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Comparison of pulmonary veins in patients with and without atrial fibrillation using multidedector computed tomographic angiography

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ABSTRACT

Objectives: Atrial fibrilation (AF) develops from an arrhythmogenic ectopic focus, which triggers the vicious circle that creates arrhythmias. Arrhythmogenic foci are often located in the transition areas between the pulmonary veins and the left atrial endothelium. This study aims to compare the pulmonary vein anatomy of patients with and without AF using multidetector computed tomographic (MDCT) angiography and to evaluate the relationship between the presence of pulmonary vein variations and the development of AF.

Methods: Seventy cases (38 males, 32 females) aged between 23 and 75 (mean age: 49.9 ± 13.3) were included in this study. This study consisted of 20 patients undergoing endovascular radiofrequency catheter ablation with AF and 50 participants (control) without AF. MDCT angiography examination was performed for the evaluation of pulmonary vein anatomy and variations.

Results: Normal pulmonary vein anatomy was observed in 30% (n = 6) of the study group, 60% (n = 30) of the control group, and 51.4% (n = 36) of the total of both groups. Variation in pulmonary vein anatomy (accessory pulmonary vein or common ostium) was detected in 48.6% (n = 34/70) of the cases. The most common variation was the presence of accessory pulmonary vein (35.7%). Common ostium was found to be the second most common variation (12.8%). All common ostia were localized on the left side. Early branching of pulmonary veins was detected in 41 (58.5%) of 70 cases.

Conclusions: Accesory pulmonary vein, common ostium and early branching are more frequently present in patients with AF.

Keywords: Atrial fibrillation, pulmonary veins, multidetector computed tomographic angiography

Atrial fibrillation (AF) is the most common rhythm disorder in the community. The prevalence of AF varies between 0.4% and 1% in general, and its incidence rises to 8% after the age of 80. AF, which is responsible for 15% of all strokes, is a clinical entity with a high morbidity and mortality rate, doubling the mortality rates due to cardiovascular causes [1-3]. The main mechanism underlying the pathophysiology of AF is the arrhythmogenic ectopic focus, which triggers the vicious circle that creates arrhythmias. Arrhythmogenic foci are often located in the transition areas between the pulmonary veins and the left atrial endothelium. These transition zones, which correspond to the ostia where the pulmonary veins open to

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the left atrium, are tissues that tend to produce arrhythmias, which are covered like a shirt by the myocardial tissue embryologically [4-7].

Although there are various antiarrhythmics that can be used to control the ventricular response and maintain normal sinus rhythm in the treatment of AF, the success rate of medical treatment is low and there are many side effects. This situation has brought the search for different treatments to the agenda. Jais et al.'s [6] demonstration of the presence of ectopic pulses originating from the pulmonary veins in patients with AF not only gave a new direction to the treatment of AF, but also opened a new window in understanding the mechanism of AF. Today, endovascular radiofrequency catheter ablation (RFCA) of the arrhythmia focus located in the transition region of the pulmonary vein ostia is the most effective method used in the treatment of medically resistant AF. The success rate of RFCA depends on knowing the anatomy of the pulmonary veins and left atrium before the procedure. Today, multidetector computed tomographic (MDCT) angiography is the most preferred method for revealing the pulmonary vein anatomy before RFCA in detail and creating two- and three-dimensional images that will serve as a guide during the procedure. In recent years, various studies have been conducted to question the relationship between pulmonary vein anatomy and the development of AF, based on the basic mechanism in the pathophysiology of AF. Some authors indicated a possible role of anomalies in the number and insertion of pulmonary veins in initiating AF. It has been shown also well that changes in anatomy of pulmonary veins such as enlargement, may have an effect on arrhythmogenesis [8-14].

In this study; it was aimed to compare the pulmonary vein anatomy of patients with and without AF using 64-slice MDCT and to evaluate the relationship between the presence of pulmonary vein variations and the development of AF.

