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The positive correlation between brachial-ankle pulse wave velocity and aortic diameter in Chinese patients with diabetes

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Abstract

Aortic dilation is associated with an increased risk of cardiovascular diseases. Increased brachial-ankle pulse wave velocity (baPWV) is a hallmark of vascular aging and arterial stiffness, as well as an important risk factor for vascular disease. This study aimed to retrospectively analyze the correlation between baPWV and aortic diameter (AoD) of inpatients with diabetes. A total of 1294 diabetic patients with the detailed medical records were investigated. Arterial stiffness was assessed using baPWV and AoD using echocardiography. The results showed that baPWV and AoD increase with age ($p < 0.05$). Based on multiple linear regression analysis, age, systolic and diastolic blood pressure, left atrial diameter, right ventricle diameter, pulmonary artery diameter, peak velocity of early transmitral blood flow/peak velocity of late transmitral blood flow, and baPWV independently correlated with AoD in patients with diabetes. Additionally, an increased risk of aortic dilation occurred in the highest baPWV quartile compared with the lowest quartile ($p < 0.001$). In conclusion, baPWV is independently and positively associated with AoD. Hence, prospective cohorts or randomized clinical trials will be the next step to further determine whether interventions designed to improve arterial stiffness in patients with diabetes will reduce the risk of aortic dilation.

KEYWORDS
aortic diameter, arterial stiffness, brachial-ankle pulse wave velocity, diabetes

1 | BACKGROUND

Cardiovascular disease is a leading cause of mortality and a threat to human health worldwide. Several studies have reported that a larger aortic diameter (AoD) is prospectively associated with cardiovascular morbidity,[1,2] and has been described as an important marker of hypertension-related organ damage.[3] Moreover, excessive dilation of the aorta was linked to aneurysm formation and dissection, both of which are potentially fatal diseases.[4] To date, however, few proven therapeutic strategies are available to alleviate or reverse this progression. Thus, the study of risk factors related to aortic dilation may provide new ideas for the prevention and treatment of dilation of this condition.

AoD dilation involves the degenerative remodeling of the aortic wall. Previously, we and others reported that an increased AoD is a feature of aortic aging, which can be assessed using brachial-ankle pulse wave velocity (baPWV).[5,6] People with diabetes have a higher risk of vascular aging than the general population. Indeed, Ryder and coworkers observed accelerated vascular aging among adolescents with diabetes.[7] Endothelial dysfunction represents one of the earliest vascular complications in patients with diabetes and gradually leads to increased arterial stiffness.[8] Arterial elasticity generally deteriorates with age in the general population, and this effect is further amplified in patients with diabetes.[9] We hypothesized that vascular aging may be a risk factor for increased AoD; although the precise relationship between baPWV and AoD in patients with diabetes remains unclear. In this study, we aimed to investigate the relationship between baPWV and AoD in Chinese patients with diabetes.

2 | METHODS

2.1 | Patients

The medical records of patients with diabetes[10] were reviewed at Fujian Medical University Union Hospital (Fujian, China) between January 2018 and December 2020. These patients were hospitalized due to poor blood glucose control or diabetic complications, such as nephropathy, retinopathy, and peripheral neuropathy. The exclusion criteria included patients lacking baPWV test, patients less than 18 years old, and other confounding conditions, such as peripheral artery disease (ankle-brachial index (ABI) <0.9),[11] severe arrhythmias, congestive heart disease, valve heart disease, arteritis, myocarditis, aortic dissection, Marfan syndrome, congestive heart failure, chronic obstructive pulmonary disease, renal disease, autoimmune diseases (including systemic lupus erythematosus, rheumatic diseases), severe infection, thyroid dysfunction, or malignant tumors. Those who had used an antibiotic or probiotic usage in the past three months were also omitted.

2.2 | Ethics statement

The study was conducted in accordance with the Declaration of Helsinki (revised in 2013). The Medical Faculty of Fujian Medical University Union Hospital Ethics Committee (2021KY093) approved the study. Due to the retrospective nature of this study, the requirement for individual consent was waived.

