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RESEARCH

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Cardiac CT evaluation of left atrial diverticulum and accessory appendage

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Abstract

Background: The aim of this study was to evaluate the prevalence, location, size, and morphological features of the left atrial accessory appendage and diverticulum with cardiac computed tomography. Cardiac computed tomography obtained consecutively from 1415 patients with normal ECG findings during a 2-year period were analyzed. Left atrial appendage and diverticulum type, location, and size were recorded and analyzed according to age and gender.

Results: Cardiac computed tomography of 1415 (796 males and 619 females) participants aged 44.1 + 12.2 years old were re-evaluated, and 238 atrial diverticulum were found in 234 (16.5%) patients, accessory appendage in 93 (6.5%), and atrial diverticula and accessory appendage together in eight (0.56%) patients. The atrial diverticulum was most frequently observed in the anterosuperior localization ($n = 157$, 49.2%). One hundred and twenty-three (52%) of the atrial diverticulum were cystic, and 107 (45%) were tubular form. Accessory appendage was observed most frequently in the anterior superior location ($n = 65$, 20.4%).

Conclusions: The frequency of left atrial diverticulum was found to be 16%, and the frequency of accessory appendage was 6%, consistent with the majority of the literature. Left atrial diverticulum and accessory appendage were detected more frequently in men than in women. Cystic form is more common in left atrial diverticulum.

Keywords: Left atrial diverticulum, Left atrial accessory appendage, Cardiac CT

Background

Left atrial anatomical abnormalities such as diverticulum and accessory appendage are outward focal projections of the atrium wall. Such variations are rare and have been described based on previous pathological findings. They can be found congenital or acquired [1]. Clinically, they are usually asymptomatic. However, more frequent thrombus formation and ectopic electrical activity have been described in patients with left atrial diverticulum and appendage [2, 3]]. It is important to detect accompanying abnormalities before clinical applications. For this aim, cardiac computed tomography (CT) is generally used. Cardiac CT is a noninvasive method that is increasingly used for detailed evaluation of cardiac anatomy and structure as well as coronary anatomy.

The aim of this study was to evaluate the prevalence, imaging features, and anatomical locations of the left atrial accessory appendage and diverticulum in patients with normal sinus rhythm.

Methods

This study was planned retrospectively. This study was performed by examining contrast-enhanced cardiac CT scans obtained from 1415 patients with normal ECGs over a 2-year period between November 2018 and November 2020. All coronary CT scans were performed using multi-detector computed tomography (MDCT) (Siemens Healthcare 256 slice) and low osmolar contrast material (iohexol 350 mgI/ml, Omnipaque, Opakim Medical Products Inc, Istanbul, Turkey). ECG-based tube current modulation was used in all patients. Contrast-enhanced images were acquired during a single

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breath-hold. Unless contraindicated, cardiac CT was performed in patients with a heart rate of 60 beats per minute or more after vasodilation with oral nitroglycerin and venous administration of metoprolol. Image reconstruction was performed at a phase start of 65% of the R peak-to-R peak range, but repeated at various other phases throughout the cardiac cycle if motion artifact was present. Ventricular diastole axial, sagittal, coronal, and interactive multi-plane reconstructions, as well as maximum intensity projections and interactive volume-rendering images, were created. Thanks to these images (MIP, VR), it can be helpful in detecting the details that are overlooked in the images examined in the axial plane. All images were reviewed by three researchers with 5–15 years of experience.

In the CT evaluation, anatomical structures with a wide neck and smooth contours were accepted as an atrial diverticulum [4], and structures with a narrow neck and irregular contours were accepted as accessory appendage [5]. The longest vertical dimension and widest transverse diameter of each diverticulum were measured. The location, number, and shape of each diverticulum type were evaluated. The atrial diverticulum was divided into seven categories in terms of anatomical localization: anterosuperior, anterior inferior, superior, right lateral, left lateral, posterosuperior, and posteroinferior. The diverticulum was divided into two cystic and tubular. Structures with a vertical length to transverse diameter ratio of more than 1.5 were considered tubular diverticulums. Accessory appendages were divided into seven categories according to anatomical localization: anterosuperior, anterior inferior, superior, right lateral, left lateral, posterosuperior, and posteroinferior.

Scale variables were expressed as mean (Average) and standard deviation (SD), while categorical variables are shown as numbers (n) and percent (%). Calculations were made using statistical software (IBM SPSS Statistics 20, SPSS inc. An IBM Co, Somers, NY). Ethics committee approval of Dicle University Faculty of Medicine was obtained for this study.

Results

Cardiac CT of 1415 (796 males and 619 females) participants aged 44.1 ± 12.2 years old were re-evaluated and 238 atrial diverticulum were found in 234 (16.5%) patients, accessory appendage in 93 (6.5%), and atrial diverticula and accessory appendage together in eight (0.56%) patients.

