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Original Research Article

Cardiac CT Assessment of Left Atrial Appendages Anatomy in Patients Undergoing Coronary CT Angiography

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Abstract: *The left atrial appendage (LAA) is an anatomical, finger-like projection that arises from the left atrium (LA), characterized by unique anatomical and physiological properties distinct from those of the main atrial body. Embryologically, the LAA represents a remnant of the primordial left atrium. The morphological diversity of the left atrial appendage (LAA) is clinically significant, influencing the risk of thromboembolic events and the management strategies in patients with cardiac disease. This study aimed to evaluate the frequency distribution of four distinct morphological types of the LAA among patients undergoing cardiac imaging.* ***Objective:*** *To determine the frequency of four morphological types (chicken wing, windsock, cauliflower, and cactus) of the left atrial appendage using cardiac computed tomography (CT).* ***Methods:*** *A cross-sectional descriptive study was conducted at the Cardiac Imaging Section, Medical Teaching Institute - Hayatabad Medical Complex, Peshawar, Pakistan, from July 22, 2022, to January 22, 2023. All included patients underwent imaging using a minimum 64-slice cardiac CT scanner, without preference for a specific vendor. Patients presented in a non-fasting state to ensure consistent loading conditions of the left atrium, as fasting state variations could affect the assessment of LAA morphology.* ***Results:*** *Out of 167 patients, the chicken wing morphology was the most prevalent, identified in 57 patients (34.1%). The cactus morphology was observed in 40 patients (24.0%), followed by the windsock morphology in 39 patients (23.4%), and the cauliflower morphology in 31 patients (18.6%).* ***Conclusion:*** *This study highlights chicken wing morphology as the predominant type among patients attending cardiac imaging at our institution, followed by cactus, windsock, and cauliflower types. Awareness of the prevalence and distribution of LAA morphologies within specific populations can aid in clinical decision-making, particularly in assessing stroke risk and developing personalized therapeutic approaches.*
Keywords: Left Atrial Appendage, Morphology, Cardiac Computed Tomography, Thromboembolic Risk, Embryology

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Introduction

The left atrial appendage (LAA) is a small, muscular pouch attached to the heart's left atrium (LA), characterized by its complex and variable anatomy. It originates embryologically as a remnant of the primordial left atrium and serves as a contractile reservoir, contributing to cardiac output and atrial natriuretic peptide secretion (1, 2). Despite its physiological roles, the LAA is clinically significant due to its involvement in thrombus formation, particularly in patients with atrial fibrillation (AF), where over 90% of cardiac thrombi originate in the LAA(3).
Cardiac computed tomography (CT), particularly coronary CT angiography (CCTA), has emerged as a non-invasive modality capable of providing high-resolution images of the cardiac chambers, including the LAA. With its detailed visualization capabilities, cardiac CT is instrumental in assessing LAA morphology, volume, and orientation. It can influence therapeutic decisions such as stroke prevention strategies and suitability for LAA occlusion devices (4, 5).
LAA morphology is known to vary significantly among individuals and is commonly categorized into four types: chicken wing, windsock, cactus, and cauliflower. These morphological variants may have different thromboembolic risks and clinical implications (6). Accurate classification and evaluation of these morphological types using CT imaging can aid in risk stratification and individualized treatment planning.
This study aims to evaluate the anatomical variations of the LAA using cardiac CT in patients undergoing CCTA and determine the frequency of different morphological types in a local patient population.

