

# Left Atrial Appendage Orifice Area and Morphology is Closely Associated with Flow Velocity in Patients with Nonvalvular Atrial Fibrillation

Lei Chen

the Affiliated Hospital of Xuzhou Medical University

Changjiang Xu

Xuzhou Medical University

Wensu Chen

the Affiliated Hospital of Xuzhou Medical University

Chaoqun Zhang (✉ [c475764096@163.com](mailto:c475764096@163.com))

the Affiliated Hospital of Xuzhou Medical University

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## Research Article

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# Abstract

**Background** Thromboembolic events are the most serious complication of atrial fibrillation (AF), and the left atrial appendage (LAA) is the most important site of thrombosis in patients with atrial fibrillation. During the period of COVID-19, a non-invasive left atrial appendage detection method is particularly important in order to reduce the exposure of the virus. This study used CT three-dimensional reconstruction methods to explore the relationship between LAA morphology, LAA orifice area and its mechanical function in patients with non-valvular atrial fibrillation (NVAF).

**Methods** A total of 81 consecutive patients with NVAF (36 cases of paroxysmal atrial fibrillation and 45 cases of persistent atrial fibrillation) who were planned to undergo catheter radiofrequency ablation were enrolled. All patients were examined by transthoracic echocardiography (TTE), TEE, and computed tomography angiography (CTA) before surgery. The LAA orifice area was obtained according to the images of CTA. According to the left atrial appendage morphology, it was divided into chicken wing type and non-chicken wing type. At the same time, TEE was performed to determine left atrial appendage flow velocity (LAAFV), and the relationship between the left atrial appendage orifice area and LAAFV was analyzed.

**Results** The LAAFV in Non-chicken wing group was lower than that in Chicken wing group ( $36.2 \pm 15.0$  cm/s vs.  $49.1 \pm 22.0$  cm/s,  $P < 0.05$ ). In the subgroup analysis, the LAAFV in Non-chicken wing group was lower than that in Chicken wing group in the paroxysmal AF ( $44.0 \pm 14.3$  cm/s vs.  $60.2 \pm 22.8$  cm/s,  $P < 0.05$ ); In the persistent AF, similar results were observed ( $29.7 \pm 12.4$  cm/s vs.  $40.8 \pm 17.7$  cm/s,  $P < 0.05$ ). The LAAFV in persistent AF group was lower than that in paroxysmal AF group ( $34.6 \pm 15.8$  cm/s vs.  $49.9 \pm 20.0$  cm/s,  $P < 0.001$ ). The LAAFV was negatively correlated with left atrial dimension ( $R = -0.451$ ,  $P < 0.001$ ) and LAA orifice area ( $R = -0.438$ ,  $P < 0.001$ ), while it was positively correlated with LVEF ( $R = 0.271$ ,  $P < 0.001$ ). Multiple linear regression analysis showed that LAA morphology ( $\beta = -0.319$ ,  $P < 0.001$ ), LAA orifice area ( $\beta = -0.219$ ,  $P = 0.030$ ), AF type ( $\beta = -0.283$ ,  $P = 0.003$ ) and left atrial diameter (LAD) ( $\beta = -0.241$ ,  $P = 0.018$ ) were independent predictors of LAAFV.

**Conclusion** The LAA orifice area is closely related to the mechanical function of the LAA in patients with NVAF. The larger LAA orifice area and LAD, Non-chicken wing LAA and persistent AF are independent predictors of decreased mechanical function of the left atrial appendage.

## Background

Atrial fibrillation (AF) is currently the most common arrhythmia encountered in clinical practice. Epidemiological surveys show that the incidence of AF in the population is approximately 0.4%-1%. With the aging of the global population, the incidence rate is gradually increasing. It is estimated that, by 2035, the incidence of AF will double the current incidence [1]. AF poses a huge threat and can cause serious damage to the life and health of patients, greatly increasing the risk of ischemic stroke, systemic artery embolism, heart failure, and other diseases, as well as having high disability and fatality rates [2-5].

Thromboembolic events are the most serious complication of AF. Studies have shown that the left atrial appendage is the most important site of thrombosis in patients with AF, and nonvalvular atrial fibrillation (NVAF) thrombi are almost all located in the left atrial appendage [6–7]. Previous studies have shown that left atrial appendage flow velocity (LAAFV) is closely related to the formation of left atrial mural thrombus and spontaneous imaging [8]. Transesophageal echocardiography (TEE) is currently the most widely used examination method to assess left atrial appendage function and thrombosis [9], but this examination is semi-invasive. The examination process is relatively painful, and there are many contraindications. In addition, the coronavirus disease-19 (COVID-19) has spread globally and is still difficult to control, during the period of COVID-19, the guidelines recommend that it is best to use non-invasive imaging methods to reduce the risk of virus exposure [10–12]. With the development of CT and 3D reconstruction technologies, 3D CT reconstruction has become a simple and reliable way to understand the structure and morphology of the left atrial appendage [7–8]. At present, there are few relevant studies on the left atrial appendage (LAA) morphology or orifice area on its mechanical function, and there are still controversies. This study investigates the relationship between LAA morphology, LAA orifice area and its mechanical function in patients with NVAF and attempts to identify an effective index that can predict the reduction in mechanical function of LAA.

## Methods

### Research objects

A retrospective analysis of patients with NVAF who were hospitalized in the Department of Cardiology, Affiliated Hospital of Xuzhou Medical University from November 2016 to November 2020. Inclusion criteria included AF was diagnosed by ECG or 24-hour Holter, all patients received TTE, TEE, and CTA examinations, and the interval between TEE and CTA examinations was within 48 hours, patients with paroxysmal AF show sinus rhythm during TEE examination, and those with persistent AF show an AF rhythm. Exclusion criteria included incomplete clinical data, complications with valvular heart disease (moderate to severe mitral valve stenosis), patent foramen ovale, artificial valve replacement, poor CT image quality and complete LAA data that could not be obtained, severe liver and kidney dysfunction, patients with thyroid disease or multiple organ dysfunction, etc. Finally, a total of 81 patients were selected, including 36 cases (44.4%) with paroxysmal AF and 45 cases (55.6%) with persistent AF, with an average age of  $61.8 \pm 8.8$  years. The basic clinical data of the patients are shown in Table 1.