METHODS

Patient Population

Seventy cases (38 males, 32 females) aged between 23 and 75 (mean age: 49.9 ± 13.3) were included in this study. The study group consisted of 20 consecutive patients (mean age: 44.5 ± 12.5 years [range, 26-68 years]; 11 males, 9 females) who were diagnosed with AF and planned for RFCA treatment [AF(+) group], MDCT angiography examination was performed for the evaluation of pulmonary vein anatomy and variations. MDCT images of the control group [AF(-) group] consisting of 50 cases (mean age: 46.4 ± 11.7 years [range, 22-71 years]; 27 males, 23 females) who had no history of AF and underwent cardiac MDCT angiography examination with another preliminary diagnosis were retrospectively analyzed. There were no statistically significant differences between the study group and the control group in regard to age, sex, presence of hypertension or left ventricular systolic dysfunction. Patients with clinically important valvular disease, coronary artery bypass grafts and severe left ventricular dysfunction were not included to the study.

Informed consent was obtained from all patients and the study was approved by the local Ethics Committee of our hospital. (2010/247).

MDCT Scanning Protocol

A 64-detector CT scanner (Aquilion; Toshiba Medical Systems; Tokyo, Japan) and the same protocol were used for the examination of all patients. While patients were laid down in the supine position electrocardiography (ECG) electrodes were attached and they were monitorized. Firstly, antero-posterior and lateral scanogram images were obtained in order to determine the position of the heart and the borders of the examination area. Images were obtained during a single breath hold from the top of the diaphragm to the top of the aortic arch. An 80-100 ml iodinated contrast agent (Iomeron, Iomeprol 400 mgI/ml, Bracco, Italy veya Iopromid, Ultravist 370 mgI/ml, Schering AG, Germany) was given at a flow rate of 4-5 ml/sec through an 18-20 G cannula that was placed inside the right antecubital vein, and then 40 ml saline was given at the same rate. Optimal scan time was determined by using the automatic bolus tracking method (Sure Start, Toshiba Medical System). The region of interest (ROI) was placed over the left atrium in study group and over the descending aorta in control group, and an adjustment was carried out so that scanning would start automatically when maximum contrasting reached 180 HU. Scanning parameters were as follows: collimation 64×0.5 mm, tube voltage: 120 kV, tube current: 300-500 mA, tube rotation time: 400 ms, slice thickness: 0.5 mm, increment 0.3 mm.

MDCT Image Analysis

A retrospective ECG-gated technique was used for the reconstruction of images. The raw data obtained from the coronary CTA examination were reconstructed at the 75% phase (mid-diastolic phase) of R-R interval by using 0.5 mm slice thickness and 0.3 mm increment. Two- and three-dimensional images were rendered by using multiplanar reformat (MPR), maximum intensity projection (MIP), and volume rendering (VR) methods by transferring the obtained axial images to a separate workstation (Vitrea 2, Vital Images, Minnesota, USA). Scans were analyzed by consensus of two observers unaware of the clinical data.

Assessment of the pulmonary veins was first conducted by examining the anatomy of the pulmonary veins and their insertion into the left atrium on three-dimensional VR images. After, two-dimensional MPR images in three different orthogonal planes (transverse, coronal and, sagittal) were evaluated to determine the number of pulmonary veins, the number of ostia and branching pattern of the pulmonary veins. Normal pulmonary venous anatomy was defined as the presence of single right and left superior and inferior pulmonary veins that drain into the left atrium without a common ostium or any accessory pulmonary veins. The ostial insertion of the pulmonary veins was defined as either separate insertion or common ostium. Pulmonary veins that either entered this virtual border of the left atrium separately or bifurcated within a distance of less than 5 mm from the border were defined as having separate ostia. If the distance between the virtual border of the left atrium and and the bifurcation of both pulmonary veins was 5 mm or larger on transverse and coronal planes, the ostium was defined as a common ostium. Accessory pulmonary vein was defined as a additional pulmonary vein entered the left atrium with a separate ostium from the superior and inferior pulmonary veins. Early Branching was defined as bifurcation of the pulmonary vein within 10 mm of origin from the virtual border of the left atrium. Measurements of pulmonary vein diameters were made at the level of the ostium. The diameter of the ostium of each pulmonary vein was measured in antero-posterior (AP) and supero-inferior (SI) directions. MPR images were used to obtain images in planes that were perpendicular to the course of the veins to allow measurements in two orthogonal directions. To determine the shape of the pulmonary vein ostia the venous ostium index (VOI) was calculated for all pulmonary veins by dividing AP measurements by SI measurements. By comparing the data obtained, it was investigated whether there was a statistically significant difference between the two groups in terms of the presence of pulmonary vein variations, pulmonary vein diameters and VOI.