Methodology

This descriptive cross-sectional study was conducted in the Cardiac Imaging Section of Hayatabad Medical Complex, Peshawar, over six months from July 22, 2022, to January 22, 2023. The study aimed to assess the anatomical variations of the left atrial appendage (LAA) in patients undergoing coronary computed tomography angiography (CCTA). A sample size of 167 patients was calculated using the OpenEpi software, based on an anticipated frequency of the cactus-type LAA morphology (19.4%), with a 95% confidence level and a 6% margin of error. A non-probability consecutive sampling technique was employed for participant recruitment.
Eligible participants included male and female patients aged between 18 and 70 years who had clinical indications for outpatient CCTA to evaluate conditions such as coronary artery disease, congenital heart disease, aortic pathologies, or pericardial disease. Patients were excluded if they had a documented contrast allergy, renal impairment defined as an estimated glomerular filtration rate (eGFR) below 30 mL/min or serum creatinine levels above 2 mg/dL, acute decompensated heart failure, valvular heart disease, or CT scans compromised by motion artifacts that precluded adequate evaluation of the LAA.
Before participation, informed written consent was obtained from each patient following approval by the institutional ethics review board. Cardiac CT imaging was performed using a GE Optima CT660 128-slice scanner. Patients were scanned in a non-fasting state to minimize variation in LAA dimensions. Caffeine and smoking were avoided before the scan to reduce fluctuations in heart rate. Renal function was assessed,

and nephrotoxic medications were withheld in patients with impaired renal function.

Imaging acquisition followed a standardized protocol. A cranio-caudal tomogram was performed to define the scanning volume, and bolus tracking was used with the region of interest placed in the left atrium or ascending aorta. The tube voltage was adjusted between 80 and 140 kV based on the patient's body mass index (BMI). A prospective ECG-gated acquisition technique was utilized. Slice thickness ranged from 0.5 mm to 1.0 mm, and an iodinated contrast agent (350 mg iodine/mL) was administered using a dual-head power injector at a rate of 5–7 mL/s, followed by a 50 mL saline flush at the same rate to reduce streak artifacts. The contrast volume varied between 40 and 100 mL, depending on patient weight and renal function.

Post-processing was performed on a dedicated workstation equipped with GE Optima software. Multiplanar and three-dimensional volume-rendered reconstructions were used to evaluate LAA morphology. The morphology of the LAA was assessed from 3D reconstructed images and double-oblique multiplanar views. The classification of LAA morphologies into four categories—chicken wing, cactus, windsock, and cauliflower—was based on established anatomical criteria. To minimize radiation exposure, transesophageal echocardiography (TEE) was used instead of CT to confirm or exclude the presence of LAA thrombi. (Figure 1A, B)

All patients also underwent 12-lead electrocardiogram (ECG) and transthoracic echocardiography to assess cardiac structure and function. CT scans of patients undergoing CCTA for other clinical indications, including coronary artery disease, congenital heart defects, aortic diseases, and structural heart abnormalities, were additionally analyzed for LAA morphology. Relevant clinical data, including demographic variables, comorbidities (e.g., diabetes, hypertension, stroke), and lifestyle factors (e.g., smoking status), were documented using a predesigned data collection form.

Data analysis was carried out using IBM SPSS Statistics version 22. Descriptive statistics were computed, including the calculation of means and standard deviations for continuous variables (age, height, weight, and BMI) and frequencies and percentages for categorical variables (gender, LAA morphological type, comorbidities, and clinical history). Demographic and clinical parameters stratified the distribution of LAA morphologies, and associations were assessed using the Chi-square test, with a p-value of less than 0.05 considered statistically significant.

Results

This study was conducted on 167 patients who presented at the Cardiac Imaging Unit, MTI-Hayatabad Medical Hospital, Peshawar. Table 1 presents the descriptive statistics and categorical distribution of the study population. The mean age of the participants was 34.42 ± 11.88 years, with an average weight of 74.66 kg, a height of 5.75 feet, and a BMI of 25.98 kg/m². Most participants were under 35 (66.5%), and 58.7% were male. Comorbidities such as diabetes mellitus (22.8%), hypertension (30.5%), atrial fibrillation (24.6%), and stroke (17.4%) were noted. About 18.6% had congenital heart disease, and 17.4% were smokers. Among the LAA morphological types, the most common was the Chicken Wing type (34.1%), followed by Cactus (24.0%), Windsock (23.4%), and Cauliflower (18.6%).

