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Three-dimensional morphometric analysis of the abdominal aorta and common iliac arteries in adult women of Zhuang and Han in Guangxi: associations with age and ethnicity

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Abstract

Purpose

Three-dimensional (3D) morphometric data of the abdominal aorta (AA) and common iliac arteries (CIA) in Chinese women are scarce. This study established centreline-based 3D reference values of the AA and CIA in adult Zhuang and Han women in Guangxi, and analysed their associations with age, body surface area (BSA) and blood pressure.

Methods

After ethical approval, 187 contrast-enhanced CTA datasets of adult women (83 Zhuang, 104 Han; mean age 52.7 ± 11.5 years), free of aortic and iliac pathology as verified by two senior radiologists, were retrospectively analysed. Lengths, diameters, cross-sectional areas, tortuosity index, ellipticity and angulation were measured perpendicular to the centreline. Reproducibility was assessed with intraclass correlation coefficients and Bland–Altman analysis; correlations and multiple linear regression determined associations with demographic and haemodynamic variables.

Results

Mean AA length was 146.76 ± 13.55 mm and distal diameter 13.01 ± 1.59 mm. Zhuang women had a nominally shorter and less tortuous AA than Han women (p = 0.047 and 0.043), but neither difference survived Benjamini–Hochberg correction. The left CIA was longer and had a smaller proximal calibre than the right (surviving correction), whereas the distal differences were nominal. Age was the dominant independent determinant of diameter and tortuosity (β = 0.35–0.48), with BSA contributing to the diameters only; adjusted R^2 was 0.046 for length but 0.273–0.277 for diameters.

Conclusion

Age was the dominant determinant of AA geometry in adult women from Guangxi. The left CIA was consistently longer and had a smaller proximal calibre than the right. Ethnic differences were nominal only. These reference values may inform stent-graft selection and preprocedural planning for endovascular repair in Chinese women.

Introduction

Aortic and iliac artery diseases—encompassing abdominal aortic aneurysm (AAA), dissection, and aortoiliac occlusive disease—represent a major cause of cardiovascular morbidity and mortality worldwide. Rupture of an AAA carries a mortality rate exceeding 80%, and even with timely intervention, the burden of disease on patients and healthcare systems remains substantial[11]. The epidemiology of

AAA has evolved considerably, with declining tobacco use and advances in endovascular repair contributing to improved outcomes; nonetheless, significant disparities persist across sex, race, and ethnicity in disease detection, treatment, and prognosis[8]. Importantly, female sex has been identified as an independent risk factor predisposing to aneurysm rupture, and women present with distinct morphological and biomechanical characteristics that influence both the natural history of disease and the feasibility of endovascular treatment[2]. These observations underscore the critical importance of sex- and population-specific morphological reference data for accurate risk stratification and individualized treatment planning.

Current diagnosis of aortic and iliac artery disease relies primarily on computed tomography angiography (CTA), magnetic resonance angiography, and ultrasonography[2]. Treatment options include open surgical repair and endovascular aortic repair (EVAR), with the latter increasingly favored in patients at high surgical risk[8]. Endovascular planning depends heavily on precise morphometric parameters—including vessel length, diameter, tortuosity, ellipticity, and angulation—for stent-graft sizing of both the aorta and the common iliac arteries[1]. Nevertheless, the morphological parameters currently used for device sizing and risk prediction are largely derived from Western populations and other Asian cohorts, and data specific to Chinese women—particularly ethnic minorities such as the Zhuang—remain sparse. Moreover, conventional two-dimensional measurements cannot fully capture three-dimensional features such as tortuosity, ellipticity, and angulation, which have been increasingly recognized as clinically relevant[13].

Recent advances in three-dimensional reconstruction and quantitative image analysis have enabled more comprehensive characterization of aortic morphology. Computational approaches have demonstrated that morphological and geometric features beyond maximum diameter—including tortuosity, angulation, and cross-sectional ellipticity—contribute to the prediction of disease progression and rupture risk, and may facilitate personalized therapeutic decision-making[13]. Concurrently, population genetics studies have revealed that the Zhuang, the largest ethnic minority in China, share common ancestry with the Han population while retaining distinct genetic substructure shaped by long-term admixture and introgression[16]. Such genetic divergence may plausibly influence vascular remodeling and arterial morphology, yet no study has systematically compared three-dimensional aortic and iliac morphometry between Zhuang and Han women. This constitutes a critical knowledge gap, as the absence of ethnicity- and sex-specific normative data may lead to mismatched device selection and inaccurate risk assessment in these populations.

The specific objectives of this study were fivefold: first, to establish three-dimensional morphometric reference values of the abdominal aorta and bilateral common iliac arteries in adult Zhuang and Han women; second, to compare these parameters between ethnicities and between sides; third, to evaluate their associations with age, body surface area, and blood pressure; fourth, to construct regression models identifying the major determinants of aortic morphology; and fifth, to assess measurement reproducibility. By providing ethnicity- and sex-specific normative data, this study aims to inform

personalized device selection, improve risk stratification, and lay the groundwork for future comparative studies in aortic and iliac artery disease.

Materials and Methods

Study design and participants

This retrospective, descriptive, cross-sectional study was reported in accordance with the STROBE statement [4], and the completed checklist is provided in the Supplementary Materials. The study was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University; the requirement for individual informed consent was waived owing to the retrospective design. All patients had provided written informed consent for iodinated contrast administration before CTA, and patient information was anonymised.