Statistical Analysis

Statistical analyses were performed using the SPSS 15.0 software pack (SPSS Inc., Chicago, Ill, USA). Continuous variables are expressed as means ± standard deviation (SD) and dichotomous data are expressed as numbers and percentages. Paired Student t-test was used to compare continuous variables between AF(+) and AF(-) groups. Comparisons of categorical variables between the two groups were performed by Chi-square test. Values of $p < 0.05$ were considered significant.

RESULTS

Normal pulmonary vein anatomy was observed in 30% (n = 6) of the study group, 60% (n = 30) of the control group, and 51.4% (n = 36) of the total of both groups. In the evaluation made considering the sum of both groups (n = 70); variation in pulmonary vein anatomy (accessory pulmonary vein or common os-

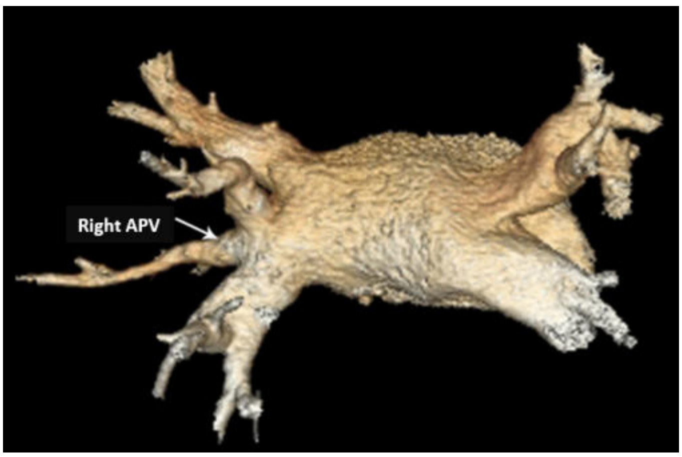

Fig. 1. **Three-dimensional MDCT angiography image of a 50-year-old female patient with atrial fibrillation shows an accessory pulmonary vein (APV) on the right.**

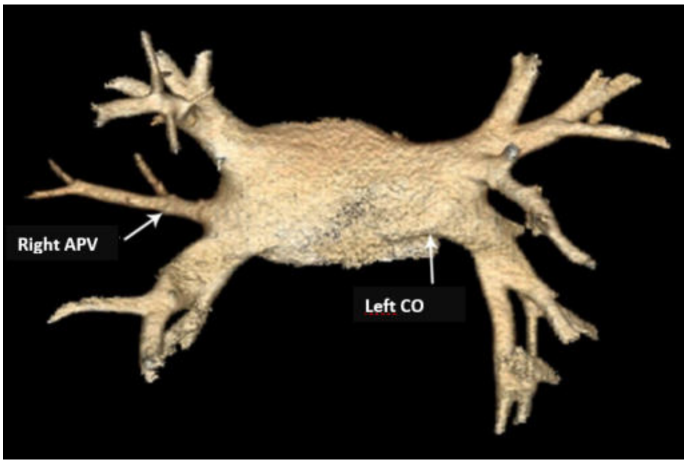

Fig. 2. **Three-dimensional MDCT angiography image of a 30-year-old male patient with atrial fibrillation shows the accessory pulmonary vein (APV) on the right and the common ostium (CO) on the left.**

tium) was detected in 48.6% (n = 34/70) of the cases (Figs. 1 and 2).

The rate of variation was 70% in the AF(+) group and 40% in the AF(-) group. The most common variation was the presence of accessory pulmonary vein (35.7%). Accessory pulmonary vein was present in 8 (40%) of AF(+) cases and 17 (34%) of AF(-) cases. Although the rate of accessory pulmonary vein was higher in the AF(+) group, the difference between the two groups was not significant in the statistical evaluation (p = 0.844). Common ostium was found to be the second most common variation (12.8%) (Figs. 2 and 3). Common ostium was present in 6 (30%) of AF(+) cases and 3 (6%) of AF(-) cases. All common ostia were localized on the left side. When the AF(+) group and the AF(-) group were compared in terms of having common ostium, the difference between the two groups was found to be statistically significant (p = 0.021). Early branching of pulmonary veins was detected in 41 (58.5%) of 70 cases (Fig. 4).

