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ANALYZING PULMONARY VENOUS DRAINAGE PATTERNS TO THE LEFT ATRIUM AND DETERMINING THE PREVALENCE OF EACH VARIATION IN PULMONARY VENOUS ARCHITECTURE ON CT

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ABSTRACT

Background: ectopic atrial electric activity, especially in patients with atrial fibrillation, is mostly caused by drainage sites in the pulmonary veins. Anatomical variations in the pulmonary veins are frequently observed. Especially when it comes to the preoperative planning of heart and lung operations, these differences might be crucial.

Aim: Assessing the patterns of pulmonary venous drainage to the left atrium and the frequency of each variant in pulmonary venous architecture on CT was the goal of the current investigation.

Methods: The structural characteristics of the pulmonary vein and its drainage pattern into the left atrium were evaluated in this study using 600 thoracic multidetector CT (computed tomography) images that were evaluated retrospectively. For each pattern, a percentage was calculated, and results were formulated.

Results: The study results showed that among 600 subjects assessed, 266 females and 326 males in the study showed variation in the anatomy. In the right pulmonary vein, the most common drainage pattern seen was ostia in 77.33% of subjects followed by 19% of subjects that showed 3 to 4 ostia, and 3.67% showed a single ostium. On the left side, three patterns were seen where 63.33% showed a single venous ostium which was more common than 2 ostia in 35.67% of subjects. Three ostia were reported in 1% (n=6) of subjects. In both left and right pulmonary veins, 12 subjects had single pulmonary venous ostium bilaterally.

Conclusion: The present study concludes that the variations seen in pulmonary venous anatomy are not uncommon. However, these are frequently asymptomatic, knowledge of these variations is vital when planning for pulmonary venous isolation and for cardiothoracic surgery planning.

Keywords: Computed tomography, pulmonary veins, pulmonary drainage, variations, anatomical variations.

Introduction

In the human body, the vascular system depicts a plethora of various patterns in different individuals which is considered as the normal anatomical variation of the human body. However, the function of the pulmonary vein as a medium for the carrying of the oxygenated blood is clear, pulmonary veins also carry a special and vital role for the radiologists concerning their physiological and anatomical functions.[1]

The drainage site of the pulmonary veins is a vital source of ectopic atrial electrical activity, that usually and commonly initiates paroxysms of the atrial fibrillation. There has been an increase as reported for selective radiofrequency ablation of these arrhythmogenic foci to manage and treat the subjects with refractory atrial fibrillation. These invasive procedures are largely dependent on the precision in mapping the atrial anatomy of the human body.[2]

Variations in the anatomy of the pulmonary vein and the presence of variants and in cases of anomalous anatomy can be of vital importance, particularly in preoperative planning of cardiac and pulmonary surgery. It is also vital to know cardiac and pulmonary vasculature which forms an important part of the thoracic interventions, not only for diagnostic reasons, but, also for prevention and prediction of different life-threatening complications which might arise.[3] The present study aimed to assess the patterns of pulmonary venous drainage to the left atrium and to assess the frequency of each variant in pulmonary venous anatomy on CT (computed tomography).

MATERIALS AND METHODS

The present observational assessment study was aimed to assess the patterns of pulmonary venous drainage to the left atrium and to assess the frequency of each variant in pulmonary venous anatomy on CT (computed tomography). Verbal and written informed consent were taken from all the subjects before study participation.

The study retrospectively assessed 600 subjects from both genders which were assessed using thoracic multidetector computed tomography within the defined study period. In all the included subjects anatomical features of the pulmonary vein and associated drainage patterns to the left atrium were assessed. Also, the percentage of each combination and pattern were calculated and assessed.

The inclusion criteria for the study were all the scans from thoracic computed tomography of subjects aged more than 15 years. Subjects, where images depicted distortion in the anatomy of either lung parenchyma or pulmonary veins due to lung or mediastinal pathologies or where poor enhancement of the pulmonary vein was seen, were excluded from the study.

All the included CT (computed tomography) assessments were done on a single machine using 160 slices of CT with subjects being placed in the supine position and after holding a deep breath. For each case, data were taken using one of these scans CT coronary angiogram, CT aortogram, CT pulmonary angiography, and Contrast-enhanced conventional CT chest. The scans were taken as0.9 mm thickness. Soft copy DICOM images were retrieved from the Institutional software data.