Abdominal contrast-enhanced CTA scans of adult women acquired at the First Affiliated Hospital of Guangxi Medical University between December 2022 and March 2023 were retrieved from the picture archiving and communication system. Scans were included if: (1) the participant, her parents and her grandparents had all resided in the Guangxi Zhuang Autonomous Region for three consecutive generations and were registered in the household registry as belonging to the same ethnicity (Zhuang or Han); (2) the participant was 18–85 years of age; (3) the images were independently reviewed by two senior radiologists and confirmed to be free of abdominal aortic aneurysm, aortic dissection, overt atherosclerotic stenosis (stenosis < 50%), Takayasu arteritis, congenital vascular malformation or other severe cardiovascular disease such as Marfan syndrome; and (4) clinical data, including age, ethnicity, native place and indication for the examination, were complete. Scans were excluded in the presence of: (1) non-Guangxi household registration or unclear ethnicity; (2) severe motion artefacts or circumferential calcification precluding lumen assessment; or (3) previous abdominal aortic or iliac arterial surgery or endovascular treatment.

In total, 221 scans were screened and 34 were excluded according to the above criteria; 187 women (83 Zhuang, 104 Han) were finally included. An a priori sample size calculation, based on a between-ethnicity difference of 0.5 mm in distal aortic diameter with a pooled standard deviation of 1.6 mm (two-sided $\alpha = 0.05$, power 0.80), indicated 161 subjects per group. Allowing for a 15% exclusion rate, the finally included sample did not reach this estimate. A recalculation based on the achieved sample size indicated that the minimum detectable between-group difference at 80% power was approximately 0.66 mm; smaller differences may therefore have been missed, and the negative findings of the between-ethnicity comparisons should be interpreted accordingly.

CT protocol

CT protocol

All scans were performed with a 256-slice spiral CT scanner (Philips Brilliance iCT; Philips Healthcare, Best, the Netherlands). The scanning parameters were: detector collimation 128×0.625 mm; tube voltage 120 kV; automatic tube current modulation (ATCM; reference tube current 320 mAs); gantry rotation time 0.5 s/rot; pitch 0.993; field of view 350×350 mm; matrix 512×512; reconstruction slice thickness/increment 0.625/0.625 mm; and iDose⁴ iterative reconstruction (level 3).

A non-ionic iodinated contrast agent (ioversol, 350 mgI/mL; 60 mL) was injected as a bolus through an antecubital vein at 4–5 mL/s, followed by 40 mL of 0.9% sodium chloride solution at the same flow rate. Bolus tracking was applied with the region of interest placed in the descending aortic lumen (approximately at the T11 level), a trigger threshold of 100 HU and a post-trigger delay of 6 s for arterial-phase acquisition. The raw data were transferred to a Philips Extended Brilliance Workspace workstation for thin-slice reconstruction.

Three-dimensional reconstruction and morphometric measurements

The DICOM data were imported into Mimics 21.0 (Materialise, Leuven, Belgium) and processed as follows: (1) the contrast-filled vascular lumen was initially segmented using a CT-value threshold (lower limit 150 HU); (2) masks of the abdominal aorta (AA) and the bilateral common iliac arteries (CIA) were generated by region growing; (3) calcified plaques, adjacent veins and lumbar arterial branches were removed by layer-by-layer manual mask editing, cross-checked by two post-processing physicians; (4) three-dimensional (3D) models were calculated and smoothed with five iterations; (5) the centreline was extracted automatically and errors at branch points were corrected manually; and (6) all parameters were measured on cross-sections perpendicular to the centreline, each measurement being performed in triplicate and averaged.

The morphological parameters were defined as follows (Fig. 1). The AA length was the centreline arc length fromthe inferior margin of the 12th thoracic (T12) vertebral body (anatomically corresponding to the aortic hiatus of the diaphragm) to the aortic bifurcation, and the CIA length the centreline arc length from the aortic bifurcation to the ipsilateral CIA bifurcation. Diameters and cross-sectional areas were measured at four AA landmarks—immediately inferior to the inferior margin of the T12 vertebral body (proximal AA, anatomically corresponding to the aortic hiatus), immediately inferior to the renal arteries (mid-proximal AA), at the origin of the inferior mesenteric artery (mid-distal AA) and 1 cm superior to the aortic bifurcation (distal AA)—and at the origin and bifurcation of each CIA. All diameters were lumen (inner wall-to-inner wall) diameters measured perpendicular to the centreline. The tortuosity index (TI) was calculated as (Lcurve − Lstraight)/Lstraight, where Lcurve is the centreline arc length and Lstraight the straight-line distance between the two length landmarks [6]; a TI of 0 indicates a straight vessel and larger values indicate greater tortuosity. The TI quantifies the severity of tortuosity but not its phenotypic appearance. The ellipticity index (EI) was calculated as (Dmax − Dmin)/Dmax. The inter-iliac angle and the CIA-internal iliac artery (CIA-IIA) angles were read from the 3D models using the angle measurement tool in Mimics.

Measurement reproducibility

Thirty scans (15 Zhuang, 15 Han) were randomly selected for the reproducibility assessment. The distal aortic diameter and the left CIA length were chosen as representative parameters, because they are the primary targets of stent-graft sizing and represent the most and least demanding measurement tasks, respectively; the reproducibility of the remaining parameters was not formally assessed and is acknowledged as a limitation. The two parameters were independently measured by two physicians with more than 5 years of experience in image post-processing, one of whom repeated the measurements after an interval of 2 weeks. Intra- and inter-observer agreement was evaluated using the intraclass correlation coefficient (*ICC*), and Bland-Altman plots (difference against mean) were constructed for each parameter. An $ICC > 0.75$ was considered to indicate good reproducibility [10].

Statistical analysis

Body surface area (BSA) was calculated with the Mosteller formula from height and weight recorded on the day of the CTA examination. Blood pressure was measured with a calibrated electronic sphygmomanometer on the right brachial artery after 5 minutes of seated rest, before contrast administration.

