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Age-associated aortic arch morphological characteristics and acute type B aortic dissection: a retrospective case-control study

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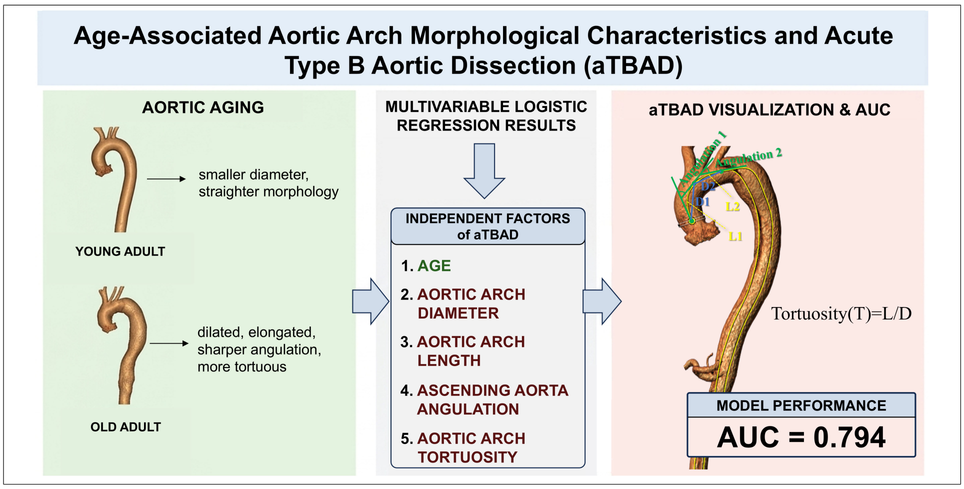

Abstract

Aim: To evaluate age-related changes in aortic morphology and identify morphological features independently associated with acute type B aortic dissection (aTBAD).

Methods: This multicenter, retrospective, case-control study enrolled a total of 203 participants (106 patients with aTBAD and 97 non-aortic disease controls) who underwent computed tomography angiography (CTA). Aortic dimensions and geometric parameters, including diameters, lengths, volumes, angulations, and tortuosity of the ascending aorta and aortic arch, were measured using three-dimensional reconstruction. The associations between aortic variables and age were assessed using linear regression analyses adjusted for gender and body surface area. Independent morphological factors linked to aTBAD were identified using multivariable logistic regression, and the model's performance was assessed through the area under the receiver operating characteristic curve (AUC).

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Results: Most aortic morphological variables were positively correlated with age in both groups; however, true lumen variables in the descending aorta were not associated with age. Compared with controls, the aTBAD group exhibited significantly greater diameters, lengths, volumes, angulations, and tortuosity of the ascending aorta and aortic arch (all $P < 0.05$). Multivariable analysis identified five independent factors associated with aTBAD, including aortic arch diameter, aortic arch length, aortic arch tortuosity, ascending aorta angulation, and age. The model's AUC was 0.794.

Conclusions: Increased aortic arch diameter, length, tortuosity, and ascending aorta angulation are independently associated with aTBAD occurrence, although these morphological variables are positively correlated with age. These findings suggest that incorporating age-related changes in aortic morphology may aid in the identification of patients at increased risk for aTBAD.

INTRODUCTION

Acute aortic dissection is a critical condition marked by a rupture in the inner layer of the aortic wall. Notably, acute type B aortic dissection (aTBAD) accounts for approximately one-third of all acute aortic dissections[1,2]. Despite the rapid progression in diagnostic and therapeutic techniques, the in-hospital mortality rate of patients with aTBAD remains high at up to 13%[3]. In addition to conventional risk factors, such as hypertension, smoking and hyperlipidemia, aging itself confers an important risk factor for aTBAD. Computed tomography angiography (CTA) has gradually become the commonly used and primary imaging modality for diagnosing aTBAD[4]. Previous studies have identified the aortic anatomical and morphological parameters based on three-dimensional CTA reconstruction as potential predictors of aTBAD[5-7]. However, the effects of aging on aortic morphology have not been adequately studied.

In view of the fact that the aorta continues to expand, elongate and unfold with advancing age, findings obtained without standardizing the aortic variables for age may not be entirely justified[8,9]. Importantly, the threshold values of aortic variables used for risk stratification of aTBAD were also different in each age stage. Moreover, it is uncertain if age is linked to alterations in the true and false lumens of the descending aorta after aTBAD.

Accordingly, the main goal of this study was to analyze the correlations between age and aortic morphological variables in patients with aTBAD and controls, and identify independent factors related to aTBAD by multivariate logistic regression analysis. Together, these findings may provide additional information for clinical evaluation and surveillance of patients with aTBAD-related morphological features.

