Original Article

Morphological changes in the orifices of the left atrial appendage and left atrium in patients with atrial fibrillation

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Background: As an integral part of the left atrium (LA), the left atrial appendage (LAA) plays an important role in atrial fibrillation (AF). However, the relationship between LAA remodeling and AF has not been clearly defined. This retrospective case-control study aimed to assess the morphological and functional features of the LA and the LAA in AF patients using images obtained by computed tomography angiography (CTA).

Methods: A total of 140 AF patients and 64 patients without AF or other cardiovascular diseases who underwent CTA scans between September 2016 and August 2017 were enrolled in this observational study as the experimental and the control groups, respectively. The major and minor axes, area, and perimeter of the LAA orifice, the LAA depth, and the volume of both the LAA and LA were analyzed. The data of the AF group and the control group were compared. The *t*-test was used to analyze the normally distributed data, and the Wilcoxon rank-sum test was used for abnormally distributed data. The best critical value of predictors of AF was calculated using receiver operating characteristic (ROC) curve analysis. The correlation of the LAA volume change with the major and minor axes, area, and perimeter of the LAA orifice, and the LAA depth were analyzed using the Pearson correlation coefficient.

Results: The LAA orifice's minor axis, LAA volume, and LA volume were significantly greater (P=0.004, P=0.010, and P<0.001, respectively) in patients with AF than in those without AF. The LAA volume [95% confidence interval (CI): 1.01 to 1.30; P=0.038] and LA volume (95% CI: 1.03 to 1.07; P<0.001) were significantly independent predictors of AF. An LAA volume of 8.75 mL had the highest predictive value for AF [area under the curve (AUC), 0.612], with a sensitivity of 76.6% and a specificity of 48.6%. In contrast, an LA volume of 97.15 mL had the highest predictive value for AF (AUC, 0.771), with a sensitivity of 90.6% and a specificity of 53.6%. The change of LAA volume was positively weakly correlated with the area and perimeter of the LAA orifice (r=0.1703 and r=0.1378, respectively). The LAA emptying fraction was negatively correlated with the major axis and the area of the LAA orifice. The major and minor axes, area, and perimeter of the LAA orifice, and LAA depth were significantly greater in female than in male patients (P=0.003, P=0.003, P=0.001, P=0.019, and P<0.001, respectively).

Conclusions: The AF patients had a longer minor axis of the LAA orifice than that of the control group, resulting in a more circular LAA orifice. The LAA orifice area and perimeter were positively correlated with LAA volume change. The LAA orifice major and minor axes, area, and perimeter, and the LAA depth of the female patients were significantly greater than those of their male counterparts in AF patients.

Keywords: Left atrial appendage (LAA); orifice; emptying function; atrial fibrillation (AF); left atrium (LA)

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Introduction

Atrial fibrillation (AF) is a common tachyarrhythmia (1). The left atrial appendage (LAA) plays an important role in AF, and changes in the morphology and anatomy of the LAA have been shown to be significantly associated with the occurrence, development, and recurrence of AF (2). When the heart rhythm is normal, the LAA contraction and relaxation occur at a certain rhythm. However, AF involves irregular contraction of the left atrium (LA), and the LAA loses the normal contraction rhythm (3), resulting in a reduced contraction ability of the auricle wall and incomplete emptying of blood from the LAA. Incomplete emptying, accompanied by slow blood flow and damage to the cardiovascular endothelium, results in morphologic changes of the LAA, which are likely to cause thrombosis and severe ischemic stroke events. Although the mechanism of initiation of thrombosis is very complicated (4), the LAA morphologic change plays a crucial role in stroke (5).

Multiple imaging modalities are available to assess cardiac morphology and function (6). Echocardiography is a widely used means of non-invasively assessing cardiac anatomy (7). Transesophageal ultrasound is the "gold standard" for diagnosing thrombus in LAA (8). However, variations in the imaging plane and imaging angle implemented by different technicians affect how morphological structures are displayed. Therefore, the measurement is subjective (9). Cardiac magnetic resonance imaging (MRI) can accurately measure the volume and blood flow velocity in LAA, and the results are highly consistent with those of transesophageal ultrasound (10). Nonetheless, MRI is time-consuming and expensive. In contrast, multi-slice spiral computed tomography (CT) has the advantages of flexibility, noninvasiveness, high accuracy, and 3D imaging when obtaining the LAA and coronary artery parameters.