The right pulmonary veins in 28 (40%) cases, the left in 8 (11.4%) cases, and bilateral pulmonary veins in 5 (7.1%) cases gave early branches. Early branching was mainly (68.2%) localized on the right side. Right early branching was present in 10 (50%) AF(+) cases and 18 (36%) AF(-) cases. Although the rate of right early branching was higher in the AF(+) group, the difference between the two groups was not significant in the statistical evaluation (p = 0.265). It was determined that 85% of the right-sided localized early branches originate from the inferior pulmonary vein and 15% from the superior pulmonary vein, while all of the left-sided early branches originate from the inferior pulmonary vein. Comparison of two groups in terms of the presence of accessory pulmonary vein, common ostium and early branching is seen in (Table 1).

When the sum of both groups (n = 70) was evaluated, the mean AP diameters were 15.7 ± 2.4 mm for the right superior pulmonary vein (RSPV); 15.3 ± 2.4 mm for right inferior pulmonary vein (RIPV); 14.4 ± 2.5 mm for left superior pulmonary vein (LSPV); for the left inferior pulmonary vein (LIPV), it was found to be 13.0 ± 2.2 mm. SI diameter mean was 17.4 ± 2.5 mm for RSPV; 16.7 ± 2.7 mm for RIPV; 17.5 ± 2.6 mm for LSPV; it was found to be 16.4 ± 2.5 mm for LIPV. According to these findings, in general, the

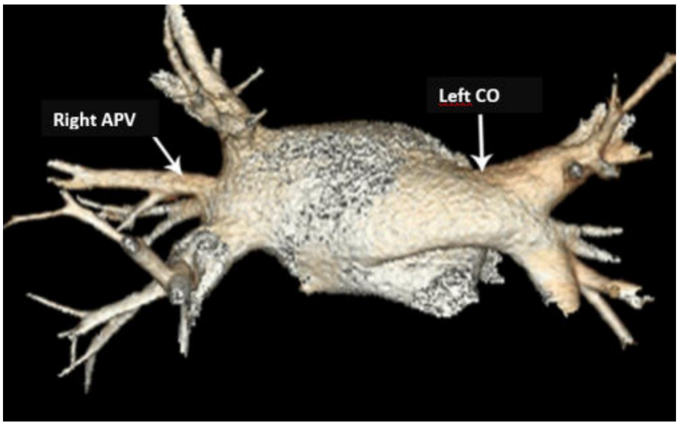

Fig. 3. **Three-dimensional MDCT angiography images (a, b) of a 59-year-old male patient with atrial fibrillation showing the accessory pulmonary vein (APV) on the right and the common ostium (CO) on the left.**

Fig. 4. **TEarly branching (EB) on both sides and common ostium (CO) on the left in three-dimensional MDCT angiography image of a 50-year-old male patient with atrial fibrillation. (APV) on the right and the common ostium (CO) on the left.**

Table 1. Comparison of AF (+) group and AF (-) group in terms of APV, CO and EB variant

	AF(+)	AF (-)	*p* value
Right APV, n (%)	8 (40)	17 (34)	0.844
Left CO, n (%)	**6 (30)**	**3 (6)**	**0.021**
Right EB, n (%)	10 (50)	18 (36)	0.265
Right + left EB, n (%)	**2 (50)**	**2 (50)**	

APV = accessory pulmonary vein, CO = common ostium, EB = early branching

mean diameter of the superior pulmonary veins was larger than the mean diameter of the inferior pulmonary veins, and the mean diameters of the right pulmonary veins were larger than the mean diameters of the left pulmonary veins. When AF(+) and AF(-) group pulmonary veins were compared in terms of AP diameters; there was no significant difference between the two groups in terms of AP diameters of RSPV, RIPV, LSPV and LIPV (p = 0.672, p = 0.136, p = 0.820 and p = 0.782, respectively). In the comparison