MATERIAL AND METHODS

This retrospective case-control study, conducted across multiple centers, received approval from the Ethics Committee of the First Affiliated Hospital of Zhengzhou University and the Second Xiangya Hospital of Central South University, which served as the central institutional review board for all participating centers (approval number: SQ2025-194). The study's retrospective design allowed for the waiver of individual informed consent.

Study population

Patients diagnosed with aTBAD at the First Affiliated Hospital of Zhengzhou University and the Second Xiangya Hospital of Central South University between 1 January 2024 and 31 December 2024 were retrospectively screened and analyzed. According to established criteria, aortic dissection acuity can be classified into the following types: uncomplicated, high-risk and complicated[2]. The high-risk type includes aortic dissection with refractory hypertension or pain. The complicated type includes aortic dissection with rupture and malperfusion syndrome (renal malperfusion, visceral malperfusion, lower extremity malperfusion). Participants in the aTBAD group had to meet these inclusion criteria:

(1) Initial onset;

(2) CTA was conducted within two weeks following the start of the dissection.

Individuals were excluded from the aTBAD group based on the following criteria:

(1) Connective tissue diseases (including Marfan syndrome, Ehlers-Danlos syndrome and Loeys-Dietz syndrome);

(2) Bicuspid aortic valve;

(3) Traumatic aortic dissection;

(4) Isolated abdominal aortic dissection;

(5) Aortic surgery history, including both open and endovascular approaches;

(6) Non-A non-B aortic dissection;

(7) Diseases that might lead to distortion of aortic morphology (e.g., pneumothorax, barrel chest, mediastinal masses, scoliosis and history of spinal surgery).

Patients in the control group underwent aortic CTA examinations for various clinical indications, including suspected aortic dissection (excluded by CTA), suspected aortic aneurysm (excluded by CTA), suspected pulmonary embolism, preoperative evaluation for coronary artery disease and trauma evaluation between 1 January 2022 and 31 December 2024. The detailed distribution of CTA indications is provided in Supplementary Table 1.

Individuals were excluded from the control group based on the following criteria:

(1) Known aortic diseases (including aortic dissection, aortic aneurysm, connective tissue diseases and bicuspid aortic valve);

(2) Aortic surgery history, including both open and endovascular approaches;

(3) Thoracic and spinal diseases that might lead to distortion of aortic morphology.

All imaging measurements and statistical analyses were performed between 1 December 2025 and 28 February 2026.

Imaging analysis

CTA image data with a 1.5 mm slice thickness were obtained using a second-generation dual-source computed tomography scanner (Somatom Definition Flash; Siemens Healthcare, Germany) and stored in the Digital Imaging and Communication in Medicine (DICOM) format for image processing and visualization.