Statistical analyses were performed with SPSS 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test in combination with skewness, and the homogeneity of variances using Levene's test. Normally distributed data with homogeneous variances are presented as mean ± SD, and skewed data (absolute skewness > 2) as median (P25, P75). Between-ethnicity comparisons were performed using independent-samples t tests and between-side comparisons using paired t tests; for skewed data, the Mann-Whitney U test and the Wilcoxon signed-rank test were used, respectively. Correlations were analysed using Pearson's correlation for normally distributed variables and Spearman's rank correlation for skewed variables. Multiple linear regression was performed with age, BSA, systolic blood pressure and diastolic blood pressure as independent variables, and collinearity was diagnosed using the variance inflation factor (*VIF*).

To account for the simultaneous testing of multiple parameters, Benjamini-Hochberg false discovery rate (FDR) correction was applied to the families of between-ethnicity and between-side comparisons, and corrected P values are reported alongside the nominal values. Fourteen cases with missing data were handled by complete-case analysis and excluded from correlation and regression analyses (173 cases retained). All hypothesis tests were two-sided, and $p < 0.05$ was considered statistically significant.

Results

Measurement reproducibility and sample characteristics

The intra-observer and inter-observer *ICC*[S] for the distal aortic diameter and the left CIA length were both greater than 0.80 (see Supplementary Materials), and Bland-Altman analysis showed that the mean differences of each parameter were close to 0, with 95% limits of agreement within clinically acceptable ranges, indicating good reproducibility of the three-dimensional measurement method.

A total of 187 adult women (83 Zhuang, 104 Han) were included, with a mean age of 52.7 ± 11.5 years, mean body surface area (BSA) of 1.49 ± 0.13 m², mean systolic blood pressure of 126.83 ± 21.66 mmHg and mean diastolic blood pressure of 80.00 ± 17.71 mmHg. Age, BSA and blood pressure did not differ significantly between the two ethnic groups (all $p > 0.05$). Fourteen cases with missing data were excluded by complete-case analysis; therefore, correlation and regression analyses included 173 cases (79 Zhuang, 94 Han). The AA length in the whole group was 146.76 ± 13.55 mm and the distal diameter 13.01 ± 1.59 mm; the distributions of the remaining parameters are shown in Tables 1 and 2.

Table 1
Ethnic differences in the morphological parameters of the abdominal aorta in adult Zhuang and Han women in Guangxi (mean ± SD or median (P25, P75))

Parameter	Zhuang(n = 83)	Han(n = 104)	Overall mean	t/Z value	P value	FDR adjust
Length(mm)[a]	144.56 ± 13.09	148.52 ± 13.72	146.76 ± 13.55	-2.00	0.047	0.354
Tortuosity index[a]	0.02(0.01, 0.03)	0.02(0.01, 0.04)	0.02(0.01, 0.03)	-2.05	0.043	0.650
Proximal diameter(mm)	18.07 ± 2.07	18.46 ± 2.2	18.28 ± 2.15	-1.25	0.214	0.356
Proximal cross-sectional area(mm^2)	259.22 ± 59.37	271.39 ± 64.74	265.99 ± 62.54	-1.33	0.187	0.400
Proximal ellipticity index	0.33 ± 0.12	0.33 ± 0.10	0.33 ± 0.11	-0.13	0.898	0.962
Mid-proximal diameter(mm)	16.14 ± 2.02	16.26 ± 2.13	16.21 ± 2.08	-0.38	0.704	0.881
Mid-proximal cross-sectional area (mm^2)	207.41 ± 51.99	210.15 ± 55.99	208.93 ± 54.13	-0.34	0.732	0.844
Mid-proximal ellipticity index	0.41 ± 0.13	0.40 ± 0.12	0.4 ± 0.13	1.01	0.315	0.430
Mid-distal diameter (mm)	13.22 ± 1.61	13.50 ± 1.71	13.38 ± 1.67	-1.14	0.257	0.386
Mid-distal cross-sectional area (mm^2)	138.71 ± 33.29	145.34 ± 36.98	142.4 ± 35.45	-1.27	0.204	0.383
Mid-distal ellipticity index	0.29 ± 0.10	0.28 ± 0.09	0.29 ± 0.10	0.13	0.899	0.899
Distal diameter(mm)	12.82 ± 1.57	13.16 ± 1.59	13.01 ± 1.59	-1.44	0.151	0.454
Distal cross-sectional area(mm^2)	130.11 ± 31.21	136.52 ± 33.84	133.67 ± 32.77	-1.33	0.185	0.462
Distal ellipticity index	0.41 ± 0.12	0.44 ± 0.15	0.43 ± 0.14	-1.65	0.100	0.374
Inter-iliac angle(°)	46.84 ± 12.42	43.45 ± 11.32	44.95 ± 11.91	1.95	0.053	0.264

[a] $P < 0.05$, [b] remained significant after Benjamini-Hochberg correction

Table 2
Side differences in the morphological parameters of the common iliac arteries in adult Zhuang and Han women (mean ± SD)

Parameter	Left CIA(n = 187)	Right CIA(n = 187)	Overall mean	t/Z value	P value	FDR adjust
Length(mm)[a b]	49.62 ± 17.67	46.7 ± 16.6	48.42 ± 17.28	3.38	0.001	0.003
Tortuosity index	0.03(0.02, 0.05)	0.03(0.02, 0.05)	0.03(0.02, 0.05)	-0.38	0.297	0.445
Proximal diameter(mm)[a b]	8.75 ± 1.16	8.89 ± 1.18	8.76 ± 1.15	-3.45	0.001	0.003
Proximal cross-sectional area(mm^2)[a b]	60.82 ± 16.15	63.45 ± 17.03	61.32 ± 16.25	-3.73	0.000	0.002
Proximal ellipticity index	0.42 ± 0.1	0.43 ± 0.1	0.42 ± 0.1	-0.85	0.395	0.507
Distal diameter(mm)[a]	8.74 ± 1.53	8.88 ± 1.43	8.75 ± 1.51	-2.08	0.039	0.069
Distal cross-sectional area(mm^2)[a]	61.05 ± 21.55	63.17 ± 20.53	61.4 ± 21.48	-2.15	0.033	0.075
Distal ellipticity index	0.43 ± 0.12	0.44 ± 0.13	0.43 ± 0.12	-0.63	0.530	0.596
CIA-IIA angle(°)	27.42 ± 12.97	27.81 ± 11.33	27.68 ± 12.13	-0.39	0.696	0.696