Table 1  
Clinical data of the study population

Variables	All population( <i>n</i> = 81)	PaAF ( <i>n</i> = 36)	PeAF ( <i>n</i> = 45)	<i>P</i> -value
Age (years)	61.8 ± 8.8	63.2 ± 8.8	60.7 ± 8.8	0.198
Male ( <i>n</i> , %)	57(70.4)	26(72.2)	31(68.9)	0.744
BMI (kg/m <sup>2</sup> )	25.6 ± 3.0	25.5 ± 3.1	25.7 ± 3.0	0.722
Hypertension ( <i>n</i> ,%)	30(37.0)	12(33.3)	18(40.0)	0.537
Diabetes ( <i>n</i> ,%)	11(13.6)	5(13.9)	6(13.3)	1.000
CAD ( <i>n</i> ,%)	27(33.3)	13(36.1)	14(31.1)	0.635
Past Stroke ( <i>n</i> ,%)	16(19.8)	5(13.9)	11(24.4)	0.236
CHF ( <i>n</i> ,%)	11(13.6)	6(16.7)	5(11.1)	0.690
Smokers ( <i>n</i> ,%)	24(29.6)	13(36.1)	11(24.4)	0.253
CHA <sub>2</sub> DS <sub>2</sub> -VAScscores	2.1 ± 1.6	2.1 ± 1.6	2.2 ± 1.6	0.730

## Diagnostic criteria for atrial fibrillation

The electrocardiogram or 24-hour Holter electrocardiogram showed the disappearance of P waves and replaced them with f waves of different sizes, shapes, and amplitudes. The frequency of the f wave is 350 to 600 times/min, and the R-R interval is absolutely unequal (Fig. 1). According to the duration of AF, it is divided into paroxysmal AF (PaAF) and persistent AF (PeAF). PaAF is defined as AF that terminates within 7 days, and PeAF is defined as AF that lasts more than 7 days [13].

## Transthoracic echocardiography (TTE) examination

A Philips EPIQ 7c ultrasonic diagnostic apparatus, S5-1 probe, and probe with a frequency 1–5 MHz were used. The patient was placed in the left decubitus position, and the patient's left atrium anteroposterior diameter, left ventricular end-diastolic diameter, left ventricular ejection fraction (measured by biplane Simpson method), left ventricular posterior wall thickness, ventricular septal thickness and other parameters were recorded in detail.

## TEE examination and the determination of LAAFV

A Philips iE33 color Doppler ultrasound diagnostic apparatus and a X7-2t transesophageal matrix real-time 3D probe with a frequency of 2–7 MHz were used. Before the examination, patients fasted for 6–8 hours. They were connected to the ECG synchronization recording, the pulse Doppler sampling volume

was placed within one-third of the proximal opening of the LAA, and the LAA blood flow spectrum was obtained. The blood flow spectrum of the LAA is a regular two-way wave in sinus rhythm and an irregular sawtooth waveform in AF. The peak value of the positive wave is recorded in 3 and 10 cardiac cycles, which is the maximum row of the LAA. Air velocity and take the average value as the left atrial appendage flow velocity (LAAFV) [14] (Fig. 2–3).

## Computed tomography angiography (CTA) and 3D reconstruction

The CT imaging data were acquired by the German Siemens dual-source CT machine (SOMATOM Definition, SIEMENS Germany). Iodomidol (60–80 ml) was injected into the cubital vein at a flow rate of 5 ml/s, and then 50 ml of normal saline was injected at a rate of 5 ml/s. Contrast agent tracking technology triggered enhanced scanning. The following scan parameters were used—trigger plane: ascending aorta root level, trigger threshold: 90–100 Hu, start scanning after 6 s delay, scanning time 5–12 s, scanning range: 1 cm below tracheal carina to 1.5 cm lower edge of the heart, detector width 2.0 mm×32.0 mm×0.6 mm, layer thickness 2.0 mm×64.0 mm×0.6 mm, frame rotation time 330 ms, heart rate dependent pitch 0.2–0.5, tube current 400 mA, and voltage 120 kV.

## Measurement of LAA volume and its morphology

The GE AW4.6 Workstation was used to perform 3D reconstruction of the original CT images to obtain 3D images of the LAA and left atrium (LA). Then, a cutting tool was used to separate the LAA from the LA to obtain the LAA volume. According to the morphological characteristics of the LAA, it can be divided into chicken wing (there is an obvious fold at the proximal or middle part of the main lobe of the left atrial appendage) and non-chicken wing (other forms beside chicken wings) (Fig. 4–5).

## Measurement of the LAA orifice area

The long diameter (D1) and short diameter (D2) of the LAA orifice were measured by a Philips IntelliSpace Portal workstation. The LAA orifice was manually cross-sectioned from the multiplanar reconstruction image, and the orifice area was determined by its narrowest part. By creating a plane perpendicular to the axis of the left atrial ear neck, a cross-sectional view of the LAA is generated (Fig. 6). The formula  $0.785 \times D1 \times D2$  was used to calculate the LAA orifice area [15].

## Statistical analysis

SPSS 22.0 software was used for statistical analysis. Measurement data are expressed as the mean  $\pm$  standard deviation, and independent sample t-test was used for comparison between groups. Count data are expressed by the number of cases and percentage (%), and the  $\chi^2$  test or Fisher's exact probability

method was used for comparison between groups. T-test or simple linear regression analysis was used to determine each parameter that may affect LAAFV. Then, the findings were incorporated into multiple linear regression analysis to evaluate the independent predictors that determine LAAFV.  $P < 0.05$  was considered statistically significant.

## Results

### 1. Comparison of baseline data

As shown in Table 1. There were no significant differences in age, sex, BMI, hypertension, diabetes, coronary artery disease, past stroke, congestive heart failure, smokers and CHA2DS2-VASc scores between PeAF group and PaAF group ( $p > 0.05$ ).

### 2. Comparison of ultrasound and 3D CT reconstruction of left atrial appendage data

There were no significant differences in LVEDD, LVST, LVPWT, LVEF, E/e' between PeAF group and PaAF group ( $p > 0.05$ ). The LAD in PeAF group was larger than that in PaAF group ( $p < 0.05$ ), and LAAFV was lower than that in PaAF group ( $p < 0.001$ ). There was no significant difference in LAA morphology and LAA volume between the two groups through CT ( $p > 0.05$ ). However, the LAA orifice area in PeAF group was larger than that in PaAF group ( $p < 0.05$ ) (Table 2).

Table 2  
Ultrasound and 3D CT reconstruction of left atrial appendage data

Variables	All population( $n = 81$ )	PaAF ( $n = 36$ )	PeAF ( $n = 45$ )	P-value
LAD (mm)	41.9 ± 5.3	40.3 ± 4.3	43.2 ± 5.7	0.016
LVEDD (mm)	49.7 ± 5.2	49.1 ± 3.5	50.2 ± 6.2	0.344
IVST (mm)	9.5 ± 1.4	9.4 ± 1.5	9.5 ± 1.3	0.694
LVPWT (mm)	9.2 ± 1.2	9.0 ± 1.0	9.4 ± 1.4	0.146
LVEF (%)	61.6 ± 9.8	63.6 ± 8.4	59.9 ± 10.7	0.101
E/e'	8.0 ± 2.8	7.5 ± 2.4	8.5 ± 3.1	0.105
LAAFV (cm/s)	41.8 ± 19.3	50.8 ± 19.8	34.6 ± 15.8	< 0.001
Non-chicken wing ( $n, \%$ )	46(56.8)	21(58.3)	25(55.6)	0.802
LAA orifice area (cm <sup>2</sup> )	4.7 ± 1.5	4.2 ± 1.6	5.1 ± 1.4	0.007
LAA volume (ml)	11.5 ± 5.1	10.8 ± 5.0	12.1 ± 5.2	0.237

### 3. Analysis of relevant parameters of LAAFV by t-test

Among all the enrolled patients, the LAAFV in Non-chicken wing group was lower compared with that in Chicken wing group ( $36.2 \pm 15.0$ cm/s vs.  $49.1 \pm 22.0$  cm/s,  $P < 0.05$ ) (Fig. 7A). Among different types of AF, the LAAFV in persistent AF group was lower compared with that in paroxysmal AF group ( $34.6 \pm 15.8$  cm/s vs.  $49.9 \pm 20.0$  cm/s,  $P < 0.001$ ) (Fig. 7B). In the subgroup analysis, the LAAFV in Non-chicken wing group was lower than that in Chicken wing group in paroxysmal AF ( $44.0 \pm 14.3$ cm/s vs.  $60.2 \pm 22.8$ cm/s,  $P < 0.05$ ); The LAAFV in Non-chicken wing group was also lower than that in Chicken wing group in persistent AF ( $29.7 \pm 12.4$  cm/s vs.  $40.8 \pm 17.7$  cm/s,  $P < 0.05$ ) (Fig. 7C).