Table 2 shows the distribution of LAA morphological types across demographic and clinical characteristics. No statistically significant associations were found between age or gender and LAA morphology (p > 0.05). However, statistically significant associations were observed between contrast allergy and LAA morphology, particularly for the Windsock (p = 0.021) and Cactus types (p = 0.025). Diabetes did not show a meaningful relationship with any LAA morphology.

Table 3 examines the relationship between left atrial appendage (LAA) morphology and various clinical parameters. No statistically significant differences were observed between LAA morphological types and hypertension, stroke, congenital heart disease, smoking status, or BMI (all p-values > 0.05). This suggests that LAA morphological types are independent of these clinical characteristics in the studied population.

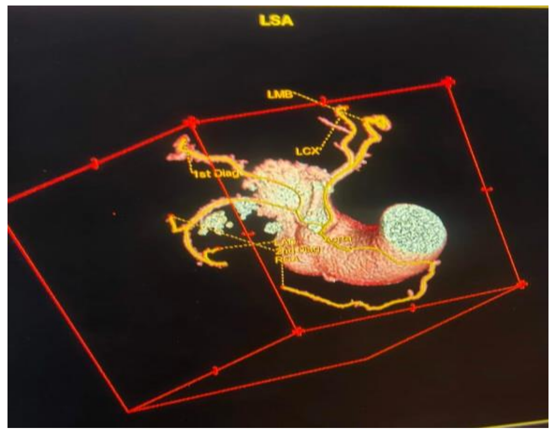

Figure 1A: 3D reconstructed CT coronary angiogram highlighting the major coronary arteries and Chicken wing LAA morphology

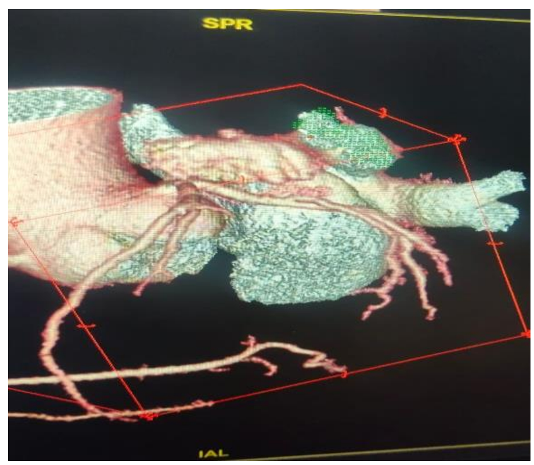

Figure 1B: 3D reconstructed CCTA in the SPR view highlighting Chicken wing LAA morphology

Table 1: Demographics, Clinical Characteristics, and LAA Morphology (n=167)

Variables	Categories	Frequency (%) / Mean ± SD
Age (years)	Mean ± SD	34.42 ± 11.88
	<35	111 (66.5%)
	>35	56 (33.5%)
Gender	Male	98 (58.7%)
	Female	69 (41.3%)
Weight (kg)	Mean ± SD	74.66 ± 14.24
Height (ft)	Mean ± SD	5.75 ± 0.13
BMI (kg/m²)	Mean ± SD	25.99 ± 5.00

Contrast Allergy	Yes	53 (31.7%)
Atrial Fibrillation	Yes	41 (24.6%)
Diabetes Mellitus	Yes	38 (22.8%)
Hypertension	Yes	51 (30.5%)
Stroke	Yes	29 (17.4%)
Congenital Heart Disease	Yes	31 (18.6%)
Smoking Status	Smoker	29 (17.4%)
LAA Morphological Types	Chicken Wing	57 (34.1%)
	Windsock	39 (23.4%)
	Cauliflower	31 (18.6%)
	Cactus	40 (24.0%)

Table 2: Stratification of LAA Morphologies with Age, Gender, Contrast Allergy, Atrial Fibrillation, and Diabetes (n=167)