[a] $P < 0.05$, [b] remained significant after Benjamini-Hochberg correction

Ethnic differences in abdominal aortic morphology

Shapiro-Wilk tests showed that, except for the tortuosity index, all AA parameters followed a normal distribution. Between-ethnicity comparison showed that only the length and tortuosity of the AA differed nominally between groups (Table 1): both were lower in Zhuang than in Han women (length: 144.56 ± 13.09 vs. 148.52 ± 13.72 mm, $t = -2.00$, $p = 0.047$; tortuosity index: 0.02 [0.01, 0.03] vs. 0.02 [0.01, 0.04], $Z = -2.05$, $p = 0.043$). Neither difference remained significant after Benjamini-Hochberg correction (corrected $p = 0.35$ and 0.65, respectively; Table 1). The inter-iliac angle did not differ significantly between ethnicities (46.84 ± 12.42° vs. 43.45 ± 11.32°, $t = 1.95$, $p > 0.05$), and none of the remaining parameters differed between groups (all $p > 0.05$, Table 1).

Side differences in common iliac artery morphology

Paired comparison showed a consistent dimensional asymmetry of the CIA (Table 2): the left CIA was longer than the right (49.62 ± 17.67 vs. 46.70 ± 16.60 mm, $t = 3.38$, $p = 0.001$), whereas its proximal

diameter (8.75 ± 1.16 vs. 8.89 ± 1.18 mm, t = − 3.45), proximal cross-sectional area (60.82 ± 16.15 vs. 63.45 ± 17.03 mm², t = − 3.73), distal diameter (8.74 ± 1.53 vs. 8.88 ± 1.43 mm, t = − 2.08) and distal cross-sectional area (61.05 ± 21.55 vs. 63.17 ± 20.53 mm², t = − 2.15) were all smaller than those of the right. The left–right differences in length, proximal diameter and proximal cross-sectional area remained significant after Benjamini–Hochberg correction (corrected p = 0.003, 0.003 and 0.002, respectively; Table 2), whereas the distal differences, although nominally significant (p = 0.039 and 0.033), did not survive correction (corrected p = 0.069 and 0.075; Table 2). The tortuosity index, proximal and distal ellipticity indices and the CIA-IIA angles did not differ significantly between sides (all p > 0.05, Table 2), indicating that the asymmetry was dimensional rather than angular.

Correlations with age, body surface area and blood pressure

Pearson analysis showed that AA length was weakly positively correlated with age, BSA and systolic blood pressure (r = 0.166–0.175, all p < 0.05), but not with diastolic blood pressure (r = 0.094, p > 0.05; Table 3). The proximal and distal diameters were positively correlated with all four variables, the distal diameter showing the strongest correlation with age (r = 0.500, p < 0.001) and the proximal diameter the next (r = 0.482, p < 0.001; Table 3). Spearman analysis showed that the tortuosity index was positively correlated with age (r_s=0.479), systolic blood pressure (r_s=0.298) and diastolic blood pressure (r_s=0.207; all p < 0.05), but not with BSA (r_s = − 0.038, p > 0.05). The proximal ellipticity index showed no significant correlation with any variable, and the distal ellipticity index correlated only weakly with BSA (r = − 0.145, p < 0.05), which did not remain significant after FDR correction. All correlations that survived Benjamini-Hochberg correction are marked in Table 3.

Simple and multiple linear regression

With age as the independent variable and the distal aortic diameter as the dependent variable, the scatterplot showed a moderate positive correlation (r = 0.500, 95% CI: 0.379–0.604, p < 0.001; Fig. 2), and the simple linear regression equation was: distal diameter (mm) = 9.342 + 0.0686×age (years), R^2=0.250.

Multiple linear regression (Table 4) confirmed age as the dominant independent factor for the tortuosity index (β = 0.35) and for both the proximal (β = 0.45) and distal (β = 0.48) diameters, with BSA contributing to the diameters to a lesser degree (β = 0.15 and 0.15, respectively); all variance inflation factors were below 10. In contrast, no independent variable reached significance in the length model (all t < 1.96, adjusted R^2=0.046), indicating that aortic length is governed by factors not captured in this dataset. The explanatory power of the models differed accordingly: adjusted R^2 was 0.046 for length but 0.273 and 0.277 for the proximal and distal diameters, respectively. The regression equations were: length (mm) = 107.026 + 0.163×age (years) + 14.418×BSA (m²) + 0.097×systolic blood pressure (mmHg)+(− 0.031)×diastolic blood pressure (mmHg); proximal diameter (mm) = 7.481 + 0.085×age (years) + 2.512×BSA (m²) + 0.007×systolic blood pressure (mmHg) + 0.022×diastolic blood pressure (mmHg); and distal diameter (mm) = 5.378 + 0.066×age (years) + 1.771×BSA (m²) + 0.002×systolic blood pressure (mmHg) + 0.015×diastolic blood pressure (mmHg) (Tables 4 and 5).