### 4. Analysis of relevant parameters of LAAFV by simple linear regression

The LAAFV was negatively correlated with the LAD ( $R = -0.451$ ,  $P < 0.001$ ) (Fig. 8A) and the LAA orifice area ( $R = -0.438$ ,  $P < 0.001$ ) (Fig. 8C). While it was positively correlated with the LVEF ( $R = 0.271$ ,  $P < 0.05$ ) (Fig. 8B).

### 5. Multiple linear regression analysis of LAAFV predictors

The statistically significant variables were included in the multiple linear regression analysis. The multiple linear regression analysis showed that LAA morphology ( $\beta = -0.319$ ,  $P < 0.001$ ), LAA orifice area ( $\beta = -0.219$ ,  $P < 0.05$ ), AF type (paroxysmal vs. persistent) ( $\beta = -0.283$ ,  $P < 0.05$ ) and LAD ( $\beta = -0.241$ ,  $P < 0.05$ ) were independent predictors of LAAFV (Table 3).

Table 3  
Multiple linear regression analysis of LAAFV predictors

Variables	B	SE	$\beta$	T	P-value
Constant	118.940	20.958		5.675	0.000
AF type (paroxysmal vs. persistent)	-10.928	3.531	-0.283	-3.095	0.003
LAD	-0.880	0.364	-0.241	-2.416	0.018
LVEF	0.149	0.178	0.076	0.834	0.407
LAA orifice area	-2.747	1.244	-0.219	-2.208	0.030
LAA morphology (Non-chicken wing vs. chicken wing)	-12.384	3.336	-0.319	-3.712	< 0.001
R <sup>2</sup> adjusted	0.412				
R <sup>2</sup>	0.449				

## Discussion

The left atrial appendage is a finger-like extension originating from the main body of LA [16]. It has active systolic and diastolic functions, and its mechanical dysfunction may lead to blood flow stagnation and thrombosis [17]. At present, the LAAFV measured by TEE is the most commonly used method to evaluate the mechanical function of the LAA. A large number of studies have shown that the risk of thrombosis is steadily increased with the decrease of LAAFV [18–20]. Handke et al. [8] conducted a TEE study on 500 patients with cerebral ischemia and found that the measurement of the LAAFV may be an important quantitative substitute parameter for evaluating the risk of left atrial thromboembolism. However, TEE is semi-invasive and requires higher personal experience of the operator and may cause complications, such as bleeding and perforation [21]. There are certain checkups, such as combined esophageal stenosis. Therefore, looking for noninvasive examination indicators that can effectively predict the mechanical function of the LAA has important clinical significance. Especially during the period of COVID-19.

At present, research on the anatomy of the LAA is still rare, and there is no uniform standard for the classification of the LAA. With the rapid development of multi-slice spiral CT and 3D reconstruction technology, it is possible to observe heart anatomy and vascular structure in detail. According to CT or MRI images of the heart, Wang [22] et al. divided LAA into four categories: chicken wing type, weathercock type, cauliflower type and cactus type. Among them, the chicken wing type is the most common form. However, due to the complex structure of LAA, sometimes it will show different morphological characteristics when viewed from different angles. It has been reported in the literature that this classification method is subjective [23]. Therefore, we refer to the relevant literature to divide LAA morphology into chicken wing type and non-chicken wing type. This classification can significantly reduce subjectivity. Previous studies have shown that LAA morphology is related to the LAAFV [24–25]. Fukushima et al. [25] reported that compared with the cactus type and cauliflower type LAA, the chicken-wing type LAA had a significantly higher flow velocity. However, the study only included patients with PaAF. Our study found that whether it is in PaAF group or PeAF group, the LAA morphology is closely related to its mechanical function. The LAAFV of chicken-wing AF is higher than that of non-chicken wing AF. The possible mechanisms are as follows: First, chicken-wing patients may have greater muscle mass to contract the LAA [26]. Second, high left atrial pressure or low left atrial compliance may change LAA morphology [24].

Compared with the direct measurement after CT three-dimensional reconstruction of the LAA, the measurement method used in this study judges that the LAA orifice is relatively less subjective and the measurement repeatability is good [22]. At present, the research on LAA orifice area and the mechanical function of LAA in patients with AF has not been reported in the literature. Our study showed that the increase of LAA orifice area in patients with NVAF is closely related to the decrease of LAAFV. Agmon et al. [27] reported that the emptying speed of the LAA of the normal population was negatively correlated with the diameter of the LAA orifice measured by TEE ( $r=-0.29$ ,  $p = 0.002$ ). Our data showed that the relationship between the LAA orifice area and its flow velocity in NVAF patients also conforms to the

same law, so LAA orifice area is an important factor in determining LAAFV. Studies have shown that LAAFV was significantly negatively correlated with the LAD [28–29]. Similar to the results of these studies, we found that LAD is negatively correlated with LAAFV. The reasons may be as follows: With the progress of AF, LA gradually undergoes structural remodeling, which in turn leads to an increase in the inner diameter and pressure of LA. The compliance of LAA is greater than that of the LA and can regulate left atrial pressure. However, the increase in left atrial pressure can lead to an increase in the afterload of LAA and lead to the decrease of LAAFV [30]. This can also explain the view that some scholars believe that LAD can predict the risk of stroke[31]. However, this needs more research to confirm.

The current guidelines recommend that AF be divided into five categories: primary AF, paroxysmal AF, persistent AF, long-term persistent AF and permanent AF [13]. Petersen et al. [32] found that from PaAF group, to PeAF, and then to long-term PeAF group, the LAAFV gradually decreased ( $51.4 \pm 25.1$  cm / s vs.  $40.9 \pm 16.3$  cm / s vs.  $29.7 \pm 15.1$  cm / s,  $P < 0.001$ ); Multiple linear regression analysis found that AF type was an independent predictor of LAAFV. It is consistent with our research results, and the reasons may be as follows: First, during the TEE and TTE examinations in this study, patients in the paroxysmal AF group were required to maintain sinus rhythm. When the heart rhythm is AF, the emptying time of LA and LAA is shortened, so the volume of LA is relatively increased. The rapid and irregular electrical activity will weaken the contractility of LAA, resulting in the decrease of LAAFV. Secondly, PeAF usually has a longer course than PaAF, the electrical remodeling and fibrosis of LA are more serious, which is more likely to cause an increase in the load of the LAA and cause systolic dysfunction, leading to the LAAFV was lower in persistent AF group than that in paroxysmal AF group. LVEF is a common indicator reflecting left ventricular function. Our study found that LAAFV is positively correlated with LVEF. However, the multiple linear regression analysis did not prove that LVEF is an independent predictor of the LAAFV. This is similar to the study of Kishima et al. [24]. The reason may be that the population included in our study is mainly NVAf patients with normal left ventricular ejection fraction.