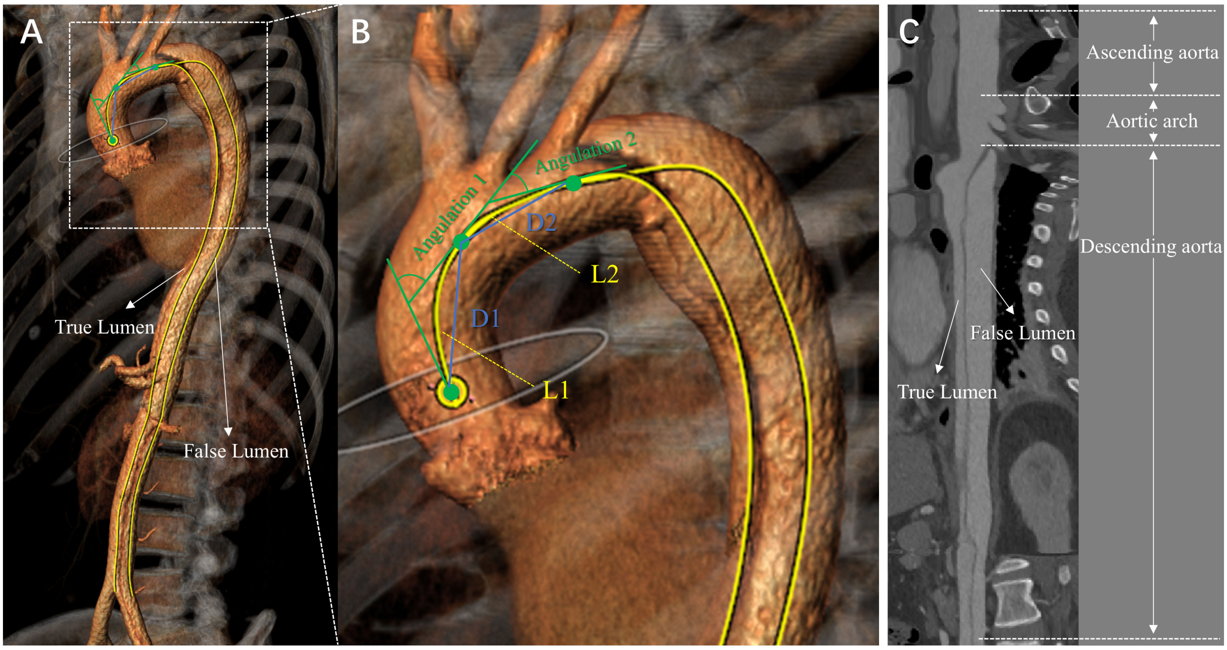

Figure 1. The procedure for measuring the morphological variables of the ascending aorta and aortic arch in a patient with aTBAD. (A and B) Aortic angulation was the angle created by tangent lines drawn at the proximal and distal points of the centerline within the ascending aorta and aortic arch segments. Aortic tortuosity was measured as the ratio of the centerline length of the ascending aorta and aortic arch segments (L1, L2) to the direct linear distance between the proximal and distal points (D1, D2); (C) The diameter, length and volume of each aortic segment were measured between the STJ, BCT and the distal left subclavian artery in the stretched vessel view. STJ: Sinotubular junction; BCT: brachiocephalic trunk; aTBAD: acute type B aortic dissection.

CTA images were reconstructed using 3 mensio Vascular software (version 10.0; Pie Medical Imaging, Maastricht, Netherlands). Measurements were performed on multiplanar reconstructed images perpendicular to the aortic centerline to minimize errors caused by aortic curvature. All CTA images were independently reviewed and measured by two experienced vascular surgeons with expertise in aortic imaging and endovascular procedures. Both observers were blinded to all clinical information and each other's measurements. Although the presence of aortic dissection could be identified from imaging characteristics, the observers were blinded to other clinical data and study hypotheses during morphological assessment. The CTA datasets were anonymized and assigned unique study codes before analysis, and the observers were not permitted to access any identifying or clinical data during the measurement process. In cases of disagreement between the two observers, consensus was reached through discussion, and a third senior vascular surgeon was consulted if necessary.

Aortic dimension and geometry

The entire aortic centerline was constructed from the sinotubular junction (STJ) to the point of the common iliac bifurcation. The aorta was divided into three segments (including the ascending aorta, aortic arch and descending aorta) by four planes that were perpendicular to the centerline: (1) the STJ; (2) the proximal brachiocephalic trunk (BCT); (3) the distal left subclavian artery (LSA); (4) the common iliac bifurcation [Figure 1]. The diameter, length and volume of each aortic segment were measured between the aforementioned planes in the stretched vessel view [Figure 1C]. Aortic angulation was the angle created by tangent lines drawn at the proximal and distal points of the centerline within the ascending aorta and aortic arch segments. Aortic tortuosity was measured as the ratio of the centerline length of the ascending aorta and aortic arch segments to the direct linear distance between the proximal and distal points [Figure 1A and B].

Statistical analysis

Continuous variables were checked for normal distribution using the Shapiro-Wilk test, with visual confirmation provided by histograms and standardized normal probability (P-P) plots. Mean ± standard deviation (SD) was used to present continuous variables, while categorical variables were shown as frequencies and percentages. Continuous variables between the aTBAD and control groups were compared using the Student's *t*-test and Mann-Whitney test. The comparison of categorical variables between the two groups was conducted using the Chi-square test and Fisher's exact test. The associations of aortic dimension and geometry with aging were tested by linear regression models adjusted for gender and body surface area (BSA). The adjusted R-squared (Adjusted R^2) modifies the ordinary R^2 by penalizing the inclusion of unnecessary factors. Multivariable logistic regression was used to pinpoint independent factors associated with aTBAD. Variables showing significance in univariate analyses were included in the models, with adjustment for age, gender, and BSA to account for potential confounding related to demographic characteristics and body size. The risks were indicated by odds ratios (ORs) and accompanied by 95% confidence intervals (CIs). The Hosmer-Lemeshow goodness-of-fit test was used to evaluate the model calibration. Internal validation of the multivariable logistic regression model was performed using bootstrap resampling with 1,000 repetitions. The model's discrimination ability was assessed by calculating the optimism-corrected area under the receiver operating characteristic curve (AUC). To assess multicollinearity among the variables in the multivariable model, variance inflation factors (VIFs) were employed. To assess measurement reproducibility, a randomly selected subset of 30 patients was independently evaluated by two observers. One observer repeated the measurements after an interval of 4 weeks. Intraclass correlation coefficients (ICCs) were used to evaluate both interobserver and intraobserver agreements. The ICCs were calculated using a two-way random-effects model with absolute agreement {ICC [2, 1])}. Univariable linear regression analyses were additionally performed to visualize the crude linear relationships between age and aortic morphological parameters. Age was analyzed as a continuous variable. For multivariable linear regression analyses, age was scaled as a 10-year increment to facilitate clinical interpretation. For univariable linear regression analyses, age was entered as the original continuous variable in years. All statistical analyses and graphs were performed with SPSS software (version 22, IBM, Armonk, NY, USA) and GraphPad Prism (GraphPad Prism 8.0.2, USA) based on the analyzed data. The schematic illustrations and the graphical abstract were created by the authors using Microsoft PowerPoint 2024. *P* values below 0.05 were regarded as statistically significant.