So far, the correlation between static geometric features and the function of the LAA is unknown. Understanding this correlation may provide basic information to investigate the mechanism of AF thrombosis. We aimed to investigate the LAA morphology, function, and their possible relationship in AF patients for clinical reference in making treatment plans. We present the following article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-22-218/rc).

Methods

Research participants

This retrospective observational case-control study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional Ethics Committee of The Second Hospital of Hebei Medical University, and informed consent was provided by all participants. A total of 140 patients with AF were enrolled in the experiment group, while 64 participants without AF were enrolled in the control group. All participants underwent a computed tomography angiography (CTA) scan between September 2016 and August 2017. The AF group was clinically diagnosed by physical examination and electrocardiogram (ECG) and included 85 males and 55 females with an age range of 30 to 80 (mean, 58.09±10.19) years. The inclusion criteria of the AF group were patients with AF that had been confirmed clinically and diagnosed by a physical examination and ECG with 256-slice spiral CT examination, including paroxysmal and persistent AF. Episodes of AF that terminated spontaneously were classified as paroxysmal; those that were sustained beyond 7 days without spontaneous conversion to sinus rhythm were classified as persistent. The exclusion criteria were as follows: poor quality CTA images, pacemaker implantation, valvular and congenital heart disease, and previous medication for AF. The control group underwent a CTA examination for chest tightness or a routine physical examination, including 40 males and 24 females aged 24–81 (mean, 56.56±7.91) years. The inclusion criteria of the control group were candidates who had a normal heart rhythm and normal blood pressure <140/90 mmHg. The exclusion criteria were poor quality CTA images, pacemaker placement or other cardiac implants, valvular and congenital heart disease, and cardiovascular diseases (*Figure 1*).

CT scanning technology

Patients were trained before scanning to respire properly according to guidance. Metoprolol was used to control

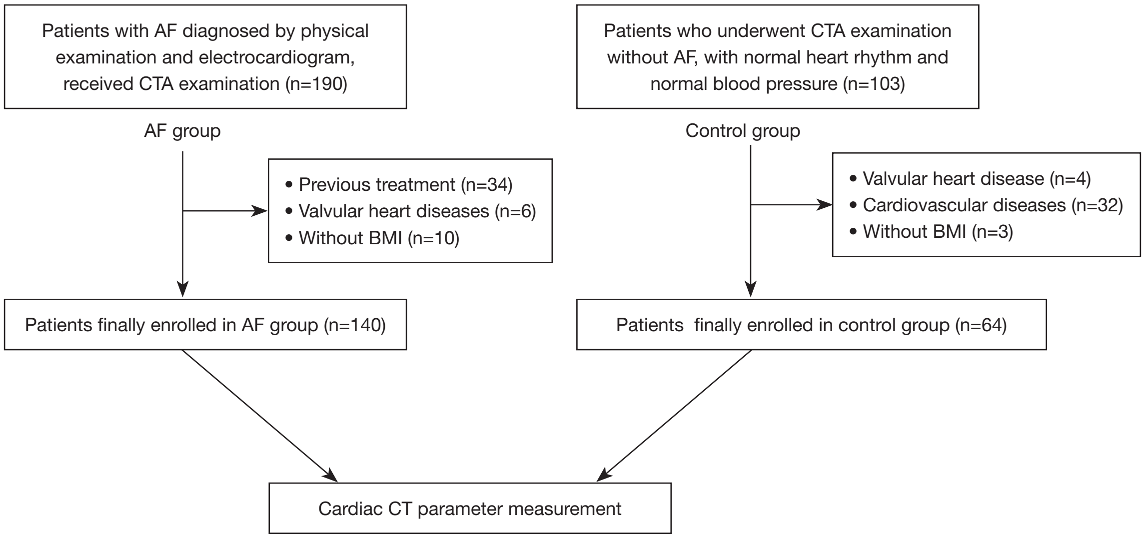

Figure 1 The flow chart of patient enrollment. AF, atrial fibrillation; CTA, computed tomography angiography; BMI, body mass index; CT, computed tomography.

the heart rate and heartbeat rhythm in patients with AF. The nonionic contrast agent iohexol (350 mgI/mL, 0.8 mL/kg) was injected venously using a double-barrel high-pressure syringe with a scan range from 0.5 cm below the tracheal bifurcation to the palpebral surface of the heart, which used the bolus tracking technique (11,12). Using the retrospective ECG gating technology, the scanning parameters were as follows: tube voltage 80–120 kV, tube current 280–350 mAs/rev, collimation 128×0.625, pitch 0.18, matrix 512×512, rotation time 330 ms, and scanning field of view (FOV) 250 mm, with adjustment of the scan voltage and current according to the patient's body mass index (BMI) to reduce scanning dose.