At present, the CHA2DS2-VASc score is the most commonly used index for clinical assessment of stroke risk stratification in NVAf patients, and is used to guide anticoagulation therapy [33]. The 2016 ESC guidelines recommended that patients with CHA2DS2-VASc score  $\geq 1$  can choose anticoagulation therapy [34]. However, previous studies have found that patients with a score of 0 are still at risk of ischemic stroke. Gage et al. found that NVAf patients with a CHA2DS2-VASc score of 0 have an annual stroke risk as high as 1.9% [35]. Moreover, the score mainly focuses on clinical indicators, and does not pay attention to the influence of heart structure and function on thrombosis. Therefore, the scoring system is not sufficient to comprehensively assess the risk of stroke in patients. Our study showed that non-chicken wing LAA in patients with NVAf can cause the decrease of LAAFV, which may increase the risk of thrombosis. Our research on the morphology and mechanical function of LAA may provide additional clinical significance for stroke risk stratification in NVAf patients. However, this study still has some limitations. First, this study is a retrospective, single-center, small-sample study. It is hoped that there will be a larger cohort for further prospective studies in the future; Second, there is still no uniform standard for the LAA morphology. Some clinical studies divide it into four types, this study only

classifies it into two types. This classification can minimize the difference between observers, but it may not be precise enough.

## Conclusions

The LAA orifice area is closely related to the mechanical function of the LAA in patients with NVAf. The larger LAA orifice area and LAD, Non-chicken wing LAA and persistent AF are independent predictors of decreased mechanical function of the left atrial appendage.

## Abbreviations

AF: Atrial fibrillation; BMI: Body mass index; CHF: Congestive heart failure; CTA: Computed tomography angiography; CW: Chicken Wing type; LA: Left atrium; LAA: Left atrial appendage; LAD: Left atrial diameter; LAAFV: Left atrial appendage flow velocity; LVEF: Left ventricular ejection fraction; LVEDD left ventricular end diastolic dimension, IVST interventricular septal thickness, LVPWT left ventricular posterior wall thickness; TEE: Transesophageal echocardiography; TTE: Transthoracic echocardiography; PaAF: Paroxysmal atrial fibrillation; PeAF: Persistent atrial fibrillation.

## Declarations

## Acknowledgments

Not applicable.

## Consent for publication

Not applicable.

## Funding

Not applicable.

## Ethics approval and consent to participate

This study has been approved by the Ethics Committee of the Affiliated Hospital of Xuzhou Medical University (Xuzhou, china), and the ethics number is: XYFY2020-KL178-01. All methods have been implemented in accordance with relevant guidelines and regulations, and all enrolled patients have signed the informed consent.

# Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

## Authors' contributions

LC, CX and CZ performed the experiments and analyzed the data. LC and CZ designed the study and wrote the manuscript. All authors read and approved the manuscript and agree to be accountable for all aspects of the research in ensuring that the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## Competing interests

The authors declare that they have no competing interests.

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## Figures

姓名:57 住院号: 心率:69 bpm P-R:220ms RV5/SV1:2.41/0.71mV  
性别: 病区: P:90ms QT/QTc:434/465ms RV5+SV1: 3.12mV  
年龄: 床号: QRS:88ms QRS电轴:+19° 临床诊断:

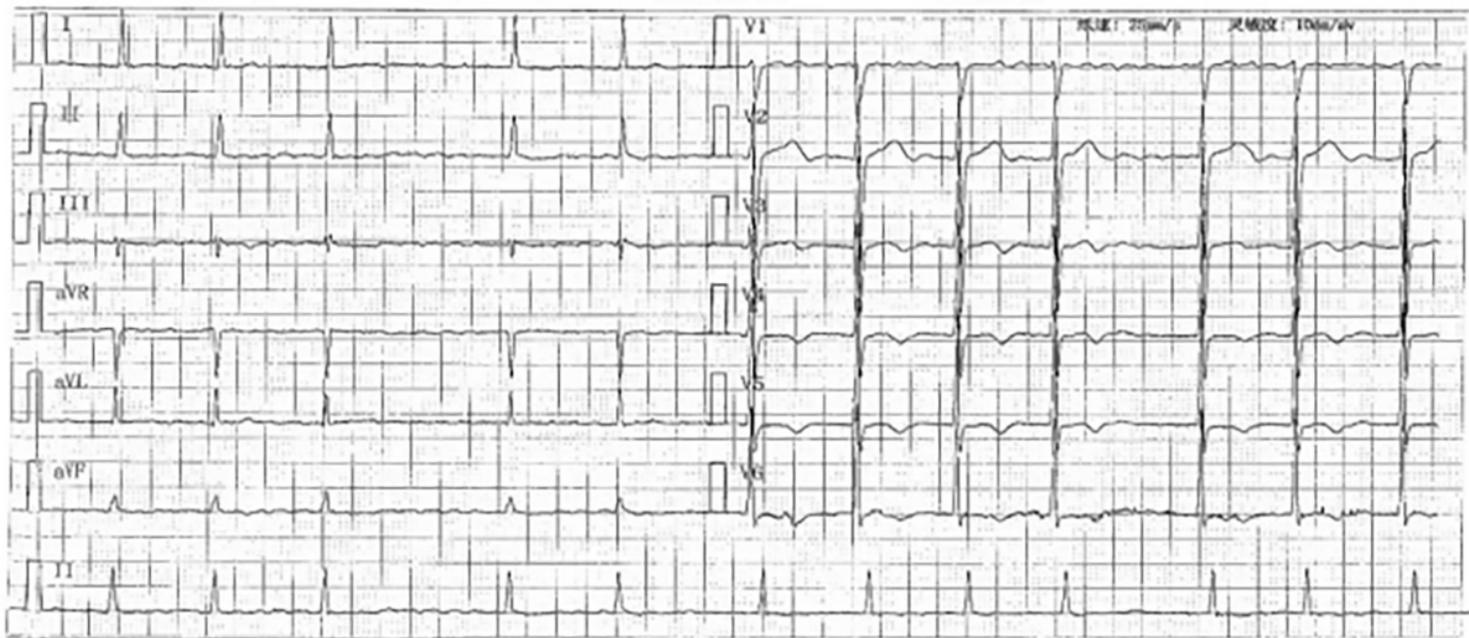


Figure 1

ECG of atrial fibrillation

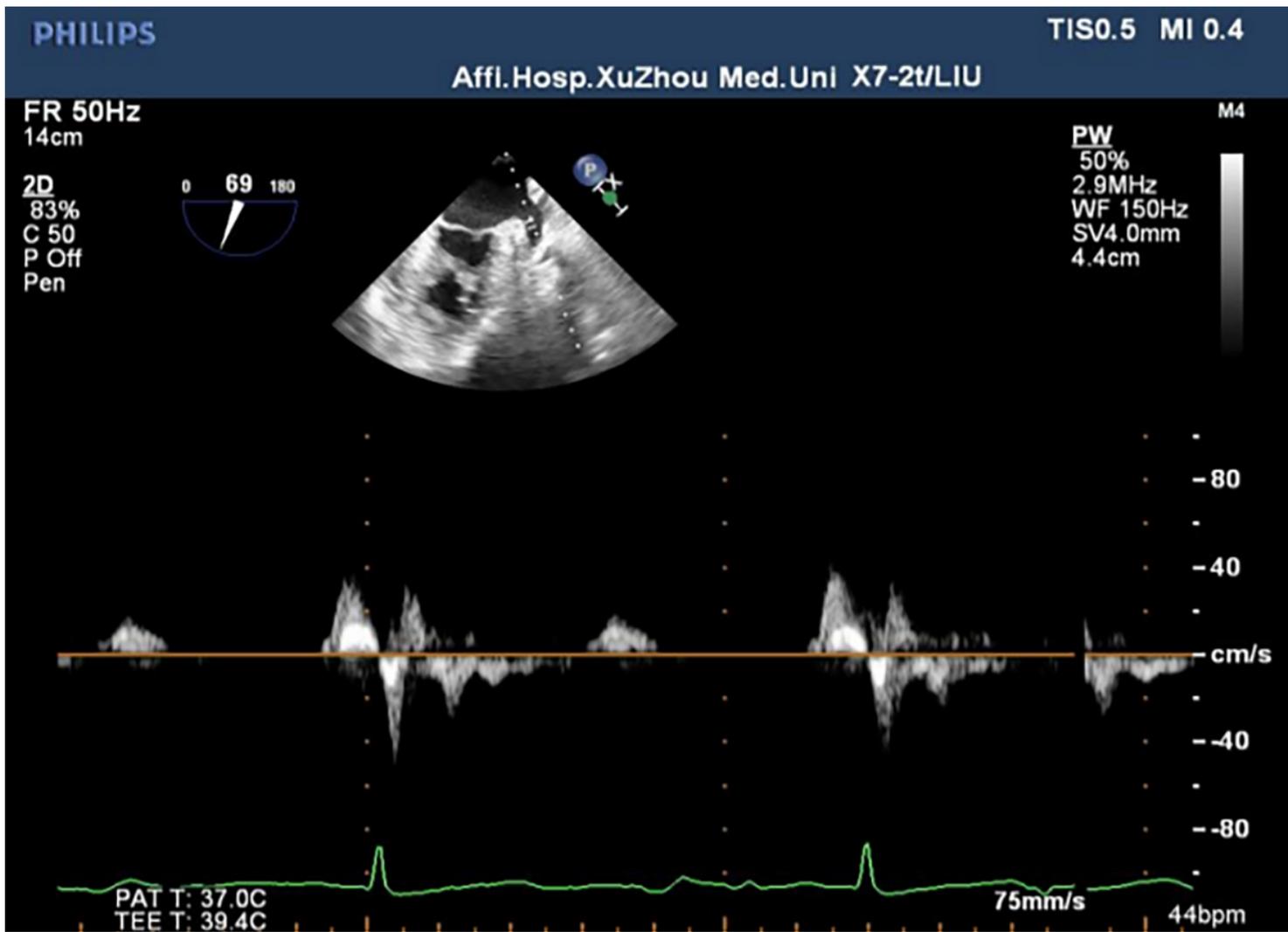


Figure 2