The ages of 234 patients with atrial diverticulum were ranged 18–80 (mean ± SD: 43 ± 11, $p = 0.526$), and 105 (44.9%) of the patients were female and 129 (55.1%) were male ($p = 0.557$). The mean vertical diameter of the diverticulum was 6.2 ± 2.6 mm and the mean transverse diameter was 3.8 ± 2.1 mm. The vertical and transverse diameter of the diverticulum was significantly increased with age ($p = 0.016$; $r = 0.157$ and $p < 0.001$; $r = 0.237$, Pearson Correlation).

Atrial diverticulum was most frequently observed in the anterosuperior localization ($n = 157$, 49.2%) and the least observed in the posterosuperior and right lateral localizations ($n = 3$, 0.9%). Other locations and their frequencies are shown in Table 1.

Of the patients with atrial diverticulum, 123 (52%) had cystic (Fig. 1) and 107 (45%) tubular (Fig. 2) diverticula. In three of the four patients with two diverticula, cystic tubular forms were found in both diverticula, and the diverticulum found in the other patient was tubular.

The ages of the patients (93) with accessory appendages were between 19 and 80 (mean + SD: 45 ± 12, $p = 0.218$), and 40 (41.9%) of the patients were female and 54 (58.0%) were male ($p = 0.756$). Accessory appendage (Fig. 3) was observed most frequently in the anterior superior location ($n = 65$, 20.4%) and least in the posteroinferior location ($n = 1$, 0.3%). No accessory appendage is observed in its posterosuperior location. The distribution of accessory appendage according to localization is shown in Table 2.

Discussion

The atrial diverticulum was considered as one of the rare cardiac anomalies in the past. Recently, pathologies such as diverticula and accessory appendages are detected at higher rates due to the increasing use of MDCT in cardiac imaging.

Atrial diverticula are usually asymptomatic structures. It is diagnosed incidentally during cardiac CT. The etiology of the left atrial diverticulum is unclear. Most patients do not have hemodynamic disturbances that create the appropriate environment for the development

Table 1 Left atrial diverticulum localization distribution

	Frequency	Percent (%)
Anterosuperior	157	49.2
Superior	32	10
Right lateral	3	0.9
Left lateral	6	1.9
Posterosuperior	3	0.9
Posteroinferior	5	1.6
Anteroinferior	24	7.5
Anterosuperior/anterosuperior	2	0.6
Anteroinferior/anteroinferior	1	0.3
Anterosuperior/superior	1	0.3
Total	234	

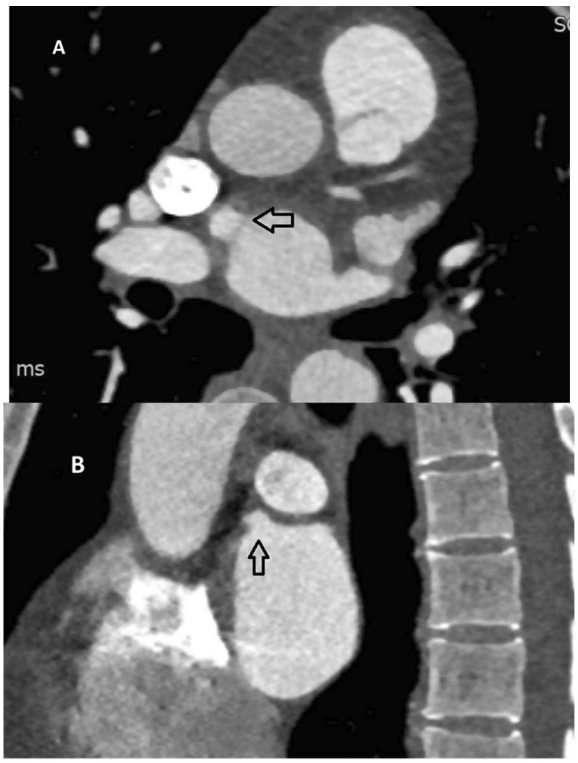

Fig. 1 Axial (**A**) and sagittal (**B**) images of the cystic diverticulum in the anterosuperior location of the left atrium are observed