To minimize potential bias, this multicenter study applied predefined inclusion and exclusion criteria and used a control group with comparable baseline characteristics. Aortic measurements were performed using standardized CTA protocols and three-dimensional reconstruction. Multivariable analyses adjusted for age, gender, and BSA were conducted to reduce potential confounding, and age-related effects on aortic morphology were specifically considered in assessment.

RESULTS

Since this was a retrospective multicenter case-control study, a formal sample size calculation was not conducted. The number of consecutive eligible patients who satisfied the predefined inclusion and exclusion criteria during the study period at the participating institutions determined the study size.

The features of participants from the aTBAD and control groups are shown in Table 1. The study included 203 patients who satisfied the inclusion and exclusion criteria, with 106 in the aTBAD group and 97 in the control group. The clinical features of the enrolled aTBAD patients, including the proportion of uncomplicated, high-risk and complicated aTBAD, were provided in Supplementary Table 2. No significant differences were found in the baseline characteristics between the two groups, with all *P*-values exceeding 0.05.

Table 1. Baseline characteristics between the two groups

	aTBAD group	Control group	*P* value
Number of patients	106	97	
Age (y)	58 ± 12	57 ± 14	0.58
Male, n (%)	75 (70.8)	68 (70.1)	0.92
BSA (m^2)	2.0 ± 0.2	2.0 ± 0.1	1.00
Past or current smoking, n (%)	57 (53.8)	53 (54.6)	0.90
Hypertension, n (%)	69 (65.1)	61 (62.9)	0.74
Hypercholesterolemia, n (%)	58 (54.7)	50 (51.5)	0.65
Diabetes, n (%)	26 (24.5)	25 (25.8)	0.84

BSA: Body surface area; aTBAD: acute type B aortic dissection.

Aortic dimension and geometry

Compared with the control group, patients with aTBAD exhibited significantly greater average diameters of the ascending aorta and aortic arch, with increases of 15.9% and 14.8%, respectively (both $P < 0.001$). In patients with aTBAD, the ascending aortic and aortic arch lengths were significantly longer than those in controls, showing relative differences of 5.0% and 7.3%, respectively ($P = 0.013$, $P < 0.001$). Similarly, the volumes of these two aortic segments were significantly dilated by 9.0% and 23.9% in the aTBAD group compared with the control group ($P = 0.007$, $P < 0.001$). The angulations of the ascending aorta and aortic arch were sharper in the aTBAD group, with increases of 8.2% and 27.6% compared with controls (both $P < 0.001$). The tortuosity of both aortic segments was also increased by 2.9% and 3.9% in the aTBAD group relative to controls (both $P < 0.001$) [Table 2]. The dimensions and geometric characteristics of the true lumen (TL) and total arterial lumen (TAL) in the descending aorta were assessed to identify the extent of TL compression associated with the presence of the false lumen [Table 3]. Compared with the TAL, the diameter, length, and volume of the TL were reduced by 49.4%, 4.3%, and 69.6%, respectively (all $P < 0.001$). Since the TL centerline was predominantly located in inner side of the aortic arch, TL angulation exceeded TAL angulation, although the difference was not statistically significant ($P > 0.05$). The tortuosity of the TL was reduced by 3.5% compared with the TAL ($P < 0.001$). There were significant differences between the TAL and control groups in descending aortic dimensions and geometry (all $P < 0.001$).

A Chi-square value of 6.842 with 8 degrees of freedom was obtained from the Hosmer-Lemeshow goodness-of-fit test ($P = 0.554$), indicating no significant lack of fit and supporting adequate model calibration. The multivariable logistic regression model showed no significant multicollinearity among the variables, with all VIF values below 5. The reproducibility analysis demonstrated excellent agreement for all CTA-derived morphological parameters. The interobserver ICCs varied between 0.88 and 0.96, while the intraobserver ICCs varied between 0.92 and 0.97 [Supplementary Table 3].