Table 2. Comparison of antero-posterior (AP) and supero-inferior (SI) diameters and venous ostium index (VOI) of pulmonary veins (PV) in AF(+) and AF(-) patients

x	Number	Mean	SD
Age (years)	70	50.0	13.3
SI-RSPV (mm)	70	17.4	2.5
SI-RIPV (mm)	70	16.7	2.7
SI-LSPV (mm)	61	17.5	2.6
SI-LIPV (mm)	61	16.4	2.5
AP-RSPV (mm)	70	15.7	2.4
AP-RIPV (mm)	70	15.3	2.4
AP-LSPV (mm)	61	14.4	2.5
AP-LIPV (mm)	61	13.0	2.3
VOI-RSPV	70	0.9	0.1
VOI-RIPV	70	0.9	0.2
VOI-LSPV	61	0.8	0.2
VOI-LIPV	61	0.8	0.1

PV = pulmonary vein, RSPV = right superior pulmonary vein, RIPV = right inferior pulmonary vein, LSPV = left superior pulmonary vein, LIPV = left inferior pulmonary vein, VOI = venous ostium index, SD = standard deviation

made in terms of SI diameters of pulmonary veins, no significant difference was found between the two groups in terms of SI diameters of RSPV, LSPV and LIPV (p = 0.220, p = 0.953 and p = 0.627, respectively), while SI diameters of RIPV were found in the AF(+) group was found to be significantly higher than the AF(-) group (p = 0.016) (Table 2).

When the AF(+) and AF(-) groups were compared in terms of the VOI value obtained by dividing the AP diameter measurements by the SI diameter measurements; the VOI value of RIPV was lower in the AF(+) group than in the AF(-) group, and the difference was statistically significant ($p < 0.001$). However, the difference between the two groups in terms of VOI values of RSPV, LSPV and LIPV was not statistically significant (p = 0.078, p = 0.931 and p =0.739, respectively) (Table 2).

DISCUSSION

Today, it is known that the main localizations of ectopic foci, which are the triggers of most paroxysmal AF, are the ostia of the pulmonary veins. The answer to why ectopic foci that give rise to AF are located in the ostia, which is the opening of the pulmonary veins into the left atrium, is hidden in the embryological development stages. At the beginning of embryological development, the pulmonary vein confluences are covered by the atrial wall [13].

In the later stages of embryological development, the atrial wall is covered by myocardial tissue. In this phase, which is called musculization or atrialization, the pulmonary vein ostia are surrounded by myocardial tissue like a shirt. Therefore, the localizations where ectopic foci arise are localizations where myocardial tissue remnants from past stages of embryological development are present. Since this myocardial tissue around the ostia of the superior pulmonary veins covers a larger area compared to the myocardial tissue around the ostia of the inferior pulmonary veins, especially the superior pulmonary veins have an important place in the pathogenesis of AF [14-18].

Normally, there are two superior pulmonary veins, one on the right and one on the left, and two inferior pulmonary veins, one on the right and one on the left. The right superior pulmonary vein drains the superior and middle lobes of the right lung, while the left superior pulmonary vein drains the superior lobe of the left lung, including the lingula. Inferior pulmonary veins on both sides drain the lower lobe on their side [19, 20]. In our study, 51.4% of the total of AF(+) and AF(-) groups; when the groups were considered separately, we observed one superior pulmonary vein with separate ostiums on the right and left and one inferior pulmonary vein with separate ostiums at a rate of 30% in the AF(+) group and 60% in the AF(-) group.

When compared to pulmonary artery anatomy, variations in pulmonary vein anatomy and developmental anomalies are observed more frequently. One of the main variations that we may encounter regarding pulmonary veins is the presence of an accessory pulmonary vein. When the veins draining the right lung middle lobe, left lung lingula or smaller segments open into the left atrium with a separate ostium instead of opening into the superior or inferior pulmonary vein, this vein is called the accessory pulmonary vein. In the literature, the most common variation was reported to be accessory pulmonary vein in some studies, while the presence of common ostium was reported more frequently in some studies.has been reported [21-23].