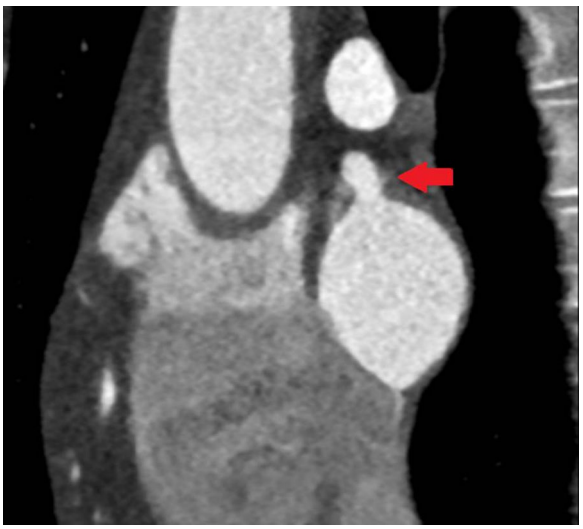

Fig. 2 Tubular diverticulum (red arrow) is observed in the superior localization of the left atrium

of acquired diverticulum. It is, therefore, more likely to have a congenital history. This study aimed to evaluate the prevalence, location, and size of left atrial accessory appendages and diverticulum in the Turkish population.

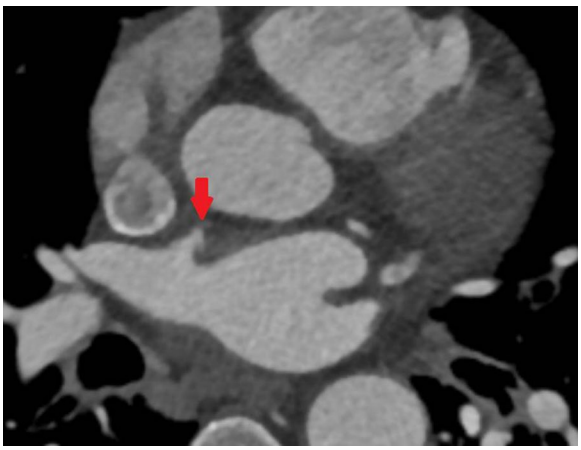

Fig. 3 Accessory appendage is observed in the anterosuperior localization of the left atrium

Table 2 Accessory appendage localization distribution

	Frequency	Percent (%)
Anteriosuperior	65	20.4
Anteroinferior	11	3.4
Right lateral	2	0.6
Left lateral	3	0.9
Superior	11	3.4
Posteroinferior	1	0.3
Posterosuperior	0	0
Total	93	

In the literature, Wan et al. [1], Genç et al. [5], Abbara et al. [6], Holda et al. [7], Incedayı et al. [8], Lazoura et al. [9] conducted similar studies by retrospectively examining cardiac CTs. A summary of these studies with different patient numbers is given in Tables 3 and 4.

Our study stands out as we included a larger sample size than what is in the literature. In our study, 238 atrial diverticula were found in 234 (16.5%) of the patients, accessory appendage in 93 (6.5%), and atrial diverticula and accessory appendage association in eight (0.5%) patients. The frequency of atrial diverticula in the literature varies between 15 and 48.4% [10], and the value we found in our study is consistent with the general literature. The values found in the studies by Genç et al. [5] and Incedayı et al. [8] were higher than the literature in general and our study. The localization distribution of the left accessory appendage is consistent with the study of Lazoura et al. [9]. We think that the reason why it is inconsistent with other studies is due to differences in anatomical localization classification. Accessory

Table 3 Rates of atrial diverticulum, accessory appendage and its association in different studies

	n	Atrial diverticula	Appendage	Diverticula + appendage
Abbara et al. [6]	529	81 (% 15.3)	20 (% 3.7)	20 (% 3.7)
Genç et al. [5]	1305	610 (% 46)	62 (% 4.6)	–
Holda et al. [7]	294	47 (% 16)	12 (% 4.1)	2 (%0.7)
Wan et al. [1]	120	20 (% 16.7)	–	–
Incedayı et al. [8]	454	186 (% 41)	–	–
Lazoura et al. [9]	200	41 (% 20.5)	13 (% 6.5)	–

Table 4 Diverticulum and appendage location, diameters, sex–age distribution coexistence of different studies

	M n, (%)	F n, (%)	Age	D Type: n, (%)	VDD (mm) (min–max)	TDD (mm) (min–max)	A Type (n, %)
Abbara et al. [6]	82 (81)	19 (19)	58 ± 13	AS: 99, (88)	6.4 ± 2.5 (3–14)	6.2 ± 3.9 (2–13)	RLPI: 15, (34)
Genç et al. [5]	505 (71.3)	203 (28.7)	–	RAS: 328, (46)	5.5 ± 3.3 (1–20)	5.9 ± 2.9 (1–18)	SL: 23, (32)
Holda et al. [7]	35 (61.4)	22 (38.6)	68.5 ± 14.6	AS: 31, (66)	5.9 ± 2.8 (1.7–16.7)	6.4 ± 3.2 (1.9–15.4)	Ant: 8, (66)
Wan et al. [1]	9 (45)	11 (55)	58.1 ± 12.9	RA: 18, (66.7)	5.4 ± 2 (1.8–9,4)	4.9 ± 3.2 (1.3–14.2)	–
Incedayı et al. [8]	140 (75)	46 (25)	–	RAS: 166, (36.6)	5.2 (2–16)	3.8 ± 1.5 (1–10)	IL:6, (42.8)
Lazoura et al. [9]	135 (67.5)	65 (32.5)	55	RAS: 36, (45)	7.8 (3–16)	7.2 (2.2–20.3)	RAS: 7, (54.8)