Image post-processing technology

A Philips i128CT EBW 4.5 workstation (Philips Healthcare, Amsterdam, Netherlands) was used to reconstruct the original images into 10 phases ranging from a 5% phase to a 95% phase, with an interval of 10%. The thickness of the reconstructed layer was 0.9 mm, and the interval was 0.45 mm. The 3D image of the LAA was obtained using the post-processing software for cardiac function. The volume of the LAA and LA was measured in each of the 10 phases. Then, the maximal volume of the LAA and LA and the minimal volume of the LAA and LA were also determined for the calculation of the emptying fraction of the LAA and LA (13).

The original images in the 75% phase of the cardiac cycle were used for multiplanar reconstruction (MPR) imaging on the Philips EBW 4.5 workstation. At the 75% phase of the cardiac cycle, the structural parameters of the LAA changed minimally (14). Then, MPR images were applied to measure the parameters of the LAA orifice at different angles. The LAA 3D images were obtained using the cardiac function processing software, and the LAA depth was measured.

Measurement methods

All parameters were analyzed by two experienced radiologists, who reached a consensus for each examination.

(I) Measurement of the LAA morphology: the LAA and LA on the cross-sectional images were identified, and a positioning line was fixed at the vertical LAA and LA junction for multiplanar reorganization. The position line was perpendicular to the LAA and LA junction, and the cross-sectional image of the LAA orifice was obtained (*Figure 2A-2C*). The LAA orifice's long diameter, short diameter, area, and perimeter were measured (*Figure 2D,2E*). The major axis line at the orifice of the LAA was the long diameter, and the minor axis was the diameter of the midpoint through the vertical length.

(II) LAA and LA volume: 3D images of the LAA and

Figure 2 Measurement of the LAA orifice. LAA orifice on axial (A), coronal (B), and oblique axial (C) images. (D,E) Measurement of the LAA orifice major and minor axes, area, and perimeter. HU, Hounsfield units; LAA, left atrial appendage.

LA were obtained with cardiac function processing software. The total volume of the LAA and LA was obtained, and the LAA was cut at the LA junction to obtain a separate image of the LAA. The software automatically calculated the volume of the LAA and LA (*Figure 3*).

(III) LAA depth: the distance from the farthest point of the LAA tip to the central point of the LAA plane was measured on the cut LAA 3D image (*Figure 3*).

(IV) LAA emptying volume and LAA emptying fraction were calculated as follows:

$$\text{LAA emptying volume} = \text{maximal LAA volume} - \text{minimal LAA volume} \quad [1]$$

$$\text{LA emptying volume} = \text{maximal LA volume} - \text{minimal LA volume} \quad [2]$$

$$\text{LAA emptying fraction} = (\text{maximal LAA volume} - \text{minimal LAA volume}) / \text{maximal LAA volume} \times 100\% \quad [3]$$

$$\text{LA emptying fraction} = (\text{maximal LA volume} - \text{minimal LA volume}) / \text{maximal LA volume} \times 100\% \quad [4]$$