Correlation of aortic variables with age

The correlations between aortic dimensional and geometric variables and age (per 10 years), adjusted for gender and BSA, were presented in Table 4. Most variables in both groups were positively correlated with age. The variables of aTBAD group showed statistically significant correlation with age, except for ascending aorta volume ($P = 0.058$). In the control group, significant correlations with age were observed for all variables except ascending aortic diameter and tortuosity. However, TL and TL/TAL of descending aorta in the aTBAD group indicated no statistically significant correlation with age (all $P > 0.05$). In the multivariable logistic regression model, five variables, including aortic arch diameter, aortic arch length, aortic arch tortuosity, ascending aortic angulation, and age, were independently associated with aTBAD [Table 5]. The AUC representing the performance of the model was 0.794. After bootstrap internal validation with 1,000

Table 2. Dimensional and geometrical variables of the ascending aorta and aortic arch in aTBAD and control patients

	aTBAD group	Control group	% change	*P* value
Aortic dimension				
Diameter (mm)				
Ascending aorta	34.2 ± 3.6	29.5 ± 2.8	15.9%	< 0.001
Aortic arch	32.5 ± 3.2	28.3 ± 2.5	14.8%	< 0.001
Length (mm)				
Ascending aorta	71.8 ± 10.8	68.4 ± 8.3	5.0%	0.013
Aortic arch	38.4 ± 4.9	35.8 ± 4.5	7.3%	< 0.001
Volume (ml)				
Ascending aorta	88.2 ± 19.6	80.9 ± 18.2	9.0%	0.007
Aortic arch	36.8 ± 11.3	29.7 ± 9.5	23.9%	< 0.001
Aortic geometry				
Angulation (°)				
Ascending aorta	85.7 ± 13.8	79.2 ± 10.6	8.2%	< 0.001
Aortic arch	52.7 ± 11.4	41.3 ± 10.9	27.6%	< 0.001
Tortuosity (%)				
Ascending aorta	115.8 ± 7.2	112.5 ± 5.9	2.9%	< 0.001
Aortic arch	108.6 ± 4.1	104.5 ± 4.3	3.9%	< 0.001

aTBAD: Acute type B aortic dissection.

Table 3. Dimensional and geometrical variables of the descending aorta in aTBAD and control patients

	aTBAD group			Control group
	TAL	TL	% change	
Aortic dimension				
Descending aorta diameter (mm)	35.2 ± 4.3	17.8 ± 3.9*	49.4%	22.5 ± 2.4†
Descending aorta length (mm)	435.2 ± 28.6	416.3 ± 26.7*	4.3%	402.1 ± 20.3†
Descending aorta volume (mL)	386.5 ± 65.3	117.4 ± 35.2*	69.6%	139.6 ± 40.3†
Aortic geometry				
Descending aorta angulation (°)	104.5 ± 12.9	106.8 ± 13.4	NA	98.5 ± 10.4†
Descending aorta tortuosity (%)	110.3 ± 4.6	106.4 ± 4.2*	3.5%	102.4 ± 3.5†

TAL: Total arterial lumen; aTBAD: acute type B aortic dissection; TL: true lumen. * $P < 0.001$ TL vesus TAL, † $P < 0.001$ control group vesus TAL.

repetitions, the optimism-corrected AUC was 0.776, indicating acceptable discrimination [Table 5]. To further illustrate the relationship between chronological age and selected aortic morphological changes, unadjusted linear regression analyses are presented in Figure 2. Consistent with the findings from the adjusted models, age was positively associated with aortic arch diameter, aortic arch length, ascending aorta angulation, and aortic arch tortuosity. The linear regression models showed that age explained 26%, 58%, 44%, and 65% of the variance in these parameters, respectively.

DISCUSSION

aTBAD is an age-related catastrophic cardiovascular condition associated with high rates of complications and mortality[10]. Of note, aging is recognized as one of the major risk factors for the occurrence of aTBAD and may also influence other established risk factors[11]. In addition, aortic anatomical and morphological