2.3 | Anthropometric and hemodynamic variables

A standardized questionnaire regarding demographic data; blood test indicators; hemodynamic parameters; and echocardiographic parameters was administered by the same trained team of interviewers. Body mass index (BMI) was calculated using the following formula: BMI (kg/m2) = weight(kg)/height2(m2). Body surface area (BSA) was calculated using the following the Mosteller formula: BSA (m^2) = ([height (cm) × weight (kg)]/3600)^{½}. The estimated glomerular filtration rate (eGFR) was calculated according to the CKD-EPI formula.[12] Alcohol consumption was categorized as no alcohol and >30 g/week for more than one year.[13] Smoking status was classified as non-smoker and current smoker (continuously smoking one or more cigarettes per day for at least six months).[13] Coronary heart disease (CHD) was diagnosed according to the European Society of Cardiology (ESC) guidelines.[14,15] Type 2 diabetes was diagnosed according to the American Diabetes Association guidelines: a fasting plasma glucose (FPG) > 126 mg/dl (7.0 mmol/L); a 2-h post-load plasma glucose (2-h PG) > 200 mg/dl (11.1 mmol/L) during oral glucose tolerance test (OGTT); A1C > 6.5% (48 mmol/mol); a patient with classic symptoms of hyperglycemia or hyperglycemic crisis; a random plasma glucose > 200 mg/dl (11.1 mmol/L); or a patients on treatment with hypoglycemic agents (oral or insulin).[10] The diagnostic criteria for type 1 diabetes and other types of diabetes are detailed in the American Diabetes Association guidelines.[10]

2.4 | Measurement of baPWV

BaPWV was measured using an automated artery stiffness detection device BP203RPE-II (VP-1000; Omron, Kyoto, Japan). Participants were not allowed to consume coffee, tea, cigarettes, or alcohol for 30 min prior to the examination and were assessed in a supine position after at least 5 min of rest. Blood pressure cuffs were wrapped on both upper arms and ankles. The electrocardiogram, phonogram, pulse volume waveform, blood pressure, and heart rate were recorded simultaneously. BaPWV was calculated as the distance between the brachial and posterior tibial arteries divided by the time interval between these two measurement points. The distance between the arteries was assessed based on the patient's height. The mean values of right and left baPWV were used for the analysis. All measurements were performed by the same experienced operator who was blinded to the participants' information.[16]

2.5 | Measurement of AoD

In the study, we used the same method (a two-dimensional echocardiographic measurement), measurement site (2 cm above the aortic valve annulus), and cardiac cycle phase (end diastolic) in all patients. The echocardiogram was performed at rest in the left lateral decubitus position with the GE Vivid E7 ultrasound system according to guidelines of the American Society of Echocardiography.[17] Images of the proximal aortic root were obtained from a parasternal long-axis view. The diameter of the proximal ascending aorta was measured as the maximal distance between the two leading edges of the anterior and posterior aortic wall 2 cm above the aortic valve annulus at the end diastole. Aortic dilation, with or without BSA adjustment was defined as an aortic diameter >34 mm in men and >31 mm in women; or >17 mm/m^2 in men and >19 mm/m^2 in women, adjusted.[17]

2.6 | Statistical analysis

The normality of the data was assessed using the Kolmogorov Smirnov test. Normally distributed variables were presented as a mean ± standard deviation and compared using the Student's *t*-test. Non-normally distributed variables were expressed as a median and interquartile