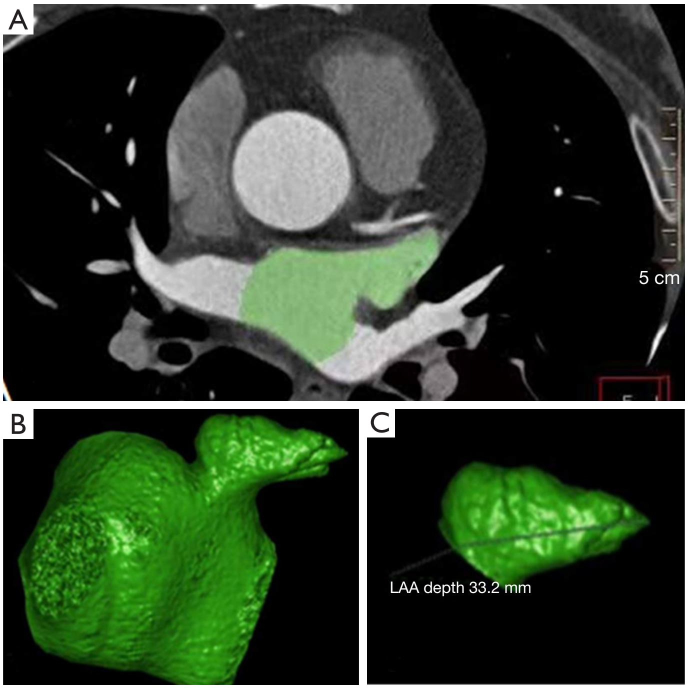

Figure 3 An AF patient, female, 56 years old. Measurement of the LA volume, LAA volume, and LAA depth. (A) The volumes of LA and LAA were calculated using cardiac function software, distracting on CT images. (B) The 3D image of the LAA and LA made by the software. (C) The LAA was obtained by separating at the LA and LAA junction, while LAA volume was calculated automatically. The LAA depth was measured from the most distal tip of the LAA to the center of the cross-section of the LAA orifice. AF, atrial fibrillation; LA, left atrium; LAA, left atrial appendage.

Statistical analysis

The data were analyzed using the SPSS 21.0 statistical software (IBM Corp., Armonk, NY, USA). The normality of data was tested with the Shapiro-Wilk test method, and when the P value was >0.05, the data were considered normally distributed. The data of the AF group and the control group were compared. The *t*-test was used to analyze the data in a normal distribution, and the Wilcoxon rank-sum test was used for the data without a normal distribution. The chi-square test was used to compare the gender ratios of the AF group. The measurement data obtained in a normal distribution were expressed as the mean ± standard deviation (SD), and the abnormally distributed measurement data were expressed as the median (interquartile range). The best critical value of predictors of AF was calculated by receiver operating characteristic (ROC) curve analysis. The correlation of the LAA volume change with the major and minor axes, area, and perimeter of the LAA orifice, and LAA depth were analyzed using the Pearson correlation coefficient. A P value <0.05 was considered statistically significant.

Results

Participants characteristics

A total of 140 patients with AF and 64 participants without AF but with a sinus rhythm were enrolled (*Figure 1*). Baseline characteristics are listed in *Table 1*. There was no significant (P>0.05) difference in age, gender, or BMI between the AF and the control groups.

Morphological and functional parameters of the LAA and LA and their correlation

Morphological and functional parameters of the LAA and LA are listed in *Table 2*. The LAA orifice minor axis (P=0.004), LAA volume (P=0.010), and LA volume (P<0.001) were significantly greater in patients with AF than in the controls. However, no significant difference (P>0.05) existed in the major axis, area, and perimeter of the LAA orifice and the LAA depth between the two groups. A comparison of the LAA function between the AF group and control group revealed that the maximal and minimal LAA

Table 1 Baseline characteristics in the AF and control group

Variables	AF group (n=140)	Control group (n=64)	Z/*t* value	P value
Male	85 (60.71)	40 (62.50)	0.059	0.877
Age (years)	58.09±10.19	56.56±7.91	−1.861#	0.063
BMI (kg/m^2)	26.67±4.84	25.58±3.85	−1.742	0.082

Data are presented as mean ± SD or n (%). #, *t* value. AF, atrial fibrillation; BMI, body mass index; SD, standard deviation.

Table 2 Comparison of morphological and functional parameters of the LAA and LA between AF and control groups

Variables	AF	Control	Z/*t* value	P value
Maximal LAA volume (mL)	11.15 (7.98, 13.50)	8.05 (6.70, 10.65)	−3.152	0.002*
Minimal LAA volume (mL)	4.90 (3.63, 7.00)	3.15 (2.10, 3.98)	−4.515	<0.001*
LAA emptying fraction	47.34 (34.75, 62.13)	63.72±7.88	−3.960	<0.001*
LAA emptying volume (mL)	5.39±2.16	5.30 (4.10, 6.20)	−0.053	0.958
Maximal LA volume (mL)	117.15 (103.53, 137.65)	90.92±17.97	−4.609	<0.001*
Minimal LA volume (mL)	76.10 (54.68, 110.65)	45.06±11.30	−5.576	<0.001*
LA emptying fraction	27.95 (16.24, 43.12)	52.19 (47.38, 53.68)	−5.913	<0.001*
LA emptying volume (mL)	37.15 (19.75, 48.25)	45.86±9.49	−3.099	0.002*
LAA volume (mL)	8.30 (6.33, 11.03)	7.37±2.30	−2.576	0.010*
LA volume (mL)	99.75 (80.65, 120.43)	76.58±15.82	−6.206	<0.001*
LAA orifice major axis (mm)	26.25±5.22	26.45±3.60	−0.845	0.398
LAA orifice minor axis (mm)	17.8±14.65	16.26±2.92	2.896*	0.004*
LAA orifice area (mm^2)	364.43 (268.32, 486.97)	343.47±95.31	−1.135	0.256
LAA orifice perimeter (mm)	71.40±15.50	69.73±9.72	−0.259	0.795
LAA depth (mm)	41.09±8.25	42.39±6.08	−1.264#	0.208

