction signal; DT, deceleration time; IVRT, isovolumetric relaxation time; PWV, pulse wave velocity; AVP, color M-mode derived propagation velocity measured along the origin of the descending aorta; CIMT, carotid artery intima–media thickness.

$P<0.001$) (Figure 4), PWV and age ($r=0.854$, $P<0.001$), and PWV and CIMT ($r=0.424$, $P<0.001$).

Discussion

In this study, we have found that AVP measured by transthoracic echocardiography is decreased in elderly people and significantly correlated with PWV and CIMT.

As a marker of vascular aging, AS is regarded to be a major risk factor for atherosclerotic events and CVDs. Besides, AS
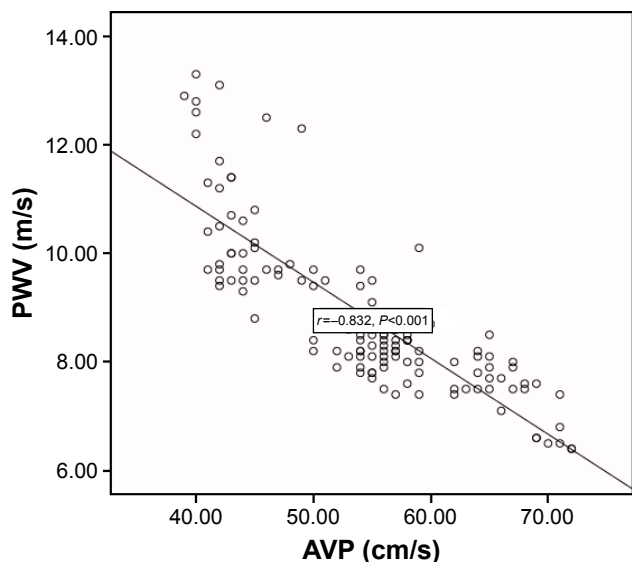
Figure 2 Scatter plot of AVP for PWV measurements.
Abbreviations: AVP, color M-mode derived propagation velocity measured along the origin of the descending aorta; PWV, pulse wave velocity.
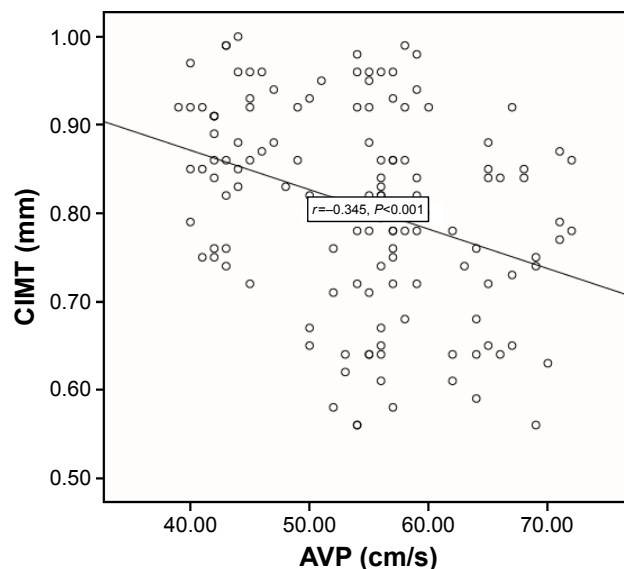
has been found to be associated with several cardiovascular risk factors including diabetes mellitus, obesity, smoking, hypercholesterolemia, hypertension, and advanced age.[6] Aortic distensibility and aortic strain decrease in parallel to the increase in the extent and the severity of the atherosclerosis. Tunica media thicken and get stiffer with the progression of atherosclerosis. Some noninvasive methods such as AVP in our study may demonstrate the atherosclerotic disease before it becomes clinically important. The arterial resistance increases as the arterial wall gets thick and stiff and the increase in arterial resistance decreases the flow and thus AVP.
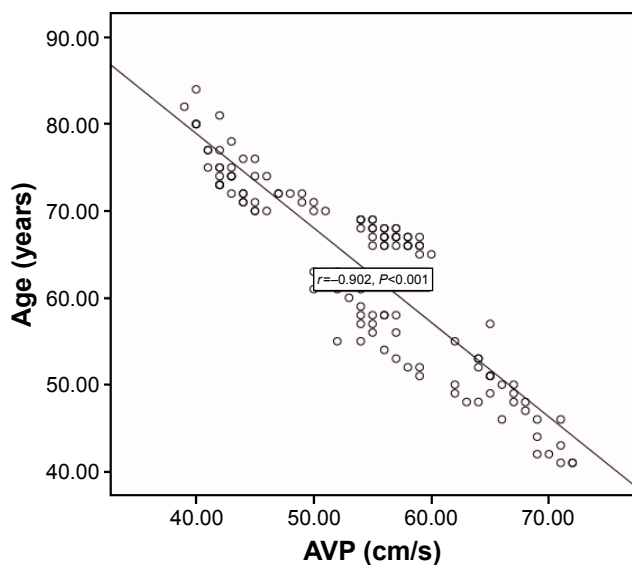