The blood flow pattern of the left atrial appendage in sinus rhythm

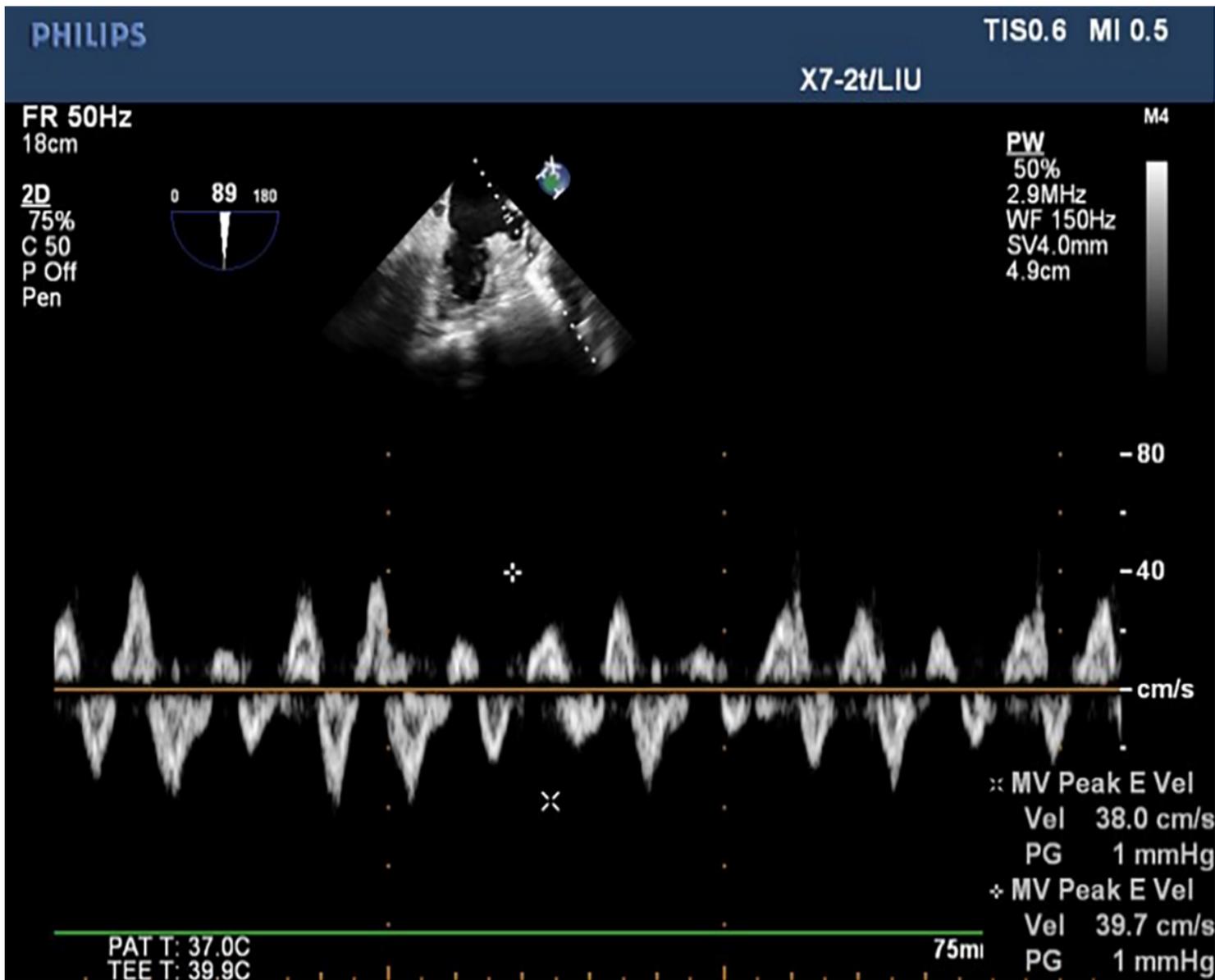
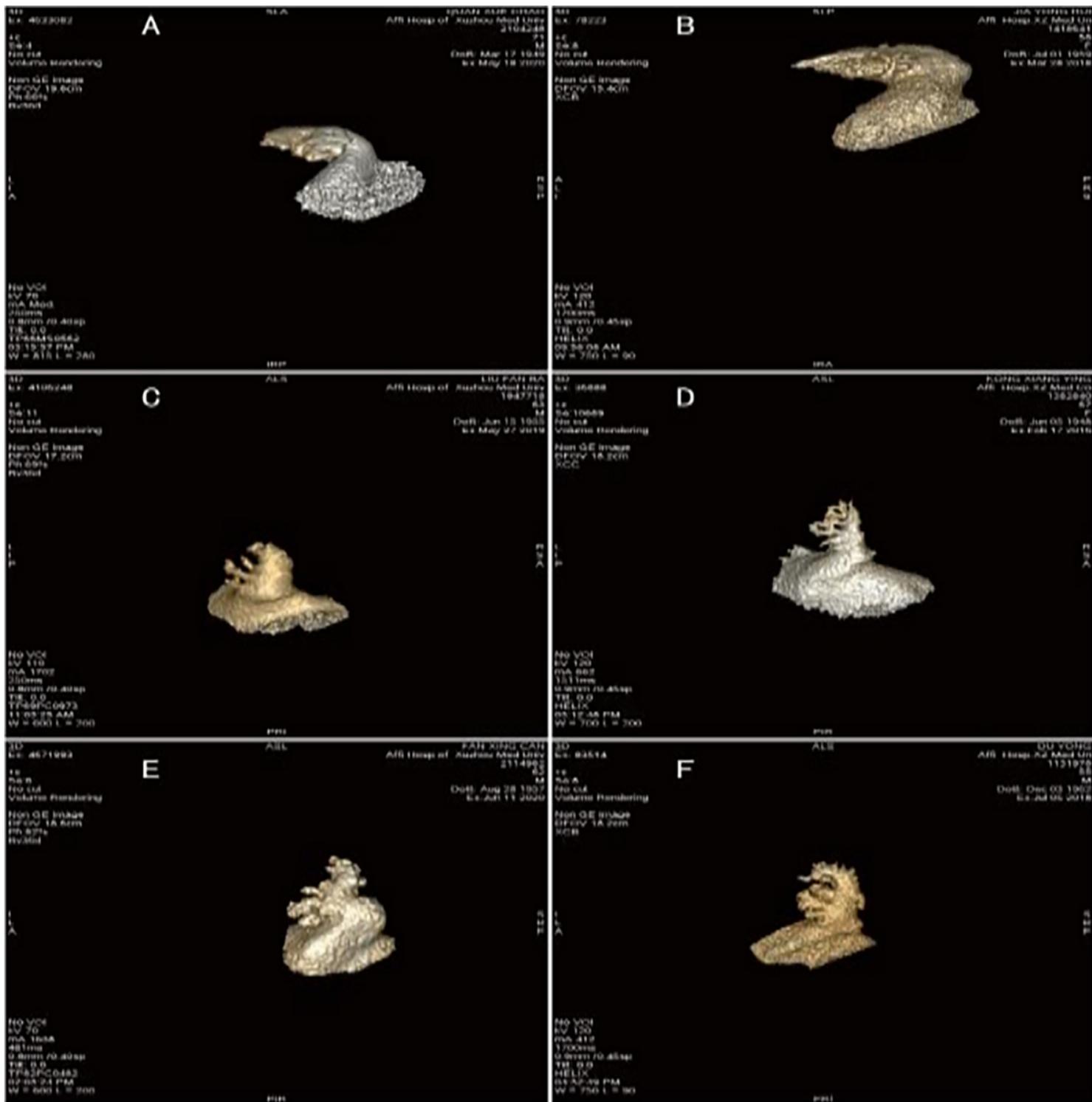