In patients with AF, the incidence of right accessory pulmonary vein was reported as 16% by Scharf *et al*. [24], 18.6% by Tsao *et al*. [25], 23% by Mclellan *et al*. [26], and 26% by Marom *et al*. [21]. In a study of 51 patients with AF, the incidence of right accessory pulmonary vein was found to be 7.8%, while the incidence of left accessory pulmonary vein was found to be 3.9% by Skowerska *et al*. [8]. The researchers did not find the presence of accessory pulmonary veins in any of the control group cases without AF. In our study, we found the presence of accessory pulmonary vein as the most common (35%) variation. This ratio was determined by Altinkaynak and Koktener [27]. It was found to be 20.4% in their study. While we detected the presence of right accessory pulmonary vein in 40% of the AF(+) group and 34% of the AF(-) group, we did not find the presence of left accessory pulmonary vein in any of the cases. In a study by Koçyiğit *et al*. [23], accessory veins were observed only on the right. The rate we found for the incidence of right accessory pulmonary vein is well above the rates reported in the literature (7.8-26%). When we compared the AF(+) and AF(-) groups in terms of the frequency of accessory pulmonary veins, we found a higher incidence of accessory pulmonary veins in the AF(+) group, but we did not find a significant difference between the two groups as a result of the statistical evaluation ($p = 0.844$).

A variation encountered in pulmonary vein anatomy is the common ostium. The common ostium, which is defined as the fusion of the superior and inferior pulmonary veins on one side and opening into the left atrium with a single ostium, is usually seen on the left side. The presence of right common ostium is a very rare condition and we did not find a right-sided common ostium in our study. In our study, we found the left common ostium to be the second most common (12.8%) variation. Left common ostium was present in 30% of AF(+) cases and 6% of AF(-) cases and we found that common ostium was significantly more common in the AF(+) group, consistent with previous studies ($p = 0.021$).). Similarly, the presence of the left common ostium was found 27.4% in AF(+) cases and 12.9% in AF(-) cases by Skowerski *et al*. [8]. In the study of Jongbloded *et al*. [28], involving 23 AF(+), 11 AF(-) cases, left common ostium incidence was found 83% in AF(+) cases, 55% in AF(-) cases. In Thai society, Wannasopha *et al*. [22] revealed that the rate of single ostium on the left (59%) is higher than the rate of single ostium. The most common variation was the left common vein, while the rate was 32.2% in the study by Altinkaynak and Koktener [27], this rate was found to be 35.6% in the study by Koçyiğit *et al*. [23].

Another variation that can be seen in pulmonary veins is early branching. Early branching is defined as bifurcation of the pulmonary vein within 10 mm of origin from the left atrium. In our study, we found early branching pattern most frequently (68.2%) in the right inferior pulmonary vein. We also detected early branching in the right superior pulmonary veins and left inferior pulmonary veins, at lower rates compared to the right inferior pulmonary veins. In some studies, it has been suggested that early branching of the left superior pulmonary vein is similar to the left inferior pulmonary vein in terms of its incidence. However, we did not find any early branch in the left superior pulmonary vein in our study.

While discussing the relationship between pulmonary vein variations and AF, one of the issues that was especially emphasized was the ostial diameter measurements of the pulmonary veins. In our study, we found the diameters of the right pulmonary veins to be larger than the diameters of the left pulmonary veins and the diameters of the superior pulmonary veins to the diameters of the inferior pulmonary veins, according to the AP and SI diameter measurements measured from MPR images. Koçyiğit *et al*. [23] also found similar findings in their study. This situation is associated with myocardial sheath covering a wider and denser area especially in the superior vein ostia during the gestational development stages. As a result, the place and importance of the superior pulmonary veins in the development of AF is particularly emphasized. Skorewski *et al*. [8] found the diameters of the left atrium and pulmonary vein to be larger (larger) in the AF(+) group than in the AF(-) group.