Table 3
Correlations of the morphological parameters of the abdominal aorta with age, body surface area and blood pressure (r/r_s, n = 173)

Parameter	Correlation coefficient(r/r_s)			
	Age(n = 173)	Body surface area(n = 173)	Systolic blood pressure(n = 173)	Diastolic blood pressure(n = 173)
Length	0.175[ab]	0.166[ab]	0.166[ab]	0.094
Tortuosity index	0.479[ab]	-0.038	0.298[ab]	0.207[ab]
Proximal diameter	0.482[ab]	0.185[ab]	0.305[ab]	0.222[ab]
Proximal ellipticity index	-0.044	0.030	-0.007	0.000
Distal diameter	0.500[ab]	0.177[ab]	0.275[ab]	0.213[ab]
Distal ellipticity index	-0.138	-0.145[a]	-0.103	-0.071

[a] $P < 0.05$, [b] remained significant after Benjamini-Hochberg correction

Table 4
Multiple linear regression analysis of the morphological parameters of the abdominal aorta with age, body surface area and blood pressure in adult Zhuang and Han women in Guangxi (n = 173)

Parameter	Age(n = 173)		Body surface area (n = 173)		Systolic blood pressure (n = 173)		Diastolic blood pressure (n = 173)	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI
Length	0.14	[-0.017, 0.342]	0.14	[-0.877, 29.713]	0.14	[-0.048, 0.241]	-0.03	[-0.269, 0.207]
Tortuosity index	0.35	[0.0005, 0.001]	-0.14	[-0.05, 0.0005]	0.1	[-0.0001, 0.0004]	0.09	[-0.0002, 0.0006]
Proximal diameter	0.45	[0.06, 0.11]	0.15	[0.369, 4.655]	0.06	[-0.013, 0.027]	0.12	[-0.012, 0.055]
Proximal ellipticity index	-0.04	[-0.002, 0.001]	0.03	[-0.106, 0.149]	0.003	[-0.001, 0.001]	-0.03	[-0.002, 0.002]
Distal diameter	0.48	[0.048, 0.085]	0.15	[0.201, 3.34]	0.02	[-0.013, 0.017]	0.11	[-0.009, 0.04]
Distal ellipticity index	-0.12	[-0.003, 0.0004]	-0.15	[-0.309, 0.001]	-0.08	[-0.002, 0.001]	0.01	[-0.002, 0.003]

Table 5
Multiple linear regression models for abdominal aortic length and diameters (B, SE, standardised *β*, *t*, 95% CI and *VIF*; *n* = 173)

Dependent variable	**Independent variable**	**B**	**SE**	***β***	***t* value**	**95%CI**	***VIF***
Length **(n = 173)**	Constant[a]	107.026	13.217	-	8.098	[80.93, 133.12]	-
	Age	0.163	0.091	0.140	1.791	[-0.02, 0.34]	1.101
	Body surface area	14.418	7.747	0.140	1.861	[-0.88, 29.71]	1.025
	Systolic blood pressure	0.097	0.073	0.142	1.321	[-0.05, 0.24]	2.086
	Diastolic blood pressure	-0.031	0.121	-0.027	-0.254	[-0.27, 0.21]	1.965
Proximal diameter **(n = 173)**	Constant[a]	7.481	1.852	-	4.040	[3.83, 11.14]	-
	Age [a]	0.085	0.013	0.454	6.661	[0.06, 0.11]	1.101
	Body surface area[a]	2.512	1.086	0.152	2.314	[0.37, 4.65]	1.025
	Systolic blood pressure	0.007	0.010	0.064	0.686	[-0.01, 0.03]	2.086
	Diastolic blood pressure	0.022	0.017	0.116	1.273	[-0.01, 0.05]	1.965
Distal diameter **(n = 173)**	Constant [a]	5.378	1.357	-	3.964	[2.7, 8.06]	-
	Age [a]	0.066	0.009	0.484	7.111	[0.05, 0.08]	1.101
	Body surface area[a]	1.771	0.795	0.146	2.227	[0.20, 3.34]	1.025
	Systolic blood pressure	0.002	0.008	0.024	0.255	[-0.01, 0.02]	2.086
	Diastolic blood pressure	0.015	0.012	0.113	1.246	[-0.01, 0.04]	1.965

[a] $P < 0.05$

Discussion

This study established three-dimensional, centreline-based morphometric reference values for the abdominal aorta (AA) and common iliac arteries (CIA) in 187 adult women from Guangxi, and analysed their associations with ethnicity, age, body surface area (BSA) and blood pressure. The main findings were threefold. First, ethnic differences in AA geometry were confined to a shorter and nominally less tortuous aorta in Zhuang women, and these differences did not remain significant after correction for multiple comparisons in larger samples. Second, the CIA displayed a consistent dimensional asymmetry, the left artery being longer but of smaller calibre than the right. Third, age was the dominant determinant of aortic diameter and tortuosity, whereas its effect on length was weak; the impact of age was thus greater on diameter than on length, consistent with the pattern reported in other populations[9].

The mean AA length in the present sample (146.76 ± 13.55 mm, measured from the inferior margin of the T12 vertebral body (anatomically corresponding to the aortic hiatus) to the bifurcation) exceeded the value reported for women in a South African CTA series measured from the coeliac trunk to the bifurcation (123.37 ± 15.60 mm) [9], a difference that is partly attributable to the longer proximal landmark used in the present study as well as to population and body-size differences. Direct comparison with the Copenhagen General Population Study [12] is constrained by differences in measurement protocol; nevertheless, the diameters reported here fall at the lower end of published ranges. The comparatively small mean BSA of this cohort (1.49 ± 0.13 m²) relative to Western reference populations plausibly accounts for this, since aortic calibre scales with body size [12, 14]. These comparisons should be interpreted descriptively, as the measurement landmarks and population compositions differ across studies, and they underline that standardised, centreline-based measurement protocols are a prerequisite for meaningful between-population comparisons.