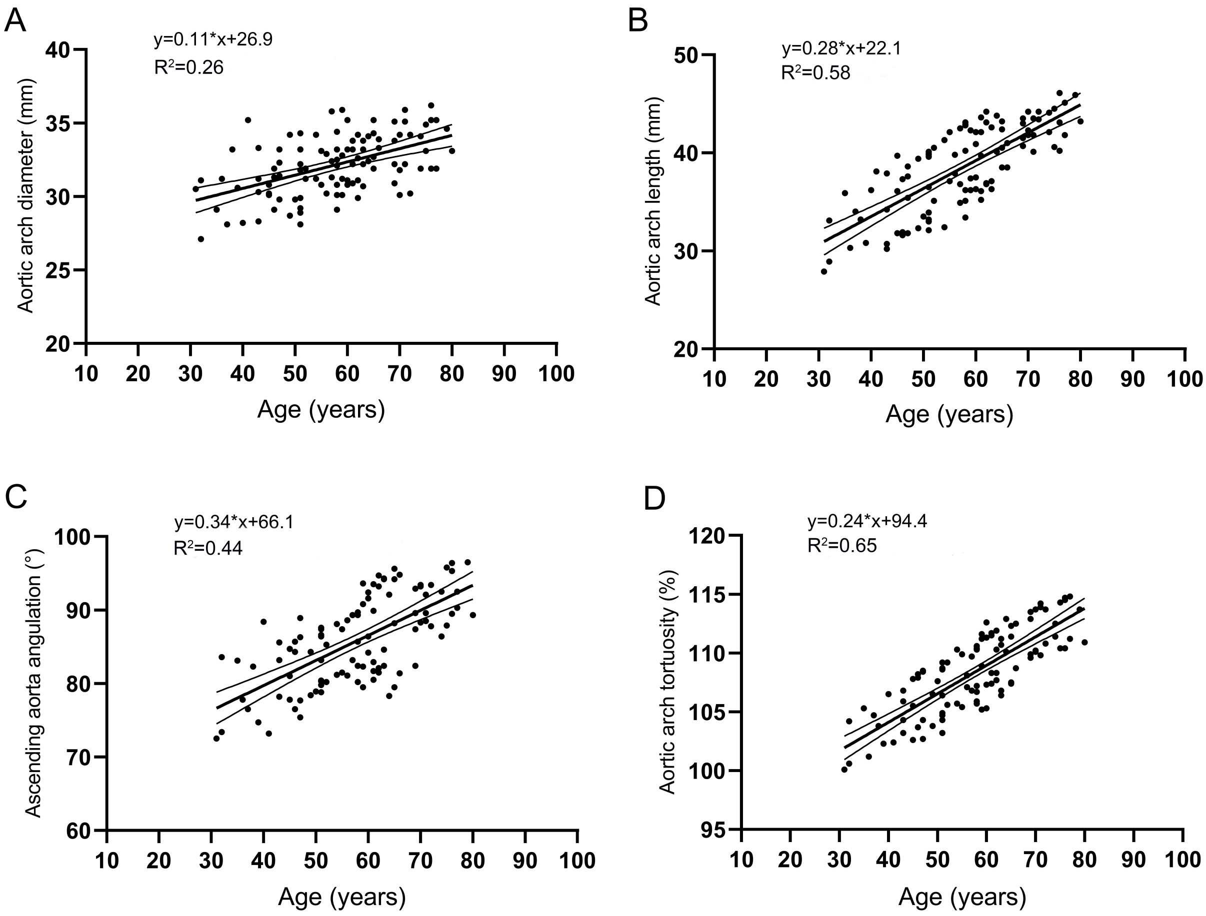

Figure 2. Unadjusted linear associations between age and aortic morphological parameters in the aTBAD group. Scatter plots illustrate the relationships between chronological age and aortic arch diameter (A), aortic arch length (B), ascending aorta angulation (C), and aortic arch tortuosity (D). R^2 represents coefficient of determination, indicating the proportion of variance explained by the univariable regression model. The slope coefficients represent the estimated change in each morphological parameter per 1-year increase in age. aTBAD: Acute type B aortic dissection.

parameters have been identified to be associated with aTBAD; however, these parameters themselves may also be subject to aging. Therefore, the effect of aging on aTBAD occurrence should not be neglected in the analysis. Herein, our main findings are as follows: (1) Age was correlated with most of the morphological parameters of ascending aorta and aortic arch in both the aTBAD and control groups; (2) Nevertheless, morphological parameters of TL and the ratio of TL to TAL were not associated with age; (3) The diameter, length and tortuosity of aortic arch and angulation of ascending aorta play independent and specific roles in the aTBAD occurrence despite their positive correlations with age. The clinical implications of the identified aortic morphological features warrant further consideration. Increased aortic diameter may reflect structural remodeling of the aortic wall, including progressive dilatation and reduced wall integrity, which are commonly observed during aortic degeneration. Aortic elongation, reflected by increased aortic length, may alter the spatial configuration of the thoracic aorta and modify the distribution of mechanical forces along the aortic wall. Similarly, increased aortic tortuosity and angulation represent geometric alterations of the aorta that may be associated with changes in local hemodynamic patterns and wall stress distribution.