The classification of pulmonary vein followed in the present study was from the classification by Marom et al in 2004 and Shah A et al in 2022[4] where drainage orifices were divided into six patterns on the right side and 2 patterns on the left side.[5]

The data gathered were analyzed statistically using SPSS (Statistical Package for the Social Sciences) software version 24.0 (IBM Corp., Armonk. NY, USA) for assessment of descriptive measures, Student t-test, ANOVA (analysis of variance), and Chi-square test. The results were expressed as mean and standard deviation and frequency and percentages. The p-value of <0.05 was considered statistically significant.

RESULTS

The present observational assessment study was aimed to assess the patterns of pulmonary venous drainage to the left atrium and to assess the frequency of each variant in pulmonary venous anatomy on CT (computed tomography). The present study assessed 600 thoracic multidetector CT (computed tomography) that were assessed retrospectively to assess the anatomical features in the pulmonary vein and its drainage pattern into the left atrium. In each pattern, a percentage was calculated and results were formulated. On the scans assessed, there were 266 females and 326 male scans in the age range of 15-94 years and the mean age in the study subjects was 45.2±3.8 years.

It was seen that for the drainage patterns in the left pulmonary veins in the study subjects, it was seen the drainage pattern of L1a was seen in 33.67% (n=202) of study subjects which was seen in the majority of the subjects followed by L1b in 29.67% (n=178) study subjects, L2a in 19% (n=114) study subjects, L2b in 16.67% (n=100) study subjects, and least has L3 seen in 1% (n=6) study subjects respectively (Table 1).

The study results showed that for Drainage patterns in right pulmonary veins, R1 was seen in 3.67% (n=22) subjects, most common was R2a in 37% (n=222) subjects followed by R2b in 36.33% (n=218) study subjects, R3a in 11.67% (n=70) subjects, R2c in 4% (n=24) study subjects, R3b in 3.67% (n=22), R3d and R4b was seen in 1.67% (n=10) study subjects, R3c in 0.33% (n=2) study subjects, and R4a and R5 was not seen in any study subject (Table 2).

It was seen that concerning combined patterns of pulmonary venous drainage in study subjects, R1 was seen in 4, 8, 6, 4, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2a in 64, 74, 30, 52, and 2 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2b was seen in 80, 58, 50, 26, and 4 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2c was seen in 8, 6, 4, 6, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3a was seen in 30, 12, 18, 10, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3b was seen in 10, 6, 4, 2, and 0 subjects from subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3c in 0, 0, 2, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3d was seen in 4, 6, 0, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R4a in no subject, R4b in 2, 8, 0, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, and R5 in no subjects. In total, L1a, L1b, L2a, L2b, and L3 respectively were seen in 202, 178, 114, 100, and 6 subjects respectively (Table 3).

DISCUSSION

The present study assessed 600 thoracic multidetector CT (computed tomography) that were assessed retrospectively to assess the anatomical features in the pulmonary vein and its drainage pattern into the left atrium. In each pattern, a percentage was calculated and results were formulated. On the scans assessed, there were 266 females and 326 male scans in the age range of 15-94 years and the mean age in the study subjects was 45.2±3.8 years. These data were comparable to the previous studies of Tekbas G et al[6] in 2012 and Jongbloed MR et al[7] in 2005 where authors assessed subjects for pulmonary venous drainage variations having demographics comparable to the present study in their respective studies.

The study results showed that for the drainage patterns in the left pulmonary veins in the study subjects, it was seen the drainage pattern of L1a was seen in 33.67% (n=202) of study subjects which was seen in majority of the subjects followed by L1b in 29.67% (n=178) study subjects, L2a in 19% (n=114) study subjects, L2b in 16.67% (n=100) study subjects, and least was L3 seen in 1% (n=6) study subjects

respectively. These results were consistent with the findings of Jongbloed MR et al[8] in 2005 and Jongbloed MR et al[9] in 2005 where the drainage patterns in the left pulmonary veins reported by the authors in their studies were similar to the results of the present study.

It was seen that for Drainage patterns in right pulmonary veins, R1 was seen in 3.67% (n=22) subjects, most common was R2a in 37% (n=222) subjects followed by R2b in 36.33% (n=218) study subjects, R3a in 11.67% (n=70) subjects, R2c in 4% (n=24) study subjects, R3b in 3.67% (n=22), R3d and R4b was seen in 1.67% (n=10) study subjects, R3c in 0.33% (n=2) study subjects, and R4a and R5 was not seen in any study subject. These findings were in agreement with the results of Akiba T et al[10] in 2010 and Sizarov A et al[11] in 2011 where drainage patterns in right pulmonary veins similar to the present study were also reported by the authors in their respective studies.