Figure 3

The blood flow pattern of the left atrial appendage in AF rhythm



**Figure 4**

The shape of the LAA. A-B Chicken-wing. C-F Non-chicken wing

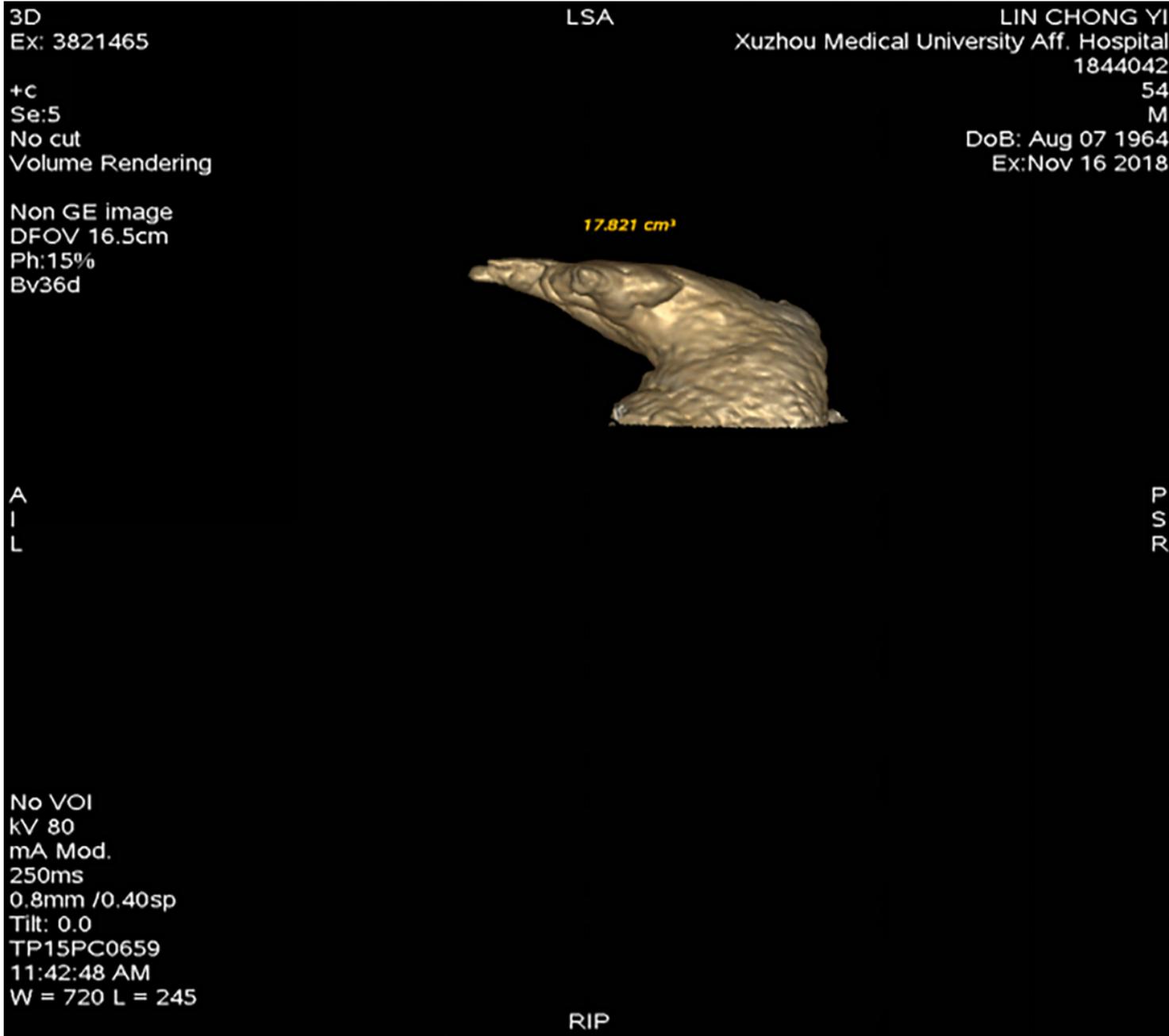
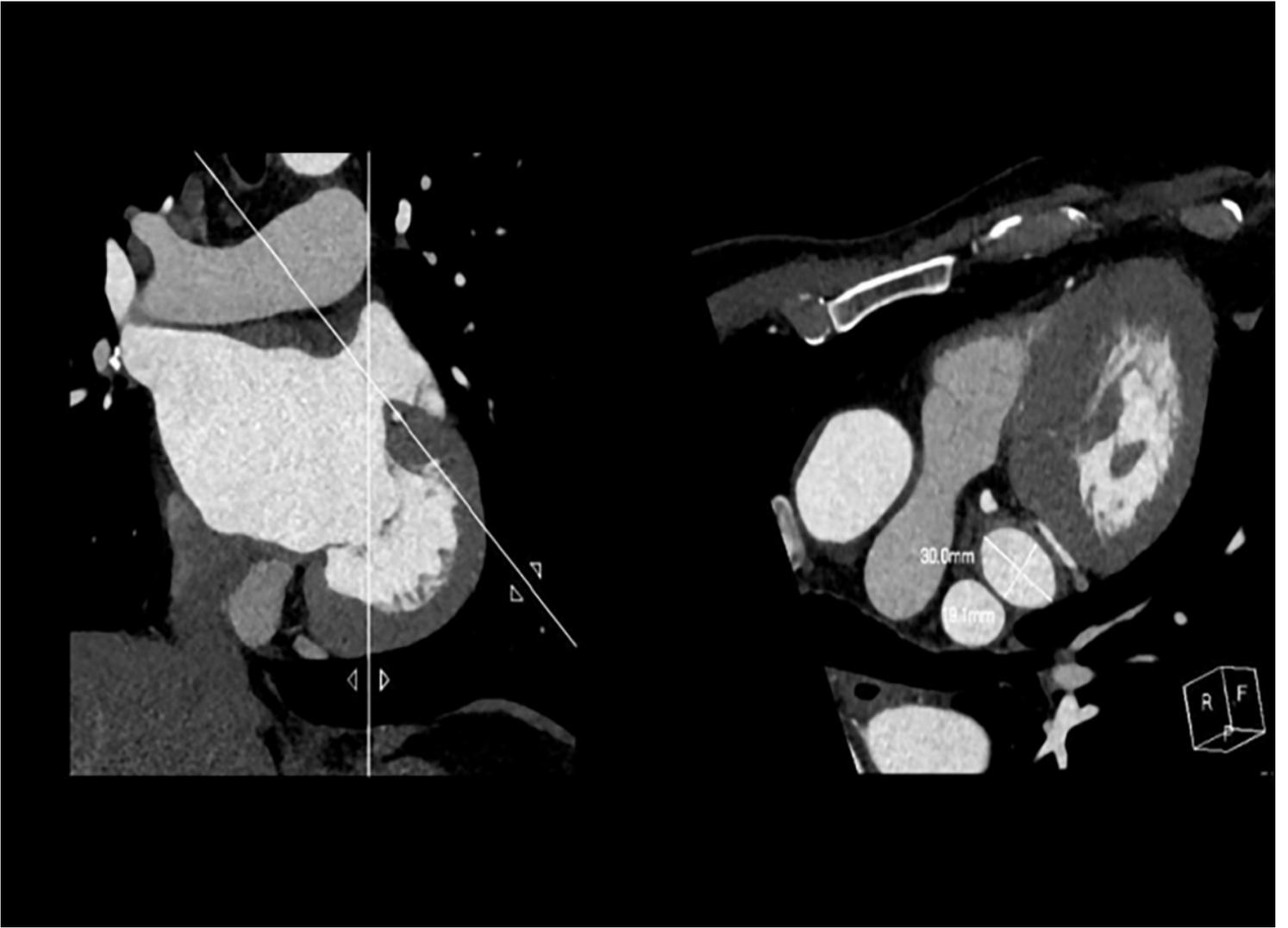