The structural remodeling of the left atrium and pulmonary veins in patients with AF may be an explanation of these changes. While it is well known that the diameter of the left atrium increases with long-standing AF, less information is available if is there a correlation between such morphological changes and the degree of left atrium and pulmonary vein enlargement. In our study, although we found the SI diameters of the pulmonary veins to be higher in the AF(+) group, we found that the difference between the two groups was not statistically significant for veins other than RIPV. There are other studies that support larger SI diameters. [23, 29]

Another concept discussed in the literature in the context of pulmonary vein AF relationship is VOI. The VOI used to evaluate the shape of the pulmonary vein ostium is the ratio of the AP diameter of the pulmonary vein to the SI diameter (VOI=AP\SI). When we evaluate the sum of both groups together; We found that the VOI values of the left pulmonary vein were smaller than those of the right pulmonary veins. Based on this result, we can say that left pulmonary vein ostia tend to be more oval shaped than right pulmonary vein ostia. Similarly, Jongbloed *et al*. [28] and Skorewski *et al*. [8]. It was also reported in the studies performed by the left pulmonary vein that the ostia of the left pulmonary vein are more oval shaped than the ostiums of the right pulmonary veins. It has been determined that the ostia on the right side are more rounded in a study by by Koçyiğit *et al*. [23]. When we compare the AF(+) and AF(-) groups in terms of VOI value; while we found the VOI value of RIPV to be significantly lower in the AF(+) group compared to the AF(-) group, we found that there was no significant difference between the two groups in terms of the VOI values of RSPV, LSPV and LIPV.

Although AF is such a frequently encountered arrhythmia, the desired level of success in the medical treatment of AF has not yet been achieved and various complications caused by drug therapy have led to a series of discussions about AF treatment. Today, endovascular RFCA of the arrhythmia focus located in the transition region of the pulmonary vein ostia is accepted as one of the effective methods in the treatment of treatment-resistant AF cases. The success rate of RFCA is closely related to knowing the anatomy of the left atrium and pulmonary veins in detail before the procedure.

Conventional catheter angiography, echocardiography, MDCT, and magnetic resonance imaging (MRI) are among the main methods that can evaluate this complicated pulmonary vein anatomy. Although conventional pulmonary vein angiography is considered a standard technique for evaluating pulmonary veins, it has some disadvantages such as being an invasive method and difficult measurement due to projection errors. Echocardiography, on the other hand, is not an appropriate method to evaluate the atriovenous junction. In addition, the evaluation of the proximal parts of the pulmonary veins by echocardiography is also insufficient.

MRI and MDCT are the most appropriate methods for evaluating the relationship between the left atrium and pulmonary veins, as well as for the morphological and dimensional evaluation of pulmonary veins, with reconstructed three-dimensional images. These two methods stand out as more preferable methods compared to other methods in that they allow the acquisition of images that can be considered as a "road map" before ablation We analyzed the pulmonary vein anatomy of the patients who will undergo RFKA with MDCT before the procedure, from both axial images and MPR and three-dimensional volume rendering images.

As a result of our study; We found that a very high rate (48.6%) of variation (accessory pulmonary vein or common ostium) was seen in pulmonary vein anatomy. The rate of variation was higher in the AF(+)

group than in the AF(-) group (70%, 40%, respectively). The most common variations are; presence of common ostium on the left, accessory pulmonary vein on the right. The incidence of premature branching in the pulmonary veins was higher in the AF(+) group than in the AF(-) group (75%, 52%, respectively). When we compare the AF(+) and AF(-) groups in terms of the ostial diameters of the pulmonary veins; While we found the SI diameter of RIPV to be higher in the AF(+) group, we found that there was no significant difference between the two groups in terms of other diameters.

Limitations

Since the study was conducted with a small number of cases, more studies are needed on this subject.

CONCLUSION

In conclusion, there is a greater variability in the pulmonary vein anatomy and detailed knowledge of the pulmonary vein anatomy and variations is required to maximise the safety and efficacy of RFCA procedure. MDCT angiography enables a valuable road map for pulmonary vein anatomy prior to RFCA in patients with AF. The number, location, and size of pulmonary veins and pulmonary vein branching anomalies are easily and accurately depicted with MDCT angiography. Accesory pulmonary vein, common ostium and early branching are more frequently present in patients with AF.

Authors' Contribution

Study Conception: PÖA, AT; Study Design: PÖA, AT; Supervision: PÖA, AT; Funding: PÖA; Materials: PÖA; Data Collection and/or Processing: PÖA; Statistical Analysis and/or Data Interpretation: PÖA, AT; Literature Review: PÖA; Manuscript Preparation: PÖA and Critical Review: AT.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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