Data are presented as mean ± SD or median (interquartile range). #, *t* value; *, P<0.05. LAA, left atrial appendage; LA, left atrium; AF, atrial fibrillation; SD, standard deviation.

volume (P=0.002 and P<0.001, respectively) and LA volume (P<0.001 and P<0.001, respectively) in patients with AF were significantly higher than those in the control group, but the LAA emptying fraction, LA emptying volume, and LA emptying fraction in patients with AF were significantly lower (P<0.001) than those in the control group. No significant difference (P>0.05) existed in the LAA emptying volume between the AF group and the control group.

The LAA volume change was estimated by the LAA volume at the 45% cardiac phase subtracting the LAA volume at the 75% cardiac phase. The LAA volume change was significantly weakly positively correlated with the area (P=0.0443) and perimeter of the LAA orifice (P=0.0400), with the r value of 0.1703 and 0.1738, respectively (*Table 3*).

The correlation of the LAA emptying fraction and LAA emptying volume with LAA depth, LAA volume, LAA orifice major and minor axes, area, and perimeter were analyzed. The LAA emptying fraction was negatively correlated with the major axis and the area of the LAA orifice (*Table 4*). The LAA emptying volume was not significantly correlated with the above parameters (*Table 5*).

Multivariate analysis (*Table 6*) showed that the LAA volume [95% confidence interval (CI): 1.01 to 1.30; P=0.038] and LA volume (95% CI: 1.03 to 1.07; P<0.001) were two significant and independent risk factors of AF. The LAA orifice minor axis was not a significant (P=0.597) risk factor for AF, with a 95% CI of 0.88 to 1.07. The covariance expansion factor of the LAA volume and LA

Table 3 Correlation between LAA volume change and LAA orifice major and minor axis, area, perimeter and LAA depth

Variables	r value	P value
LAA orifice major axis (mm)	0.1594	0.06
LAA orifice minor axis (mm)	0.0971	0.2535
LAA orifice area (mm^2)	0.1703	0.0443*
LAA orifice perimeter (mm)	0.1738	0.0400*
LAA depth (mm)	0.0891	0.2953

*, P<0.05. LAA, left atrial appendage.

Table 4 Correlation of the LAA emptying fraction with major and minor axis, area, and perimeter of the LAA orifice, and LAA depth and volume

Variables	r value	P value
LAA orifice major axis (mm)	–0.391	0.044*
LAA orifice minor axis (mm)	–0.298	0.144
LAA orifice area (mm^2)	–0.409	0.034*
LAA orifice perimeter (mm)	–0.336	0.086
LAA depth (mm)	–0.067	0.738
LAA volume (mL)	–0.215	0.281

*, P<0.05. LAA, left atrial appendage.

Table 5 Correlation of the LAA emptying volume with major and minor axes, area, and perimeter of the LAA orifice, and LAA depth and volume

Variables	r value	P value
LAA orifice major axis (mm)	–0.287	0.147
LAA orifice minor axis (mm)	–0.113	0.576
LAA orifice area (mm^2)	–0.209	0.295
LAA orifice perimeter (mm)	–0.173	0.390
LAA depth (mm)	–0.141	0.482
LAA volume (ml)	–0.006	0.977

LAA, left atrial appendage.

volume was less than 5, which indicated that the LAA volume and LA volume had no collinearity.

Predictive value of LA and LAA volumes

The ROC curve analysis showed that an LAA volume of 8.75 mL had the highest predictive value for AF [area under the curve (AUC), 0.612], with a sensitivity of 76.6% and a specificity of 48.6%, whereas an LA volume of 97.15 mL had the highest predictive value for AF (AUC, 0.771), with a sensitivity of 90.6% and a specificity of 53.6% (*Figure 4*).