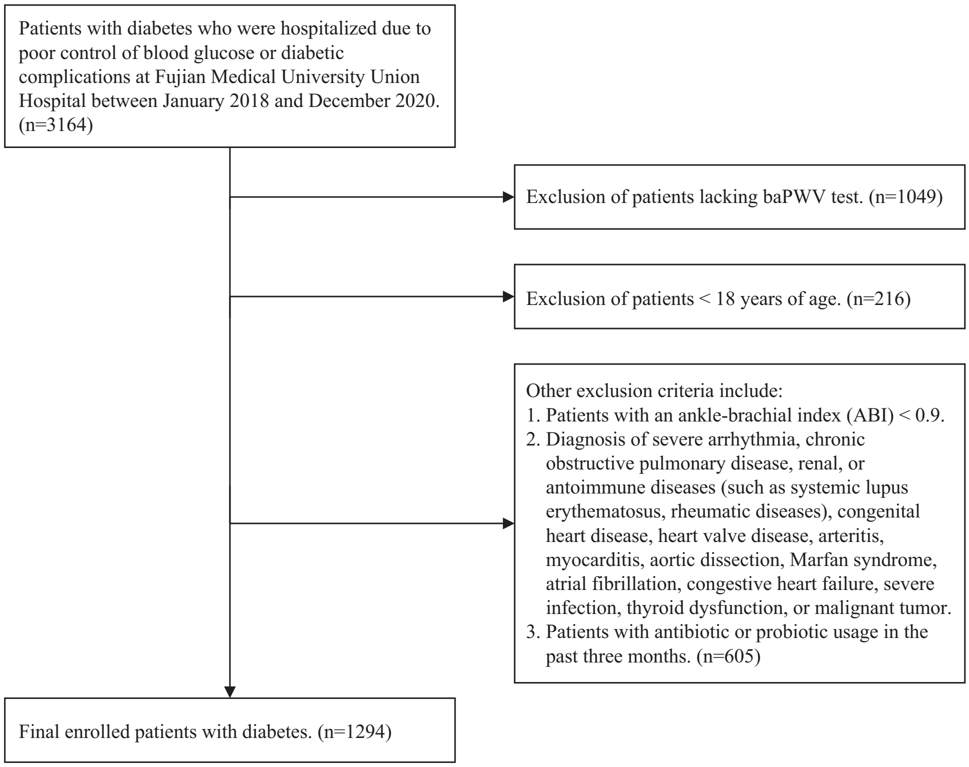

FIGURE 1 Flow chart showing the enrollment process of patients with diabetes. BaPWV: brachial-ankle pulse wave velocity

range (IQR) and analyzed using the Mann–Whitney *U*-test. Categorical variables were expressed as numbers and percentages (%) and compared using the $\chi 2$ test or Fisher's exact test (if theoretical frequency $T < 5$). Multiple linear regression analyses were performed to determine the independent determinants of AoD. BaPWV was grouped into quartiles when investigating analyzing the relationship between it and the risk of aortic dilation using logistic regression analysis. Stratified analysis was performed for age, sex, use of antihypertensive medications, BMI, and smoking status. All statistical analyses were two-sided, and a *p*-value of less than 0.05 was considered statistically significant. All data were analyzed using SPSS software (version 25.0, IL, USA).

3 | RESULTS

3.1 | Clinical characteristics of patients with diabetes in the quartile of baPWV

The enrollment process of patients is shown in Figure 1. The clinical characteristics of all 1294 patients with diabetes based on baPWV quartiles are shown in Table 1. The mean age of the patients was 55.7 ± 12.6 years, 804 (62.1%) were men, and 490 (37.9%) were women. A total of 171 patients were defined as having aortic dilation without BSA adjustment (13.2%, 109 females and 62 males). However, when applying the BSA adjustment, 500 patients were defined as having aortic dilation: the prevalence of such in patients with diabetes was 38.6%. From the lowest to the highest baPWV quartile, the mean and standard deviation were as follows: 1228.86 ± 126.47 cm/s (Q1), 1497.86 ± 61.32 cm/s (Q2), 1716.42 ± 70.89 cm/s (Q3), and 2094.16 ± 241.74 cm/s (Q4). A higher systolic blood pressure [(137.85 ± 20.22) vs. (117.48 ± 15.97) mm Hg], diastolic blood pressure [(76.16 ± 12.62) vs. (71.43 ± 11.58) mm Hg] and pulse pressure [(61.69 ± 16.52) vs. (46.05 ± 11.44) mm Hg] were observed in Q4 compared to Q1 (p <0.001). Additionally, with ascending baPWV quartile, an increasing trend in AoD [27.90 ± 2.66 (Q1), 29.42 ± 2.82 (Q2), 29.67 ± 2.59 (Q3), and 30.38 ± 2.79 (Q4) mm, p <0.001; Table S1] and AoD/BSA [15.89 ± 2.14 (Q1), 17.04 ± 2.20 (Q2), 17.54 ± 2.16 (Q3), and 18.27 ± 2.22 (Q4) mm/m2, p <0.001; Table S1] was observed. No significant intergroup differences were observed regarding BMI, fasting blood glucose, aspartate aminotransferase (AST), alkaline phosphatase (ALP), total triglyceride, total cholesterol, low-density lipoprotein cholesterol (LDL-C), percentage of CHD, and ischemic stroke (Table 1).