The study results also showed that concerning combined patterns of pulmonary venous drainage in study subjects, R1 was seen in 4, 8, 6, 4, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2a in 64, 74, 30, 52, and 2 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2b was seen in 80, 58, 50, 26, and 4 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R2c was seen in 8, 6, 4, 6, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3a was seen in 30, 12, 18, 10, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3b was seen in 10, 6, 4, 2, and 0 subjects from subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3c in 0, 0, 2, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R3d was seen in 4, 6, 0, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, R4a in no subject, R4b in 2, 8, 0, 0, and 0 subjects from L1a, L1b, L2a, L2b, and L3 respectively, and R5 in no subjects. In total, L1a, L1b, L2a, L2b, and L3 respectively were seen in 202, 178, 114, 100, and 6 subjects respectively. These results were in line with the studies of van den Berg G. et al[12] in 2011 and Niinuma H et al[13] in 2008 where concerning combined patterns of pulmonary venous drainage the results reported by the authors were consistent with the results of the present study.

CONCLUSIONS

The present study, considering its limitations, concludes that the variations seen in pulmonary venous anatomy are not uncommon. However, these are frequently asymptomatic, knowledge of these variations is vital when planning for pulmonary venous isolation and cardiothoracic surgeries planning. However, future studies are warranted to assess subjects from different geographical backgrounds and a multi-institutional setup is needed to conclude.

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Drainage pattern	**DESCRIPTION**	**Number (n)**	**Percentage (%)**
L1a	**Upper and lower lobe vein from common trunk <1cm long draining into left atrium (one ostium)**	202	33.67
L1b	**Upper and lower lobe vein from common trunk >1cm long draining into left atrium (one ostium)**	178	29.67
L2a	**The upper and lower lob vein drains to two separate atrial ostia separated by the left atrial wall**	114	19
L2b	**Upper and lower lob vein drains atrial ostia not separated by left atrial wall**	100	16.67

L3	**Three atrial ostia from the lingular segment, lower lobe, and upper lobe**	6	1
Total		600	100

Table 1: Drainage patterns in left pulmonary veins

Drainage pattern	Description	Number (n)	Percentage (%)
R1	**Lower, middle, and upper lobe veins draining to the single common ostium**	22	3.67
R2a	**Upper and lower lobe draining to 2 different ostia and middle joining proximal upper lobe vein <1cm from the ostium**	222	37
R2b	**Upper and lower lobe draining to 2 different ostia and middle joining proximal upper lobe vein <1cm from the ostium**	218	36.33
R2c	**Upper and lower lobe draining to 2 different ostia and middle joining lower lobe vein**	24	4
R3a	**Lower, middle, and upper lobe veins draining to 3 separate ostia**	70	11.67
R3b	**Lower, middle, and upper lobe veins draining to 3 separate ostia with middle lobe vein joining proximal upper lobe vein <1cm from the ostium**	22	3.67
R3c	**Lower, middle, and upper lobe veins drain to 3 separate ostia with the middle lobe vein joining the proximal upper lobe vein >1cm from the ostium**	2	0.33
R3d	**3 atrial ostia for Lower, middle, and upper lobe veins with upper lobe vein accompanied with medial segment of middle lobe vein making common channel**	10	1.67
R4a	**One upper, 1 lower, and 2 middle veins draining to 4 separate ostia**	0	0
R4b	**Superior, middle, and upper segments with lower lobe vein drain to 4 separate ostia**	10	1.67
R5	**One upper, 2 lower, and 2 middle segments with lower lobe vein drain to 5 separate ostia**	0	0
Total		600	100

Table 2: Drainage patterns in right pulmonary veins

S. No		L1a	L1b	L2a	L2b	L3	Total
1.	**R1**	4	8	6	4	0	22
2.	**R2a**	64	74	30	52	2	222
3.	**R2b**	80	58	50	26	4	218
4.	**R2c**	8	6	4	6	0	24
5.	**R3a**	30	12	18	10	0	70
6.	**R3b**	10	6	4	2	0	22
7.	**R3c**	0	0	2	0	0	2
8.	**R3d**	4	6	0	0	0	10

9.	**R4a**	0	0	0	0	0	0
10.	**R4b**	2	8	0	0	0	10
11.	**R5**	0	0	0	0	0	0
12.	**Total**	202	178	114	100	6	600

Table 3: Combined patterns of pulmonary venous drainage in study subjects