Table 6 Multivariate hazard model analysis of variables with AF occurrence

Variables	HR (95% CI)	P value
LAA orifice short diameter (mm)	0.974 (0.88–1.07)	0.597
LA volume (mL)	1.045 (1.03–1.07)	<0.001*
LAA volume (mL)	1.129 (1.01–1.30)	0.038*

*, P<0.05. AF, atrial fibrillation; LAA, left atrial appendage; LA, left atrium; HR, hazard ratio; CI, confidence interval.

LAA axis and volumes comparison between genders

The LAA axis and volumes of the males and females in the AF group were compared after standardization based on their body surface area. The major and minor axes, area, and perimeter of the LAA orifice and LAA depth in female patients were significantly greater (P<0.05) than those in male patients. No significant difference existed in the LAA volume between female and male patients (*Table 7*).

Volume-time curves of LA and LAA

The volume-time curves of LA and LAA were presented. Compared with non-AF patients, the LAA volume in patients with AF had a greater amplitude of increase even though the volume-time curves remained the same, whereas the LA volume in patients with AF had a smaller amplitude of increase over time (*Table 8*; *Figure 5*).

Discussion

Our study demonstrated that AF patients tended to have a

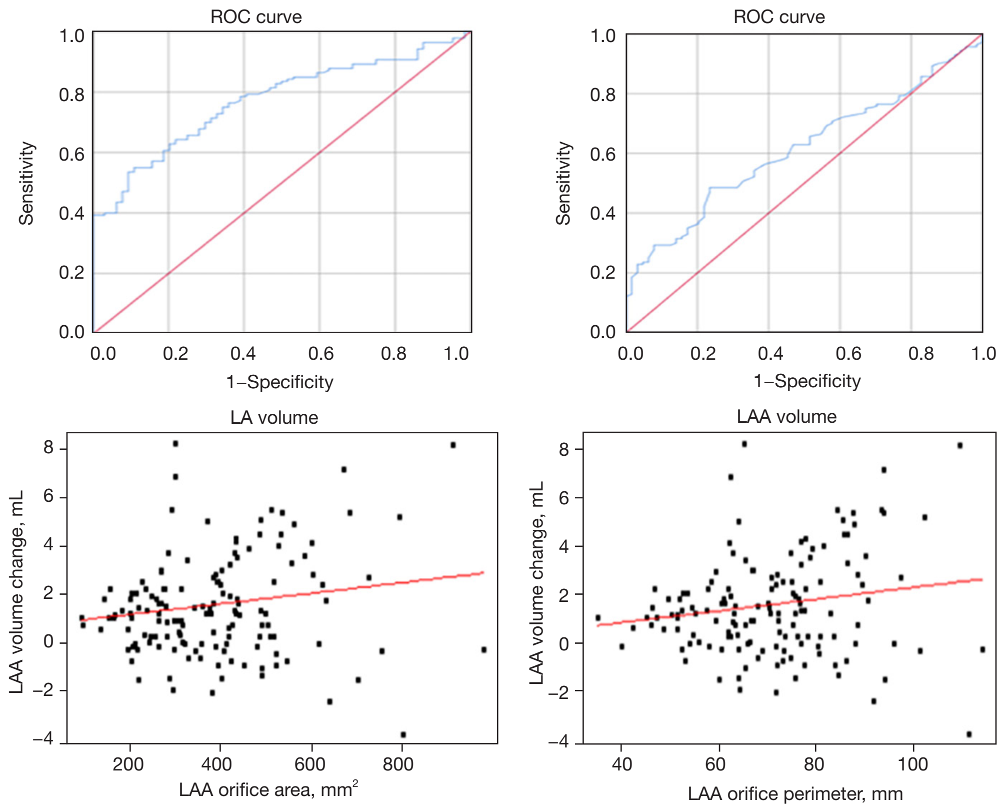

Figure 4 ROC curve analysis was performed for the volume of the LAA and LA. Correlation analysis was conducted between the LAA volume change with the area (P=0.043) and perimeter (P=0.04) of the LAA orifice. ROC, receiver operating characteristic; LA, left atrium; LAA, left atrial appendage.