Variables	Chicken Wing (%)	Windsock (%)	Cauliflower (%)	Cactus (%)	p-value
Age (<35/>35)	70.2/29.8	59.0/41.0	74.2/25.8	62.5/37.5	>0.05
Gender (M/F)	54.4/45.6	61.5/38.5	61.3/38.7	60.0/40.0	>0.05
Contrast Allergy (Y/N)	36.8/63.2	41.0/59.0	32.3/67.7	15.0/85.0	>0.05
Atrial Fibrillation(Y/N)	26.3/73.7	28.2/71.8	29.0/71.0	15.0/85.0	>0.05
Diabetes Mellitus(Y/N)	29.8/70.2	17.9/82.1	29.0/71.0	12.5/87.5	>0.05

Table 3: Stratification of LAA Morphologies with Hypertension, Stroke, Congenital Heart Disease, Smoking Status, and BMI (n=167)

Variables	Chicken Wing (%)	Windsock (%)	Cauliflower (%)	Cactus (%)	p-value
Hypertension (Y/N)	29.8/70.2	33.3/66.7	22.6/77.4	35.0/65.0	>0.05
Stroke (Y/N)	14.0/86.0	12.8/87.2	25.8/74.2	20.0/80.0	>0.05
Congenital HD (Y/N)	22.8/77.2	20.5/79.5	12.9/87.1	15.0/85.0	>0.05
Smoking Status (Y/N)	24.6/75.4	12.8/87.2	22.6/77.4	7.5/92.5	>0.05
BMI (<25/>25 kg/m²)	43.9/56.1	43.6/56.4	45.2/54.8	37.5/62.5	>0.05

Discussion

In the present study, we observed the chicken wing morphology as the most frequent type (34.1%), followed by cactus (24.0%), windsock (23.4%), and cauliflower (18.6%). This distribution aligns with several international studies but also exhibits notable differences.

Our findings regarding the dominance of chicken wing morphology are consistent with recent global research. For instance, a recent Di Biase et al. study reported that chicken wing morphology is predominant among patients with atrial fibrillation undergoing catheter ablation procedures, suggesting an association with lower thromboembolic risks compared to other types (7). Similarly, a study in China reported chicken wing morphology as the most prevalent type, observed in approximately 45% of patients, further supporting its frequent occurrence internationally (8).

Contrary to our findings, certain studies have reported alternative predominance patterns. A recent European multicenter study noted windsock morphology as the most common (9), and another conducted in South Korea indicated cactus morphology as significantly prevalent, highlighting regional variations in LAA morphology distribution (10).

In terms of clinical factors, our analysis revealed no significant association between LAA morphology and demographic or clinical characteristics, including age, gender, atrial fibrillation, diabetes mellitus, hypertension, stroke, congenital heart disease, smoking status, or BMI. These findings are consistent with those from a recent systematic review by Korhonen et al., which suggested limited evidence linking clinical characteristics with specific LAA morphologies, emphasizing the complexity of establishing such correlations without larger sample sizes and more robust methodological frameworks (11).

The variability in LAA morphological prevalence observed across different studies underscores the necessity for individualized assessment in clinical practice. Accurate characterization of LAA morphology using advanced imaging techniques, such as cardiac computed tomography, is crucial for optimizing patient management strategies, particularly in selecting and sizing devices for LAA occlusion procedures to prevent thromboembolic events.

Our study's limitations include its single-center design and relatively small sample size, which limit the generalizability of our results. Therefore, future multicentric studies involving diverse populations and larger sample sizes must validate our findings and comprehensively explore potential clinical correlations.

Conclusion

In conclusion, this study provides essential morphological data from a Pakistani population, highlighting chicken wing morphology as the predominant feature. These findings provide a foundational understanding that can enhance clinical decision-making and procedural planning, thus improving patient outcomes.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-TCDD-102-24)

Consent for publication

Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

ME
Manuscript drafting, Study Design,
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TM
Conception of Study, Development of Research Methodology Design,
MAI (Postgraduate)
Study Design, manuscript review, and critical input.

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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