3.2 | BaPWV and AoD correlation in patients with diabetes

Considering that both baPWV and AoD increased with age in patients with diabetes (Figure 2A and B), we further explored the association between baPWV and AoD using multiple linear regression analysis. We observed that baPWV was independently associated with AoD ($\beta = 0.142$, adjusted $R_2 = 0.344$, p <0.001), after adjusting for demographic data, blood test indicators, hemodynamic parameters and echocardiographic indicators (Table S2). After BSA correction of

TABLE 1 Comparison of patient clinical characteristics based on baPWV quartile ($n = 1294$)

Variables	Quartile 1	Quartile 2	Quartile 3	Quartile 4	F/χ2	p
n	323	325	321	325		
BaPWV, cm/s	1228.86 ± 126.47	1497.86 ± 61.32	1716.42 ± 70.89	2094.16 ± 241.74	2077.862	<0.001
Demographic data						
Sex *n*(%)					12.983	0.005
Male	225 (69.7%)	204 (62.8%)	191 (59.5%)	184 (56.6%)		
Female	98 (30.3%)	121 (37.2%)	130 (40.5%)	141 (43.4%)		
Age	45.88 ± 13.66	54.52 ± 10.67	59.16 ± 10.42	63.05 ± 8.06	149.28	<0.001
≥65 years, *n*(%)	22 (6.8%)	60 (18.5%)	122 (38.0%)	166 (51.1%)	185.794	<0.001
Height, cm	167.23 ± 9.06	165.21 ± 8.22	163.61 ± 8.46	162.42 ± 8.13	19.573	<0.001
Weight, kg	69.75 ± 14.93	68.05 ± 13.24	66.04 ± 11.47	63.93 ± 11.19	12.523	<0.001
BMI, kg/m^2	24.94 ± 5.01	24.87 ± 3.91	24.61 ± 3.33	24.21 ± 3.46	2.237	0.082
Current smoker, *n*(%)	121 (37.5%)	117 (36.0%)	94 (29.3%)	100 (30.8%)	6.841	0.077
Current drinker, *n*(%)	131 (40.6%)	126 (38.8%)	118 (36.8%)	102 (31.4%)	6.594	0.086
Use of antihypertensive medications, *n*(%)	89 (27.6%)	167 (51.4%)	226 (70.4%)	252 (77.5%)	197.566	<0.001
Comorbidity, *n*(%)						
Coronary heart disease	15 (4.6%)	19 (5.8%)	22 (6.9%)	24 (7.4%)	2.441	0.486
Ischemic stroke	4 (1.2%)	4 (1.2%)	12 (3.7%)	9 (2.8%)	6.695	0.082
Diabetes *n*(%)					53.511	<0.001
Type 1	47 (14.6%)	18 (5.5%)	14 (4.4%)	8 (2.5%)		
Type 2	266 (82.4%)	305 (93.8%)	302 (94.1%)	314 (96.6%)		
Other	10 (3.1%)	2 (0.6%)	5 (1.6%)	3 (0.9%)		
Complication of diabetes, *n*(%)						
Nephropathy	45 (13.9%)	92 (28.3%)	120 (37.4%)	162 (49.8%)	101.619	<0.001
Retinopathy	64 (19.8%)	94 (28.9%)	123 (38.3%)	146 (44.9%)	52.846	<0.001
Peripheral neuropathy	184 (57%)	232 (71.4%)	244 (76.0%)	261 (80.3%)	48.666	<0.001
Hemodynamic parameters						
Systolic blood pressure, mmHg	117.48 ± 15.97	126.94 ± 15.57	131.55 ± 16.90	137.85 ± 20.22	79.883	<0.001
Diastolic blood pressure, mmHg	71.43 ± 11.58	74.93 ± 10.98	75.12 ± 11.60	76.16 ± 12.62	10.012	<0.001
Pulse pressure, mmHg	46.05 ± 11.44	52.02 ± 12.85	56.43 ± 14.08	61.69 ± 16.52	74.36	<0.001
Heart rate, bpm	76.31 ± 12.08	76.51 ± 11.39	77.50 ± 10.24	79.81 ± 11.14	8.568	<0.001
Blood test indicators						
Fasting blood glucose, mmol/L	8.37 (6.19–11.34)	7.98 (6.31–10.82)	8.21 (6.35–11.48)	8.40(6.94–11.59)	3.578	0.311
ALT, IU/L	23(15–35)	22(15–35)	21(15–29)	19(14–27)	17.721	0.001
AST, IU/L	18(15–25)	19(16–26)	19(15–24)	19(15–25)	4.050	0.256
ALP, IU/L	71(61–90)	71(60–88)	73(60–90)	74(62–91)	1.231	0.746
γ-GT, IU/L	25(16–37)	28(19–46)	26(19–41)	24(17–42)	9.491	0.023
Albumin, g/L	41.50 ± 4.62	41.54 ± 4.54	41.00 ± 5.66	39.37 ± 5.47	12.926	<0.001
Blood urea nitrogen, mmol/L	5.01 ± 1.67	5.74 ± 3.21	6.07 ± 3.39	6.31 ± 3.02	12.342	<0.001
Creatinine, mmol/L	66(55–78)	67(57–79)	72(59–86)	74(60–92)	42.303	<0.001
eGFR, ml/min/1.73 m^2	106.47 ± 20.08	95.34 ± 21.99	87.29 ± 24.12	80.52 ± 23.53	79.805	<0.001
Total triglyceride, mmol/L	1.40 (1.00–2.05)	1.48 (0.98–2.22)	1.57(1.06–2.37)	1.48(1.04–2.05)	3.594	0.309
Total cholesterol, mmol/L	4.57 (3.82–5.44)	4.70 (3.85–5.44)	4.82(3.87–5.75)	4.58(3.81–5.40)	6.143	0.105
HDL-C, mmol/L	1.01 (0.83–1.26)	1.06 (0.86–1.28)	1.10(0.91–1.35)	1.08(0.89–1.38)	9.578	0.023
LDL-C, mmol/L	3.05 (2.39–3.79)	3.01 (2.29–3.85)	3.08(2.40–4.08)	3.03(2.22–3.74)	4.812	0.186