Current guidelines recommend aortic diameter as the primary morphological risk factor for aortic disease, with a descending aortic diameter > 5.5 cm serving as an indication for surgical intervention[12]. Nevertheless, studies based on the International Registry of Acute Aortic Dissection (IRAD) database have indicated that aTBAD can occur in the absence of marked aortic dilation. Specifically, 81.6% of patients with aTBAD had

Table 4. Correlation of morphological variables with age adjusted for gender and BSA

	aTBAD group			Control group		
	β-10 yrs age	Adjusted R^2	*P* value	β-10 yrs age	Adjusted R^2	*P* value
Aortic dimension						
Diameter (cm)						
Ascending aorta	0.12	0.32	0.006	0.11	0.29	0.082
Aortic arch	0.10	0.56	< 0.001	0.09	0.62	< 0.001
Length (cm)						
Ascending aorta	0.31	0.28	0.003	0.29	0.46	0.046
Aortic arch	0.28	0.64	< 0.001	0.30	0.59	< 0.001
Volume (mL)						
Ascending aorta	7.3	0.42	0.058	6.2	0.39	0.024
Aortic arch	2.4	0.34	0.007	1.5	0.61	0.003
Aortic geometry						
Angulation (°)						
Ascending aorta	3.6	0.67	< 0.001	4.3	0.49	< 0.001
Aortic arch	7.8	0.57	0.001	8.2	0.67	0.004
Tortuosity (%)						
Ascending aorta	1.7	0.53	0.035	2.5	0.51	0.058
Aortic arch	2.4	0.65	< 0.001	3.7	0.62	< 0.001

Data were obtained from linear regression models adjusted for gender and BSA. β-10 yrs age represents the estimated change in each morphological parameter associated with a 10-year increase in age. Adjusted R^2 represents the proportion of variance in each morphological parameter explained by the corresponding regression model including age, gender, and BSA. BSA: Body surface area; aTBAD: acute type B aortic dissection.

Table 5. Multivariable logistic regression analyses adjusted for age, gender, and BSA and model discrimination for morphological characteristics associated with aTBAD

	β-coefficient	Standard error	OR	95%CI	*P* value
Variable					
Age (per 10 years)	-0.24	0.073	0.79	0.68-0.91	< 0.001
Aortic arch diameter (per 5 mm)	0.73	0.23	2.08	1.32-3.26	0.002
Aortic arch length (per 10 mm)	0.64	0.26	1.89	1.14-3.16	0.014
Ascending aortic angulation (per 10°)	1.35	0.52	3.86	1.39-10.69	0.009
Aortic arch tortuosity (per 10%)	0.87	0.31	2.39	1.30-4.38	0.005
Model performance					
AUC	0.794				
Bootstrap-corrected AUC	0.776				
Hosmer-Lemeshow goodness-of-fit test	χ^2 = 6.842, df = 8, *P* = 0.554				

ORs for continuous variables were calculated according to clinically relevant increments: age per 10-year increase, aortic arch diameter per 5-mm increase, aortic arch length per 10-mm increase, ascending aortic angulation per 10° increase, and aortic arch tortuosity per 10% increase. AUC: Area under the receiver operating characteristic curve; ORs: odds ratios; BSA: body surface area; aTBAD: acute type B aortic dissection.

aortic diameters less than 5.5 cm[13], and 21.2% had aortic diameters less than 3.5 cm[14]. Therefore, beyond a single indicator of aortic diameter, evaluating additional aortic morphological parameters may provide a more comprehensive assessment of aortic geometric characteristics associated with aTBAD. Given the lack of pre-event imaging data and the substantial changes in descending aortic morphology after the aTBAD onset

[15], the present study paid more attention to the non-dissected proximal aorta region, where the aortic morphological variables remained relatively preserved after dissection.

Aging of both the healthy and pathological aorta is an irreversible and complex process that induces progressive structural and functional changes in the aortic wall over time[16]. Morphological alterations of the aorta are among the most important aspects of this process. Firstly, aging leads to changes in the components of the aortic wall, including decreased elastin and increased collagen[16-18], which reduce aortic wall compliance and may ultimately increase the risk of aortic dissection or rupture. Secondly, the aorta may elongate over time[8,19], while the vertebral column may gradually shorten with aging[20], resulting in alterations in aortic tortuosity and angulation. Due to the physiologic enlargement and unfolding of the aorta throughout life, it is not always justified to apply fixed threshold values to assess the risk of aTBAD. Interestingly, age showed a negative coefficient after adjustment for aortic morphological variables in the multivariable model. This finding should not be interpreted as indicating a protective effect of older age. Instead, this coefficient represents the residual association of chronological age with aTBAD after accounting for age-related morphological characteristics. Since several morphological parameters included in the model may themselves reflect age-associated aortic remodeling, adjustment for these variables may have altered the independent contribution of chronological age.