Figure 3 Scatter plot of AVP measurements for age.
Abbreviation: AVP, color M-mode derived propagation velocity measured along the origin of the descending aorta.

Figure 4 Scatter plot of AVP for CIMT measurements.
Abbreviations: AVP, color M-mode derived propagation velocity measured along the origin of the descending aorta; CIMT, carotid artery intima–media thickness.

In this study, we found that CIMT values increased with aging. This is an expected finding, since both AS and atherosclerosis increase with age. CIMT has been shown as an independent risk factor for coronary artery disease, and carotid atherosclerosis usually develops in concordance with coronary atherosclerosis and severity of coronary artery disease increases significantly with elevated CIMT.[24–27] CIMT measurements have been demonstrated to facilitate the risk stratification of CAD in asymptomatic patients.[28] Besides, AVP, a newly discovered parameter, was significantly associated with CIMT in our study and decreasing with aging in concordance with increasing of CIMT.

Atherosclerosis can also be demonstrated by color M-mode propagation velocity measured along the origin of the descending thoracic aorta.[23] In patients with significant subclinical atherosclerosis[18] or coronary atherosclerosis,[29] AVP and CIMT have been demonstrated to be significantly associated with each other. In a recent study, Güneş et al[12] have found that AVP was the most significant predictor of coronary artery disease and significantly correlated with aortic stiffness measurements including aortic strain, aortic distensibility, and aortofemoral PWV. These findings show that the AVP could be used as an indicator of AS. In this study, we have demonstrated for the first time that AVP increases with age and AVP is significantly correlated with PWV and CIMT, which are indicators of aortic stiffness and atherosclerosis in healthy population.

This study revealed that AVP was correlated with PWV, CIMT, and age, all of which are predictors of subclinical

atherosclerosis. Thus, we can say that AVP may be regarded as one of the important measures of atherosclerosis. Besides, PWV is the golden standard method for detection of aortic stiffness. Aortic stiffness can be also measured by several methods including aortic compliance, distensibility, augmentation index, and pulse pressure. Including PWV, these methods are usually difficult to perform and time consuming in daily practice.[30–34] However, measurement of AVP that is significantly correlated with PWV is easy compared to these methods for detection of aortic stiffness, and it does not carry additional costs for daily practice.

AVP is the flow propagation in aorta and may be influenced by the kinetic energy dispersion of pulsatile blood. A measurement of pulse propagation along the great vessel wall, pulse pressure has not been found to be correlated with age and AVP in our study. As a result, we did not think that flow propagation affected our results. This may be due to the exclusion of patients with hypertension that may affect flow propagation.

Limitations

Limited echocardiographic image quality may be an obstacle to the measurement of AVP and the reproducibility of the acquisition, and reading of the methods may constitute a limitation. Measurements may also be affected by aortic anatomy and loading conditions. Our study population has a small size that might have biased the statistical results. Large population studies are needed to confirm the applicability of AVP measurements as a screening method.

Conclusion

Measurement of AVP is noninvasive, practical, quantitative, safe, simple, and reproducible, which promotes its application in clinical and scientific research. In this study, we have demonstrated for the first time that AVP decreases with age and AVP is significantly correlated with PWV and CIMT that are indicators of aortic stiffness and atherosclerosis in healthy population. Therefore, AVP measurements can be easily applicable in clinical practice as an indicator of atherosclerosis and aortic stiffness in healthy population.

Disclosure

The authors report no conflicts of interest in this work.

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