Abbreviations: ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase;BaPWV, brachial-ankle pulse wave velocity; BMI, body mass index; eGFR, estimated glomerular filtration rate; HDL-C, high-density lipoprotein cholesterol, LDL-C, low-density lipoprotein cholesterol; γ-GT, γ-glutamyl transpeptidase.

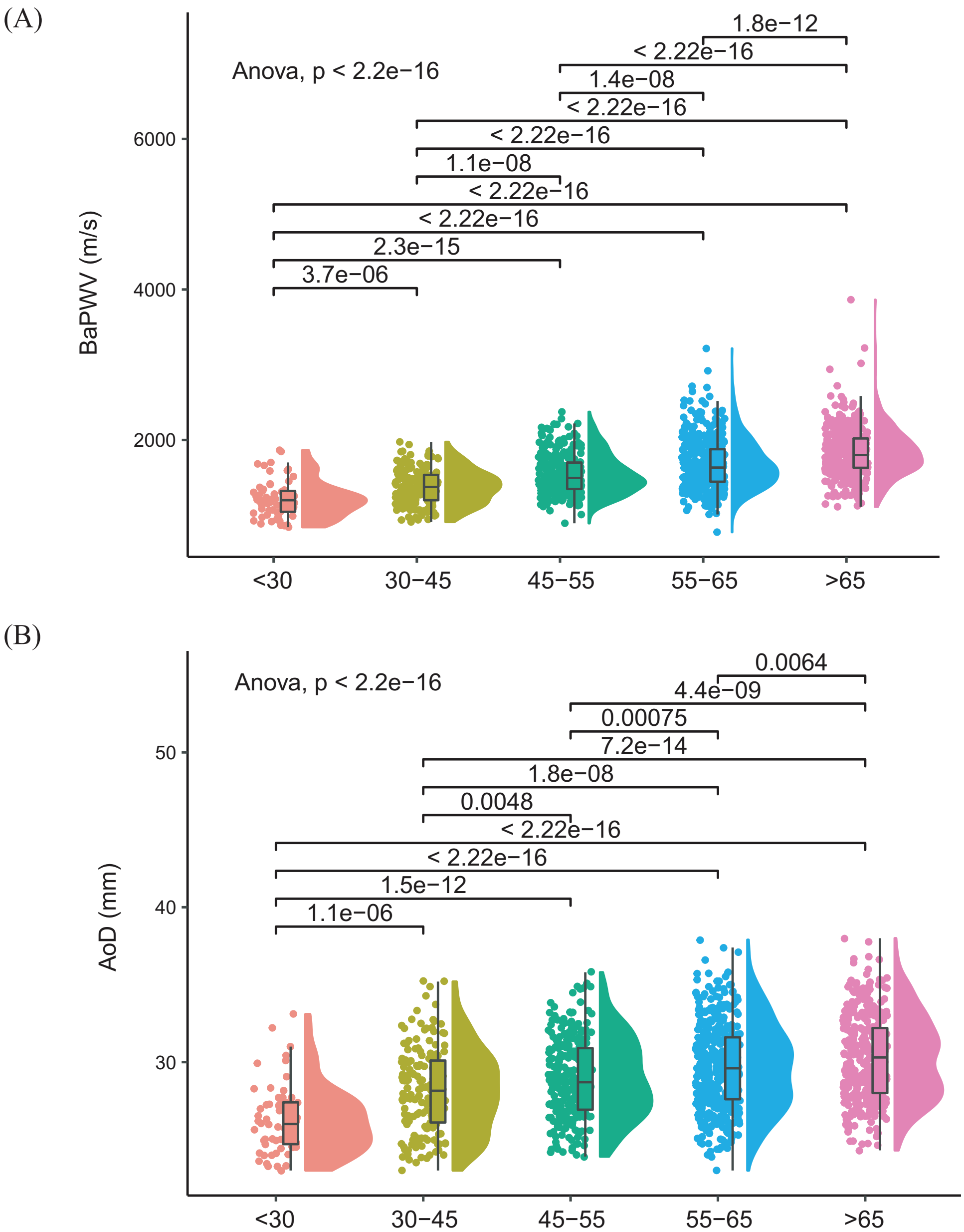

FIGURE 2 Distribution of baPWV and AoD in different age groups. (A) Distribution of baPWV in different age groups; baPWV increases with age. (B) Distribution of AoD in different age groups; AoD increases with advanced age. BaPWV: brachial-ankle pulse wave velocity; AoD: aortic diameter

AoD and sex-specific analysis, we also found that baPWV positively correlated with aortic diameter both in female and male patients (Table S3).

3.3 | Identification of independent predictors of aortic dilation in patients with diabetes

In the univariate logistic regression analysis, with the Q1 set as the reference, the baPWV in Q4 was found to be associated with an increased odds ratio (OR) for aortic dilation (OR = 9.553, 95% Confidence Interval (CI): 4.840–18.857, p <0.001; Table 2). Even after adjusting for potential confounding factors, including demographic data, blood test indicators, hemodynamic parameters and echocardiographic indicators, we made the same observation when comparing the baPWV in Q1 and Q4 (OR = 5.022, 95% CI: 2.117–11.914, p <0.001; Table 2). Additionally, after correction of AoD by BSA, baPWV in Q4 was associated with an increased OR for aortic dilation (OR = 2.395, 95% CI: 1.414–4.057, p = 0.001; Table S4), compared with the baPWV in Q1. Considering that standard values for baPWV and aortic diameter differ between men and women, we further explored the association between baPWV and aortic diameter with BSA adjustment across both sexes, respectively. We observed that the baPWV in Q4 was found to be associated with an increased OR for aortic dilation in only the men

TABLE 2 Odds ratios of the variables for increased aortic dilation in univariate and multivariable logistic regression analyses ($n = 1294$)