Table 7 LAA and LA parameters in males and females with AF after standardization by body surface area

Variables	Males	Females	Z value	P value
LAA orifice major axis (mm)	12.98±2.79	14.39±3.05	−2.955	0.003*
LAA orifice minor axis (mm)	8.71±2.55	9.95±2.53	−2.989	0.003*
LAA orifice area (mm^2)	188.22±88.39	220.24±88.80	−3.287	0.001*
LAA orifice perimeter (mm)	34.83±8.42	39.98±8.61	−2.340	0.019*
LAA depth (mm)	20.31±5.01	22.61±6.50	−3.484	0.000*
LAA volume (mL)	4.63±2.27	4.71±2.23	−0.143	0.886
LA volume (mL)	99.50 (82.30, 114.95)	59.18±27.24	−1.623	0.104

Data are presented as mean ± SD or median (interquartile range). *, P<0.05. LAA, left atrial appendage; LA, left atrium; AF, atrial fibrillation; SD, standard deviation.

more circular LAA orifice, which was positively correlated with LAA volume change. Also, the LAA orifice major axis and area were negatively correlated with the LAA emptying function. In addition, LAA anatomic parameters varied between males and females. As 3D cardiac CT is a vital tool to effectively evaluate the LAA size, these parameters may be potentially useful in guiding clinicians to choose devices properly (15).

The LAA plays an important role in AF (16). However, the relationship between LAA remodeling and AF has not

Table 8 Changes in LA and LAA volumes over time in the phase of the cardiac cycle

Variables	Phase of cardiac cycle									
	5%	15%	25%	35%	45%	55%	65%	75%	85%	95%
N-LA (mL)	45.76	54.47	70.19	84.68	90.78	81.71	68.40	68.37	65.83	48.27
AF-LA (mL)	95.09	103.87	113.74	119.22	124.85	120.42	116.22	111.06	108.79	98.31
N-LAA (mL)	3.33	5.00	6.42	7.91	8.51	6.94	6.29	6.42	6.07	3.52
AF-LAA (mL)	7.01	8.58	9.74	10.39	11.03	9.91	9.52	8.78	8.96	7.20

LA, left atrium; LAA, left atrial appendage; N-LA, LA volume in patients without AF; AF, atrial fibrillation; AF-LA, LA volume in patients with AF; N-LAA, LAA volume in patients without AF; AF-LAA, LAA volume in patients with AF.

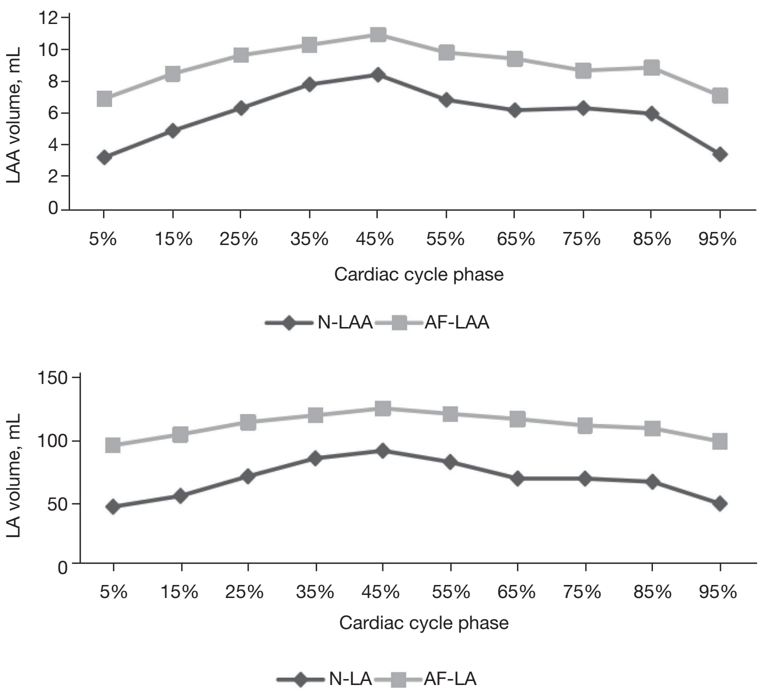

Figure 5 The volume-time curves of the LA and LAA volume over time in the cardiac cycle phase. The LAA volume in patients with AF had a greater amplitude of increase even though the volume-time curves remained the same, whereas the LA volume in patients with AF had a smaller amplitude of increase over time. LAA, left atrial appendage; N-LAA, LAA in patients without AF; AF, atrial fibrillation; AF-LAA, LAA in patients with AF; LA, left atrium; N-LA, LA in patients without AF; AF-LA, LA in patients with AF.