The between-ethnicity comparison showed that Zhuang women had a shorter (144.56 ± 13.09 vs. 148.52 ± 13.72 mm, *P* =0.047) and nominally less tortuous aorta (median TI 0.02 [0.01, 0.03] vs. 0.02 [0.01, 0.04], *P* 0.043) than Han women, whereas diameters and cross-sectional areas at all four aortic levels were statistically indistinguishable. After Benjamini–Hochberg correction, neither the length nor the tortuosity difference remained significan. Shorter stature and concomitant differences in pelvic and trunk morphology among the Zhuang, together with the well-documented paternal genetic admixture between the Zhuang and southern Han populations [16], provide plausible anatomical and genetic explanations for a shorter aortic course, since aortic length scales with body height and vertebral segment length. The absence of significant diameter differences should not, however, be interpreted as evidence of equivalence: with the achieved sample size, the study could only detect inter-group diameter differences of approximately 0.66 mm at 80% power, and smaller yet clinically meaningful differences may therefore have been missed. This limitation is particularly relevant given that differences of this magnitude approach the thresholds used in device sizing and in the definition of aortic ectasia. Future adequately powered multicentre studies with standardised centreline-based protocols are required before true equivalence between Zhuang and Han women can be asserted.

The paired comparison revealed a consistent pattern of left–right asymmetry: the left CIA was longer (49.62 ± 17.67 vs. 46.70 ± 16.60 mm), whereas its proximal and distal diameters and cross-sectional areas were smaller than those of the right. The proximal differences (diameter: 8.75 ± 1.16 vs. 8.89 ± 1.18 mm; cross-sectional area: 60.82 ± 16.15 vs. 63.45 ± 17.03 mm²) survived Benjamini–Hochberg correction (corrected p = 0.003 and 0.002), whereas the distal differences, although nominally significant (p = 0.039 and 0.033), did not survive correction (corrected p = 0.069 and 0.075) (Table 2). This asymmetry has an anatomical and embryological basis, reflecting the different courses of the common iliac arteries relative to the aortic bifurcation, the position of the left common iliac vein deep to the right CIA, and asymmetries in pelvic vascular development and branching patterns [7, 15]. From a clinical standpoint, these side-specific differences are directly relevant to endovascular aortic repair, where the iliac limb must accommodate a longer but narrower proximal left landing zone, potentially influencing stent-graft sizing, the risk of limb occlusion or kinking, and access-site selection [1]. The observation that bifurcation and iliac angulation parameters did not differ significantly between sides suggests that the asymmetry is predominantly dimensional rather than angular. The use of perpendicular-to-centreline measurements in the present study strengthens the validity of these side-specific reference values, as previous inconsistencies in reported iliac asymmetry likely reflect differences between axial and perpendicular cross-sectional measurement methods..

The correlation analyses identify age, BSA and blood pressure as coherent correlates of abdominal aortic remodelling, with the strongest associations observed for diameter and the weakest for length. The pathophysiological basis for these relationships is well established: cumulative hemodynamic load promotes elastic degradation and collagen deposition within the tunica media, leading to arterial stiffening, dilatation and increased tortuosity with advancing age, while hypertension amplifies these processes through elevated wall stress and angiotensin II-mediated extracellular matrix remodelling [3, 17]. The differential strength of correlations—diameter correlating more strongly with age (r up to 0.500) than length or tortuosity—suggests that diametric remodelling is more tightly coupled to haemodynamic and anthropometric determinants, whereas length and tortuosity are influenced by additional factors such as spinal degeneration and skeletal geometry. Notably, blood pressure showed positive zero-order correlations with most parameters but was not an independent determinant in the regression models, indicating that its apparent association is largely mediated by age.

Multivariable regression confirmed age as the dominant independent factor associated with AA tortuosity and both proximal and distal diameters (β = 0.35–0.48), with BSA contributing to the diameters, and all variance inflation factors below 10. The explanatory power of the models differed markedly: adjusted R^2 was only 0.046 for length but reached 0.273 and 0.277 for proximal and distal diameters respectively, suggesting that length is governed by factors not captured in this dataset—such as skeletal height, spinal tortuosity and genetic determinants—whereas diametric remodelling is more fully explained by chronological and haemodynamic variables. The simple age-based equation for distal diameter (diameter = 9.342 + 0.0686 × age; R^2=0.250) offers a practical quantitative tool for estimating the expected aortic calibre in women and for flagging individuals whose measured diameter deviates

appreciably from the predicted value, which may prompt further evaluation for ectasia. However, the moderate coefficient of determination indicates that a substantial proportion of variance remains unexplained, and omitted variables such as menopausal status, parity, smoking history and genetic background are likely to account for part of this residual. External validation in independent, multi-ethnic cohorts is essential before these equations are adopted into clinical or screening pathways [5].

Clinically, these findings support the use of routinely available variables to identify women at higher risk of aortic dilatation who may merit closer imaging surveillance, and they reinforce the importance of blood pressure control as a modifiable contributor to aortic remodelling. Stent grafts have relatively fixed lengths and diameters, and finding the best-fit device may be challenging given the variability of aorto-iliac anatomy with age [1]; in particular, the left CIA in this cohort combined a longer course with a smaller calibre, a configuration relevant to limb sizing and to the risk of limb kinking or occlusion. Separate reference values for each vascular segment, side and age stratum are therefore preferable to single nomograms when evaluating dilatation or planning endovascular repair in Chinese women.