	Univariate			Multivariable		
Variables	OR	95% CI	p	OR	95% CI	p
BaPWV						
Quartile 1	1	Reference		1	Reference	
Quartile 2	4.901	2.421–9.922	<0.001	3.385	1.545–7.418	0.002
Quartile 3	4.583	2.254–9.320	<0.001	2.557	1.115–5.865	0.020
Quartile 4	9.553	4.840–18.857	<0.001	5.022	2.117–11.914	<0.001
Hemodynamic parameters						
Systolic blood pressure	1.015	1.006–1.023	0.001	0.991	0.976–1.006	0.235
Diastolic blood pressure	1.010	0.996–1.023	0.162	1.027	1.005–1.050	0.017
Heart rate	0.980	0.966–0.995	0.008	0.985	0.964–1.007	0.179
Demographic data						
Age	1.077	1.057–1.097	<0.001	1.037	1.004–1.071	0.026
BMI	1.030	0.991–1.071	0.127	0.561	0.351–0.897	0.016
Use of antihypertensive medications	1.890	1.337–2.673	<0.001	0.732	0.442–1.210	0.223
current smoking	0.679	0.473–0.975	0.036	1.126	0.690–1.838	0.634
current drinking	0.718	0.507–1.016	0.061	0.828	0.518–1.323	0.430
Blood test indicators						
Fasting blood glucose	1.006	0.967–1.046	0.770	1.027	0.979–1.077	0.277
ALT	0.991	0.983–1.000	0.050	0.986	0.970–1.003	0.116
AST	0.996	0.986–1.005	0.357	1.012	0.988–1.037	0.337
ALP	0.999	0.994–1.004	0.759	0.999	0.993–1.005	0.748
γ-GT	1.000	0.997–1.002	0.943	1.001	0.997–1.004	0.646
Albumin	0.963	0.935–0.992	0.011	0.989	0.950–1.031	0.610
Blood urea nitrogen	1.048	1.001–1.098	0.045	1.016	0.925–1.116	0.736
Creatinine	1.000	0.996–1.004	0.946	0.966	0.985–1.008	0.523
eGFR	0.984	0.978–0.990	<0.001	1.000	0.980–1.020	0.982
Total triglyceride	0.990	0.919–1.066	0.787	1.014	0.825–1.247	0.893
Total cholesterol	1.033	0.922–1.156	0.577	0.742	0.366–1.505	0.408
HDL-C	0.977	0.646–1.480	0.914	0.798	0.384–1.659	0.546
LDL-C	1.065	0.935–1.212	0.343	1.570	0.780–3.161	0.206
Echocardiographic indicators						
LVED	1.026	0.985–1.070	0.216	1.410	0.673–2.955	0.362
LVES	1.029	0.984–1.075	0.210	0.753	0.423–1.339	0.334
LAD	1.108	1.069–1.148	<0.001	1.064	1.011–1.120	0.018
LVPW	1.249	1.118–1.396	<0.001	0.867	0.420–1.790	0.700
IVS	1.185	1.087–1.293	<0.001	0.768	0.366–1.612	0.486
Rv	1.191	1.089–1.303	<0.001	1.134	1.001–1.283	0.048
RVOD	1.010	0.968–1.055	0.645	0.979	0.924–1.038	0.483
Pa	1.241	1.141–1.349	<0.001	1.201	1.073–1.343	<0.001
E	0.109	0.042–0.284	<0.001	0.279	0.003–23.740	0.573
A	6.026	2.796–12.990	<0.001	0.597	0.017–20.658	0.776
E/A	0.071	0.034–0.149	<0.001	0.226	0.007–7.408	0.403