been defined clearly. It is believed that LAA morphology relates to the burden of silent cerebral ischemia in AF patients as a potential risk marker (17). Thus, the major axis, minor axis, and perimeter of the LAA orifice, as well as the depth and volume of the LAA, were measured in all AF patients and controls. The LAA orifice minor axis and LAA volume were significantly greater in AF patients than in control participants, but the LAA depth and the LAA orifice major axis, area, and perimeter were not. The minor axis of the LAA orifice in the AF group was longer than that of the control group, but the major axis of the two groups was similar. As a result, the shape of the LAA orifice changed from oval to circular in AF patients, which might affect the hemodynamics and accelerate thrombus formation of the LAA (18,19), even though it was not an independent risk factor of AF as compared with LAA volume and LA volume.

Besides the shape of the LAA orifice, the morphology of the LAA is another important indicator of embolic stroke.

The LAA morphology has 4 shapes, with the chicken wing shape considered to present a low risk of stroke, while others (windsock, cactus, and cauliflower) have a high risk of stroke (20,21). However, this study does not contribute to the analysis of the LAA morphology in association with stroke.

A widely used method to obtain the LAA volume is 3D imaging software, but the approaches to measuring the LAA orifice maximal and minimal diameters vary. For example, Boucebci *et al.* (22) measured the maximal and minimal diameters of the orifice on a 3D volume-rendering view. In contrast, we used axial images to locate the junction between the LA and LAA before reconstructing the coronal images to obtain the orifice image when measuring the major and minor axis, area, and perimeter. Theoretically, both these approaches were considered adequate to measure orifice parameters accurately.

The correlation in the LAA function with the axes, area, and perimeter of the LAA orifice and LAA depth has not been previously reported. Some researchers analyzed LAA morphologic types and functions (23,24). In our study, we found that the LAA emptying fraction was negatively correlated with the major axis and area of the LAA orifice but was not significantly correlated with LAA depth. Therefore, the assessment of the relationship between LAA function and LAA orifice morphology parameters may be more significant than the relationship between LAA function and LAA geometric features. Compared with the LAA emptying volume, the LAA emptying fraction was a crucial function parameter to present the emptying ability because the LAA emptying volume was not significantly correlated with any of the LAA parameters.

After being standardized based on the body surface area, the major and minor axes, area, and perimeter of the LAA orifice, LAA depth, and LA volume of the female patients were significantly greater than those of the male patients, but no statistical difference existed in the LAA volume between male and female patients. These results indicated that the LAA might have similar volumes between females and males even though its shape is different in AF patients. This may be related to the fact that the LAA is like a mountain with multiple peaks, and its volume cannot be simply calculated as its depth multiplied by the orifice area. Korhonen *et al.* (25) found that the area and depth of the LAA were related to the body surface area of the participant, with a greater depth of the LAA in females than in males, which was consistent with our study.

The closure device shape should be considered for different genders. However, Roh *et al.* (26) reported that gender differences only became evident in non-paroxysmal AF patients under 55 years old. However, the effect of age on the orifice shape in different genders was not analyzed because of insufficient data, which was limited by the number of patients. In the future, more investigation should be performed on this aspect.

In our study, the morphologic change of the LAA orifice in AF patients was more circular than that of the control participants, and the LAA parameters varied between genders, which might be vital for clinicians to choose a proper LAA closure device based on our outcomes because CT measurement is reliable on cardiac imaging (25,27). To avoid the influence of structural heart diseases, we excluded those patients with valvular and congenital heart disease and cardiovascular diseases.

Some limitations existed in this study; it had a retrospective design, only a small cohort of patients were enrolled, only Chinese patients were enrolled, and it was a single-center study. Future studies are needed to resolve these issues for better outcomes.

Conclusions

In the study, AF patients had a longer minor axis of the LAA orifice than that of the controls, which made the LAA orifice more circular. The LAA orifice area and perimeter positively correlated with LAA volume change. The major and minor axis, area, and perimeter of the LAA orifice and LAA depth of the females were significantly greater than those of their male counterparts in AF patients.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-22-218/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-218/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics committee of The Second Hospital of Hebei Medical University, and informed consent was provided by all the patients.

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