M: Male F: Female D: Diverticulum, VDD: Diverticulum vertical diameter, TDD: Diverticulum transverse diameter, A:Appendage AS: Anterosuperior, RAS: Right anterosuperior, RLPI: Right lateral posteroinferior, SL: Superolateral Ant: Anterior, IL: Inferolateral

appendage can be observed in a wide range of 6.5–28% in the literature [7]. Our study is compatible with the literature.

In our study, we could not find a statistically significant difference between men and women in patients with atrial diverticula. When previous studies were examined, Wan et al. [1] and Seker et al. [10] reported similar results. But, Abbara et al. [6] and Genç et al. [5] found it significantly higher in males.

Our study showed that the left atrial diverticulum was most commonly located in the anterosuperior wall of the atrium and was consistent with the literature [1, 5, 6, 8]. Also we found that the least common left atrial diverticula was the posterosuperior wall and was consistent with previous studies [5]. Wan et al. [1] reported that posterior left atrial diverticulum is more common in women. In our study, we could not detect a relationship between gender, diverticula localization, and size.

In addition to diverticula ratios, the structure of the diverticula has been investigated in the literature. In the study by Genç et al. [5], 440 (62%) of the atrial diverticulum were found to be cystic, 219 (31%) tubular, and 49 (7%) atypical shaped. In the study of Wan et al. [1], 20 (74.1%) of the 27 diverticulums detected were cystic and 7 (25.9%) tubular-shaped. In our study, 126 (52%) of 238 diverticula were cystic and 112 (47%) were tubular. The predominance of a diverticulum in cystic character is consistent with the literature.

They are usually asymptomatic. Recently, they have been suspected to cause atrial fibrillation by triggering conduction abnormalities, and various studies have been conducted to investigate the relationship between them. Many studies did not find a significant relationship [1, 5, 6, 11]. However, the evaluation of variations can guide the clinician in preventing possible complications, especially in patients with atrial fibrillation, before radiofrequency ablation therapy or in catheterizations.

MDCT provides a more detailed evaluation of cardiac anatomical structures. Allows the detection of a small diverticulum. Despite the growing role of MDCT in clinical practice, there is no consensus on the preprocedural use of MDCT. Since the clinical role of the diverticulum and appendage has not been fully established, routine cardiac CT may not be cost-effective. However, it is a valuable method in clinical requirements and in preventing possible complications before the procedure.

The most important limitations of this study are the retrospective analysis and the lack of clinical findings. No

pathological correlation could be made between the findings and the patient. In addition, although the morphological findings of the atrial diverticulum and appendage are compatible with the literature, the lack of reliability analysis between different evaluators may carry a risk of bias.

Conclusions

In this study, the frequency of left atrial diverticulum was found to be 16%, and the frequency of accessory appendage was 6%, consistent with the majority of the literature. Left atrial diverticulum and accessory appendage were detected more frequently in men than in women. The cystic form is more common in left atrial diverticulum. Left atrial diverticulum and accessory appendage were most commonly found in the anterosuperior location. Cardiac CT is a powerful imaging modality for the evaluation of left heart variations and abnormalities. We think that the size, localization or type of these variations will be understood more clearly in the future by specifying these variations in CT reports and conducting studies with large series evaluating the clinical relationship.

Abbreviations

CT: Computed Tomography; MDCT: Multi-Detector Computed Tomography; M: Male; F: Female; D: Diverticulum; VDD: Diverticulum vertical diameter; TDD: Diverticulum transverse diameter; A: Appendage; AS: Anterosuperior; RAS: Right anterosuperior; RLPI: Right lateral posteroinferior; SL: Superolateral; Ant: Anterior; IL: Inferolateral.

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Not applicable.

Author contributions

SŞ designed the study and provided data acquisition and analysis. He contributed significantly to the writing of the article. CAÖ has made important contributions to the preparation and critical review of the article. YK contributed to the study design and data collection. All authors read and approved the final manuscript.

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Availability of data and materials

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

Declarations

Ethics approval and consent to participate

Ethics committee approval was obtained at Dicle University Medical School. Written consent was obtained for this article. Since it is a retrospective study, participant consent was not required.

Consent for publication

Not required due to retrospective study.

Competing interests

The authors declare that they have no competing interests.

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