FS	0.979	0.946–1.013	0.218	0.755	0.465–1.224	0.254
LVEF	0.984	0.959–1.010	0.224	1.160	0.796–1.692	0.439

(Continues)

TABLE 2 (Continued)

Variables	Univariate OR	95% CI	p	Multivariable OR	95% CI	p
Sv	1.004	0.992–1.016	0.530	0.979	0.867–1.106	0.737
Co	0.892	0.773–1.013	0.122	0.528	0.148–1.885	0.325
Ci	0.915	0.719–1.166	0.474	1.606	0.200–12.877	0.656
LVM	1.004	1.001–1.008	0.008	0.999	0.987–1.012	0.939
LVMI	1.015	1.009–1.022	<0.001	1.017	0.960–1.077	0.572

Univariate: no adjustment. Multivariable: adjusting for demographic data, blood test indicators, hemodynamic parameters and echocardiographic indicators. Abbreviations: OR, odds ratio; CI, Confidence Interva; BaPWV, brachial-ankle pulse wave velocity; BMI, body mass index; ALT, alanine aminotransferase; AST, aspartate aminotransferase; ALP, alkaline phosphatase; γ-GT, γ-glutamyl transpeptidase; eGFR, estimated glomerular filtration rate; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; LVED, left ventricular end diastolic diameter; LVES, left ventricular end systolic diameter; LAD, left atrial diameter; LVPW, left ventricular posterior wall thickness; IVS, interventricular septal thickness; Rv, right ventricle diameter; RVOD, right ventricular outflow dimension; Pa, pulmonary artery diameter; E, peak velocity of early transmitral blood flow; A, peak velocity of late transmitral blood flow; FS, fractional shortening; LVEF, left ventricular ejection fraction; Sv, stroke volume; Co, cardiac output; Ci, cardiac index; LVM, left ventricular mass; LVMI, left ventricular mass index.

TABLE 3 Stratified association between baPWV and increased aortic dilation ($n = 1294$)

Variables	BaPWV (cm/s) OR (95% CI)	p for trend
Age (years)		
<65	1.406 (0.999–1.978)	0.051
≥65	1.524 (1.038–2.237)	0.031
Sex		
Male	1.835 (1.220–2.761)	0.004
Female	1.332 (0.959–1.849)	0.087
Use of antihypertensive medications		
No	2.021 (1.286–3.175)	0.002
Yes	1.433 (1.041–1.973)	0.027
Smoking status		
No	1.198 (0.901–1.592)	0.214
Yes	3.734 (1.989–7.013)	<0.001
BMI (kg/m²)		
<24	1.774 (1.186–2.655)	0.005
≥24	1.361 (0.987–1.877)	0.06

Adjusting for demographic data, blood test indicators, hemodynamic parameters and echocardiographic indicators. Abbreviations: BaPWV, brachial-ankle pulse wave velocity; OR, odds ratio; CI, Confidence Interva; BMI, body mass index.