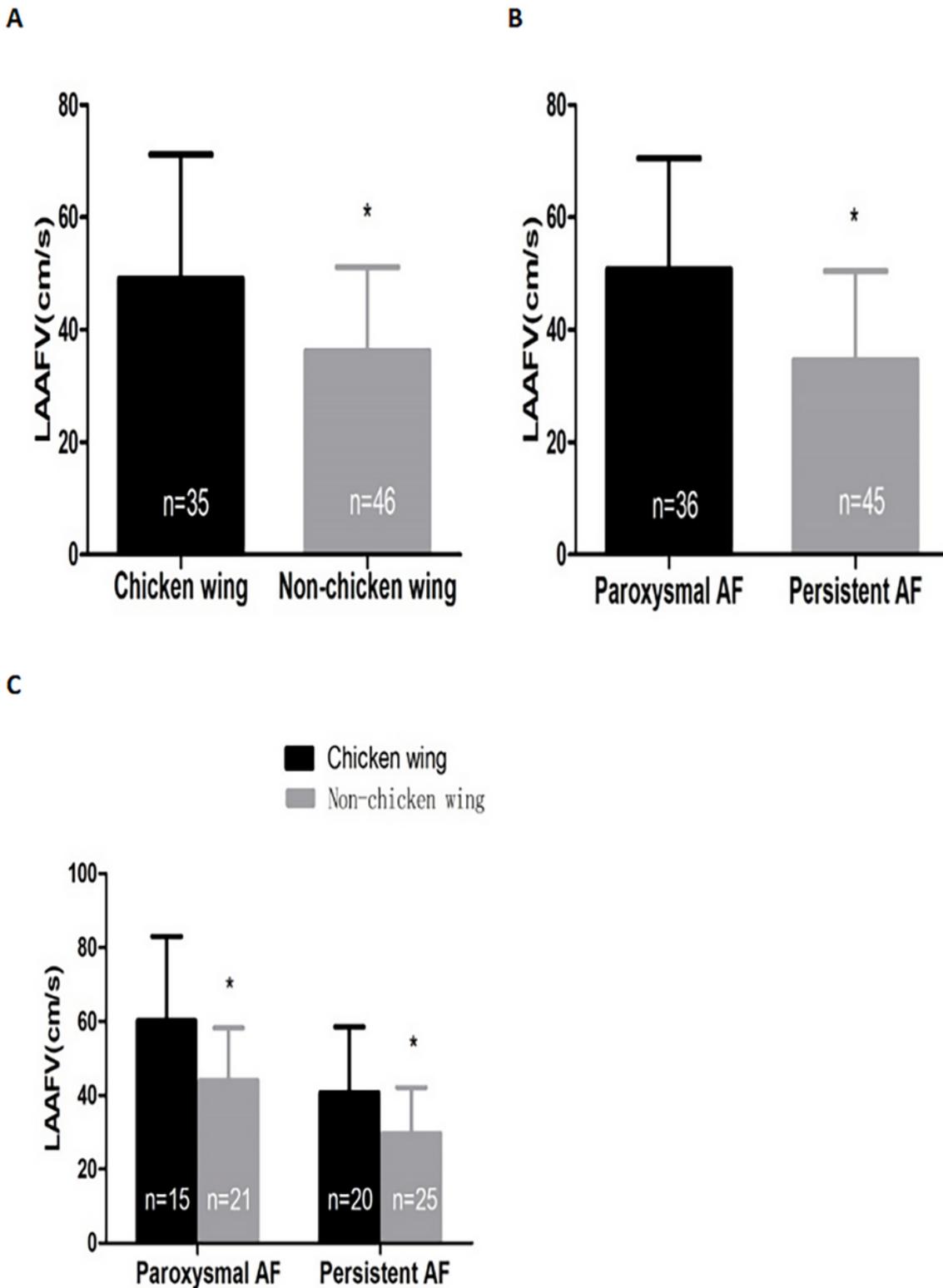
Figure 5

Left atrial appendage volume



**Figure 6**

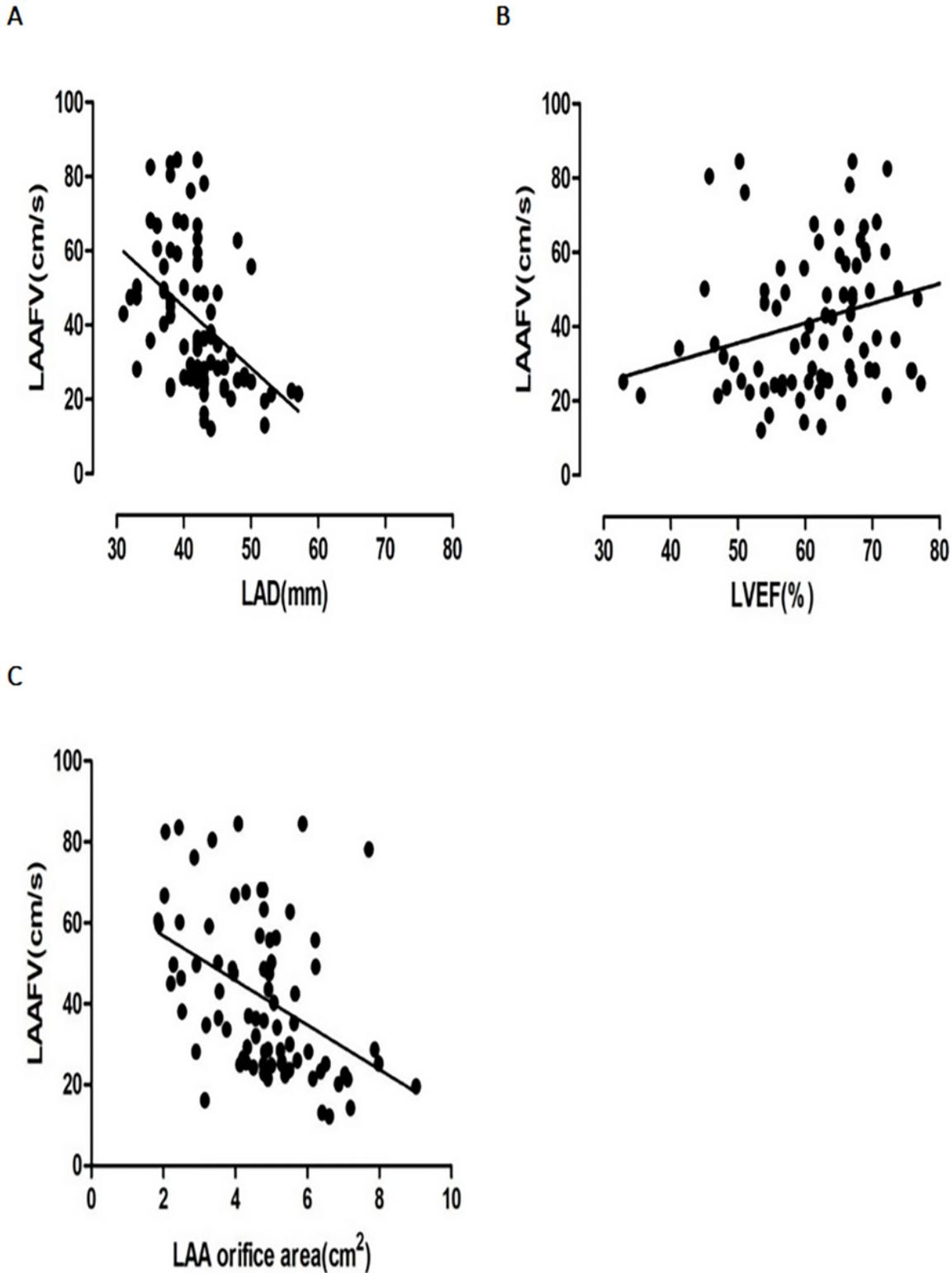
Measurement of the length and short diameter of the left atrial appendage orifice



**Figure 7**

Analysis of relevant parameters of LAAFV by t test. A Comparison of LAAFV between Chicken wing group and Non-chicken wing group. \*P<0.05: Comparison between Chicken wing and Non-chicken wing. B Comparison of LAAFV between persistent AF and paroxysmal AF. \*P<0.05: Comparison between persistent AF group and paroxysmal AF. C Comparison of LAAFV between Chicken wing group and Non-

chicken wing group in different types of AF. \*P<0.05: Comparison between Chicken wing and Non-chicken wing.



**Figure 8**

Analysis of relevant parameters of LAAFV by simple linear regression. A Comparison between LAAFV and LAD ( $Y=110.940-1.65X$ ). B Comparison between LAAFV and LVEF ( $Y=9.075+0.532X$ ). C Comparison between LAAFV and LAA orifice area ( $Y=67.858-5.506X$ ).