In non-dissecting population, age-related alterations in aortic morphology have been investigated relatively extensively[8,9,21,22]. Age-associated changes in aortic geometry are accompanied by increased aortic stiffness, which is closely pertinent to the age-related unfolding of the aortic arch[8]. Additionally, the enlargement and unfolding of the aorta are significantly accelerated in patients with hypertension[23]. Nevertheless, the correlations between aortic morphological variables in patients with aTBAD and age have been much less studied. In this study, we uniquely analyzed the morphological variables indexed to age and found that five variables, including aortic arch diameter, length, tortuosity, ascending aorta angulation and age, were independently associated with the presence of aTBAD. Moreover, in the non-aortic disease control group, the ascending aortic diameter showed a trend toward enlargement with increasing age (approximately 1 mm per decade), although this association did not reach statistical significance ($P = 0.082$). In contrast, the increase in ascending aortic length was statistically significant (approximately 3 mm per decade, $P = 0.046$), which was comparable with previous studies[9,21,24].

Moreover, we found that morphological variables of the TL were not correlated with age, even after normalization to TAL, which contradicted previous reports[25]. One possible explanation is that our study included cases with false lumen involvement extending to the abdominal aorta. In addition, false lumen size could be affected by poor control of blood pressure, the site of intimal tear and false lumen embolization. Following dissection, the true lumen becomes compressed, and the diameter, length and volume of the total lumen in the dissected descending aorta were significantly greater than those in the control group, accompanied by steeper angulation and larger tortuosity. Monitoring dimensional changes in the true lumen and false lumen may facilitate optimized preoperative planning, assessment of branch vessel perfusion, and evaluation of aortic remodeling following thoracic endovascular aortic repair (TEVAR).

Recent advances in the concept of biological aging have highlighted that chronological age may not fully represent the functional status of individual organs and vascular systems[26]. Similar concepts, such as vascular age, have been proposed to capture age-related changes beyond traditional chronological aging. In this context, our findings showing age-associated variations in aortic arch morphology suggest that quantitative assessment of aortic geometric characteristics may provide additional information regarding vascular aging. Although further longitudinal studies are required, these observations may contribute to the future development of an “aortic age” concept based on imaging-derived morphological features.

Nonetheless, there are several limitations in the present study that need to be acknowledged. First, due to the retrospective and case-control design, the results may not fully establish a causal relationship between aortic morphological variables and aTBAD. Second, the use of hospital-based controls rather than population-based healthy volunteers may introduce referral bias. However, this design was chosen because obtaining aortic CTA in truly healthy asymptomatic individuals is ethically and practically unfeasible. The control group in our study is comparable to those used in prior published studies investigating aortic morphology[8,9]. Third, although BSA and gender were adjusted in the multivariable analyses to account for body size and demographic differences, residual confounding related to other unmeasured anthropometric characteristics cannot be completely excluded. Fourth, the relatively young age of our study population may limit the generalizability of our findings to older patients with aTBAD. However, the observed associations between aortic morphological characteristics and aTBAD remained significant after adjustment for age, suggesting that these morphological features may be independently related to the presence of aTBAD after accounting for chronological age. Fifth, quantitative assessment of aortic calcification was not available in the present cohort. Calcification represents an important marker of vascular aging and aortic wall degeneration, and future studies integrating calcification burden with geometric parameters may provide a more comprehensive understanding of aortic remodeling in aTBAD. Sixth, although smoking status was comparable between the two groups, residual confounding from smoking-related exposure, including smoking intensity and cumulative pack-years, cannot be completely excluded.

CONCLUSION

Increased diameter, length and tortuosity of aortic arch and angulation of ascending aorta are independently associated with aTBAD occurrence, despite these variables being positively correlated with age. These findings suggest that incorporating age-related changes in aortic morphology may aid in the identification of patients at increased risk of aTBAD. Further research is warranted to establish age-adjusted threshold values for these parameters, which could facilitate the early risk stratification of high-risk individuals and guide preventive strategies.

DECLARATIONS

Authors' contributions

Made substantial contributions to conception and design of the study, writing -review & editing: Hua Z, Cui P, Sun L
Performed data analysis and interpretation: Li Z, Jiao Z, Cui P
Performed data acquisition: Cao H, Xu P, Zhang Q
Writing - original draft: Sun L

Availability of data and materials

The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available due to containing information that could compromise the privacy of research participants.

AI and AI-assisted tools statement

Not applicable.

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Conflicts of Interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

This multicenter retrospective case-control study was approved by the Life Science Ethics Review Committee of Zhengzhou University (approval number: SQ2025-194). The Second Xiangya Hospital of Central South University participated in the study as a collaborating institution and accepted the central ethics approval. The requirement for individual informed consent was waived due to the retrospective nature of the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (as revised in 2013).

Consent for publication

Not applicable.

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Supplementary Materials

Supplementary Materials

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