This study has several limitations that warrant consideration. Being a single-centre, retrospective cross-sectional design with a modest sample size, the study was underpowered to detect small but potentially clinically meaningful inter-ethnic differences, as the minimum detectable difference was approximately 0.66 mm. The inclusion of only adult women from the Guangxi region limits the generalizability of our findings to men and other populations, and the lack of longitudinal data precludes any causal inference regarding the relationships between age, blood pressure and aortic remodelling. Measurement reproducibility was formally verified for only two representative parameters (distal aortic diameter and left CIA length); the agreement for the remaining parameters, including tortuosity and angulation, remains to be established. Manual segmentation and centreline correction may introduce inherent measurement bias. Finally, we did not account for potential confounding factors such as hormonal status, parity, smoking or comorbidities, which may influence the observed associations.

Conclusion

In this sample of adult women from Guangxi, age had the dominant influence on abdominal aortic geometry, with aortic diameters and tortuosity increasing significantly with age, whereas its effect on length was weak; the impact of age was greater on diameter than on length. The left CIA was consistently longer and had a smaller proximal calibre than the right. Zhuang women had a nominally shorter and less tortuous abdominal aorta than Han women, although this difference did not remain significant after correction for multiple comparisons, whereas diameters were statistically indistinguishable between ethnicities. These centreline-based, three-dimensional reference values may inform stent-graft sizing, preprocedural planning for endovascular repair in Chinese women, and future studies should validate these findings in larger, multi-ethnic cohorts with longitudinal follow-up.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

Approval to conduct this study was granted by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University.

Funding

This work was supported by the Innovation and Entrepreneurship Fund of Guangxi Medical University.

Competing interests

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Consent for participation

The requirement for individual informed consent was waived owing to the retrospective design; all patients had provided written informed consent for iodinated contrast administration.

Author contributions

Li Yingxi: Manuscript writing, Data analysis, Data collection or management.

Gan Tian: Data analysis, Data collection or management.

Su Qiuju: Data collection or management.

Hongrong Yu: supervision.

Cheng Tang: resources.

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Author Contribution

Li Yingxi: Manuscript writing, Data analysis, Data collection or management. Gan Tian: Data analysis, Data collection or management. Su Qiuju: Data collection or management.Hongrong Yu: supervision. Cheng Tang: resources. All authors reviewed and approved the final manuscript.

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Data availability

The datasets analysed during the current study are available from the corresponding author on reasonable request.