(Table S5). Stratified analysis showed a significant correlation between baPWV and AoD in patients ≥ 65 years old (OR = 1.524, 95% CI: 1.038–2.237, p for trend = 0.031; Table 3), but not in patients < 65 years old (p for trend = 0.051; Table 3). Similar results were observed in male patients (OR = 1.835, 95% CI: 1.220–2.761, $p = 0.004$), and in patients with a BMI < 24 kg/m^2 (OR = 1.774, 95% CI: 1.186–2.655, $p = 0.005$; Table 3).

4 | DISCUSSION

Clinically, baPWV is a frequently-applied indicator to assess arterial stiffness[18]; however, the relationship between baPWV and AoD remains controversial. Bailey and coworkers found a negative association between carotid-femoral PWV and AoD ($r = 0.15$, $p = 0.008$) in patients with abdominal aortic aneurysms.[19] In contrast, Soulat and coworkers demonstrated a positive linear relationship between the mean thoracic AoD and thoracic aortic PWV.[20] In the current study, we observed an increased probability of aortic dilation in diabetic patients with higher baPWV quartiles. Additionally, following stratified analysis, a significant association was observed between baPWV and AoD in men, those over 65 years old, and those with a BMI < 24 kg/m^2. It is well known that the aortic structure is affected by many factors, including age, sex, and body size.[21] With aging, repetitive pulsations (30 million/year) cause fractures in the elastin lamellae of the central arteries and the calcification of the arterial media, resulting in arterial wall stiffening.[22] In this study, baPWV was found to increase with age, further supporting existing literature.

A single-center study from Boramae Medical Center (Seoul, Korea) showed that among Korean adults without overt cardiovascular disease, the association between increased arterial stiffness and aortic root dilation was stronger in women than men.[23] Conversely, our study showed that baPWV was a significant predictor of aortic dilation in men. The sex-linked differences in the mechanisms of arterial stiffening remain unclear and may include multifactorial risk factors such as smoking, alcohol consumption, obesity, and dyslipidemia, and elevations in serum uric acid levels. Subsequently, this leads to vascular endothelial damage and increased vascular stiffness.[24,25] In our study, smoking, alcohol consumption were more common in men than in women (Table S6), which might explain the significant association between baPWV and aortic dilation in only men. However, additional studies are warranted to confirm the sex differences between arterial stiffness and aortic dilation. In this study, we also observed that baPWV is associated with aortic dilation in patients with a BMI < 24 kg/m^2, and not in those with a BMI ≥ 24 kg/m^2. Previous studies have consistently shown that a high BMI may be a protective factor for arterial stiffness in adult men aged 35–55 years.[16] This may be linked to the obesity paradox, in which obesity offers certain benefits, as well as many adverse effects on the body.[26]

AoD significantly influences the left ventricular afterload and hemodynamics.[3] Several epidemiological studies showed that increased an AoD is associated with a higher incidence of cardiovascular events.[2,27] Our findings add to the evidence to connecting arterial stiffness and AoD. Considering the risk factors promoting these vascular changes, many interventions, including exercise therapy, calorie restriction, and drug therapy, are currently being investigated and developed.[24,25,28] Delaying the progression of arterial stiffness with these intervention strategies may be a potential therapeutic modality for preventing and ameliorating aortic dilation in older patients with diabetes.

Certain limitations of this study should be noted. First, no causal relationship could be determined due to the study's cross-sectional design. Second, the population comprised only inpatients, which decreased the generalizability of the results. Finally, the subjects of this study were enrolled from a single center, making further validation of our study possible by including patients from multiple centers and a larger population.

5 | CONCLUSIONS

In summary, we demonstrated that baPWV is independently and positively associated with AoD in diabetic patients. Future studies are required to determine whether interventions designed to improve artery stiffness in older patients with diabetes will reduce the risk of aortic dilation and its complications.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Huashan Hong lead the study. Liping Li, Wenhui Xie, Qingqing Li collected the data, performed the data analysis, and discussed the results. Liping Li, Wenhui Xie, Qingqing Li prepared the original draft. Huashan Hong Liping Li, Wenhui Xie, Qingqing Li reviewed and edited the final manuscript. All authors contributed to the article and approved the submitted version.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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