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Figures

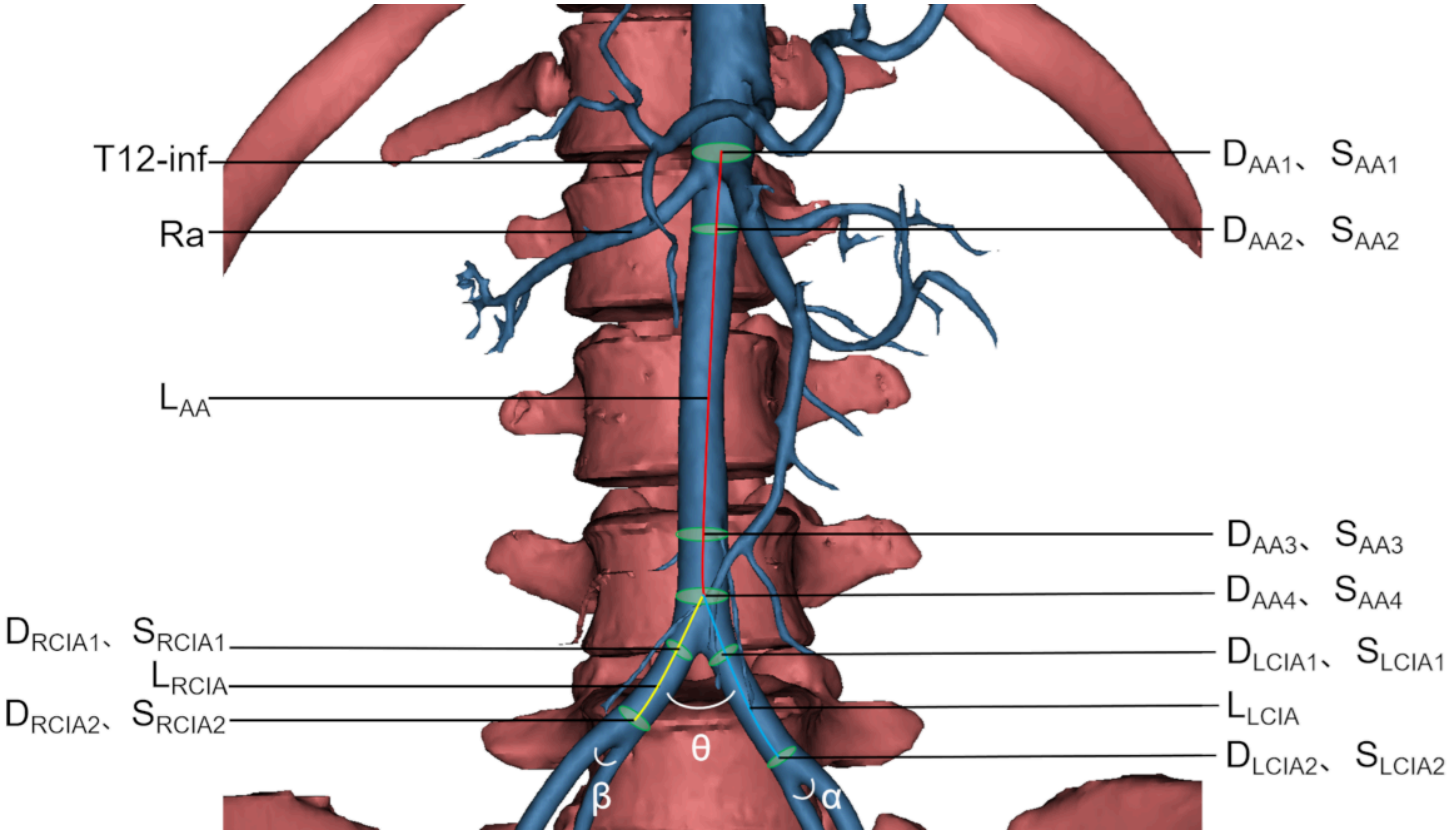

Figure 1

Schematic diagram showing the measurements of length, diameter, cross-sectional area and angulation of the abdominal aorta and its branches. T12-inf, inferior margin of the 12th thoracic vertebral body (anatomically corresponding to the aortic hiatus); RA, renal artery; L_{AA}, abdominal aorta length; L_{LCIA}/L_{RCIA}, left/right common iliac artery length; D_{AA1}-D_{AA4} and S_{AA1}-S_{AA4}, diameters and cross-sectional areas at the proximal, mid-proximal, mid-distal and distal landmarks of the abdominal aorta; D_{LCIA1}, D_{LCIA2}, D_{RCIA1}, D_{RCIA2} and S_{LCIA1}, S_{LCIA2}, S_{RCIA1}, S_{RCIA2}, diameters and cross-sectional areas at the origin and bifurcation of the left and right common iliac arteries; θ, inter-iliac angle; α, left CIA-IIA angle; β, right CIA-IIA angle

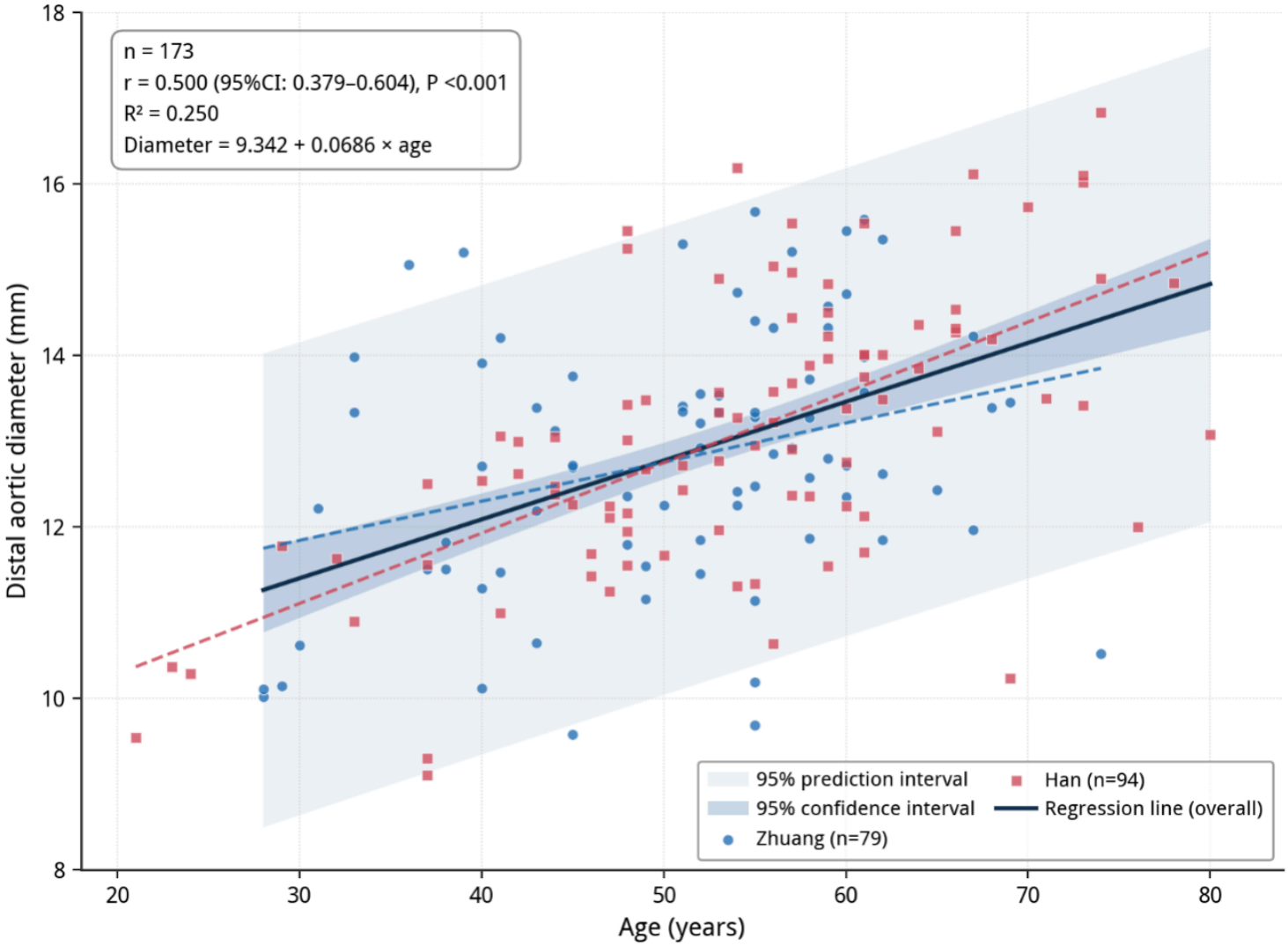

Figure 2

Scatterplot showing the relationship between distal abdominal aortic diameter and age (*n*=173). Blue circles represent Zhuang women (*n*=79) and red squares Han women (*n*=94); the black solid line is the regression line for the whole sample, the dark band the 95% confidence interval, the light band the 95% prediction interval, and the dashed lines the within-ethnicity regression lines.

Supplementary Files

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- SupplementaryMaterialICC.docx