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Anatomical Variations of Pulmonary Venous Drainage among Indian Population

Research Article

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Abstract

Background: The drainage sites of the pulmonary veins are an important source of ectopic atrial electrical activity, especially in patients with atrial fibrillation. Variations in the pulmonary venous anatomy are frequent. Differences in pulmonary vein anatomy and the presence of variant or anomalous anatomy can be of critical importance, especially for preoperative planning of pulmonary and cardiac surgery.

Objective: To assess the patterns of pulmonary venous drainage into the left atrium and to determine the frequency of each variant of pulmonary venous anatomy.

Materials and methods: 300 studies of thoracic multidetector computed tomography were retrospectively reviewed for the anatomical features of the pulmonary vein and its drainage pattern into the left atrium. The percentage of each pattern was calculated.

Results: The anatomy of pulmonary venous drainage in 300 patients (163 male and 133 female, mean age 45 years) showed some variation. In the right pulmonary vein, the most common drainage pattern was two ostia (77.33%), followed by three to four ostia (19%) and a single ostium (3.67%). On the left side, there were three patterns; a single venous ostium (63.33%) was much more common than two ostia (35.67%). Three ostia were seen in 3 cases (1%). In both right and left pulmonary veins, there were six cases that had a single pulmonary venous ostium, bilaterally.

Conclusion: Variations in PV anatomy are not uncommon. Although frequently asymptomatic, knowledge of these variations is important in while planning cardiothoracic surgeries and PV isolation..

Keywords: CT; Pulmonary veins; Variations

Introduction

The vascular system of the human body shows a plethora of different patterns in every individual. This is known as normal variation. Although the function of the pulmonary veins as a conduit for oxygenated blood is clear, they carry special importance for radiologists with regard to their anatomy and physiologic function. The pulmonary venous drainage site is an important source of ectopic atrial electrical activity, frequently initiating paroxysms of atrial fibrillation [1]. Increasingly, selective radiofrequency ablation of these arrhythmogenic foci is performed to treat patients with refractory atrial fibrillation. The invasive procedures very heavily depend upon the precision of mapping atrial anatomy [2]. Differences in pulmonary vein anatomy and the presence of variant or anomalous anatomy can be of critical importance, especially for preoperative planning of pulmonary and cardiac surgery. Knowledge of pulmonary and cardiac vasculature forms a vital part of thoracic interventions, not only for diagnostic purposes but also to predict and prevent perhaps life threatening complications.

Objective

To assess the patterns of pulmonary venous drainage into the left atrium and to determine the frequency of each variant of pulmonary venous anatomy.

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Materials & Methods

Study population

Following institutional ethics committee approval, 300 studies of thoracic multidetector computed tomography in between May 2021 to August 2021 performed for various indications were retrospectively reviewed. Anatomical features of the pulmonary vein and its drainage pattern into the left atrium was observed. The percentage of each pattern and combination of patterns was calculated.

Inclusion and Exclusion criteria

All thoracic computed tomography scans of patients above the age of 15 were included. Cases in which images showed poor pulmonary vein enhancement, distorted anatomy of either the pulmonary veins or lung parenchyma by mediastinal or lung pathologies were excluded.

CT data set

All CT examinations were obtained by Philips Brilliance 64 slice CT or Toshiba Aquilon Prime 160 slice CT with patient in the supine position and holding a deep breath. The data for each case was taken by one of the four major scans: 1) Contrast-enhanced conventional CT chest, 2) CT pulmonary angiography, 3) CT aortogram and 4) CT coronary angiogram. The scans were acquired with 0.9 mm thickness. Soft copy DICOM images were retrieved from TeraRecon Aquarius workstation (San Mateo, Calif).

Pulmonary vein classification and statistical analysis

Marom EM *et al.* classified the pulmonary vein and its drainage orifices into 6 patterns on the right side and 2 patterns on the left side [3].

Results

A total of 163 male and 133 female patient scans were studied with ages ranging from 15 to 94 and a mean age of 45. Using Marom's pulmonary venous drainage categories, the drainage patterns were summarized in Table 1 for the left pulmonary vein and Table 2 for the right pulmonary vein with L3 in table 1 and R3d in table 2 proposed as a new addition to the original classification by Marom (Figure 1).

Table 1: Left pulmonary venous drainage patterns.

Drainage pattern	Description	No. of pts	Percentage
L1a	Lower lobe vein and upper lobe vein form a common trunk less than 1 cm long draining into the left atrium (one ostium)	101	33.67
L1b	Lower lobe vein and upper lobe vein form a common trunk more than 1 cm long draining into the left atrium (one ostium)	89	29.67
L2a	The upper and lower lobe veins drain into two separate atrial ostia separated by left atrial wall	57	19.00
L2b	The upper and lower lobe veins drain into two atrial ostia which are not separated by left atrial wall	50	16.67
L3	Three atrial ostia for upper lobe, lower lobe and lingular segment	3	1.00
Total		**300**	**100.00**

Table 2: Right pulmonary venous drainage patterns.

Drainage pattern	Description	No. of pts	Percentage
R1	Upper, middle, and lower lobe veins draining into a single common ostium	11	3.67
R2a	The upper and lower lobe veins drain into two separate ostia with the middle lobe vein joining the proximal upper lobe vein less than 1 cm from the ostium	111	37.00
R2b	The upper and lower lobe veins drain into two separate ostia with the middle lobe vein joining the proximal upper lobe vein more than 1 cm from the ostium	109	36.33
R2c	The upper and lower lobe veins drain into two separate ostia with the middle lobe vein joining the lower lobe vein	12	4.00
R3a	The upper, middle, and lower veins drain into three separate ostia	35	11.67
R3b	The upper, superior segment, and lower lobe veins drain into three separate ostia with the middle lobe vein joining the proximal upper lobe vein less than 1 cm from the ostium	11	3.67
R3c	The upper, a basilar right lower lobe vein and lower lobe veins drain into three separate ostia with the middle lobe vein joining the proximal upper lobe vein less than 1 cm from the ostium	1	0.33
R3d	Three atrial ostia for the lower, lateral segment of middle and upper lobe veins, with upper lobe veins being accompanied by medial segment of middle lobe vein forming a common channel	5	1.67
R4a	One upper, two middle, and one lower lobe veins draining into four separate ostia	0	0.00
R4b	The upper, middle, superior segment, and lower lobe veins drain into four separate ostia	5	1.67
R5	One upper, two middle, two superior segment, and one lower lobe veins drain into five separate ostia	0	0.00
Total		**300**	**100.00**

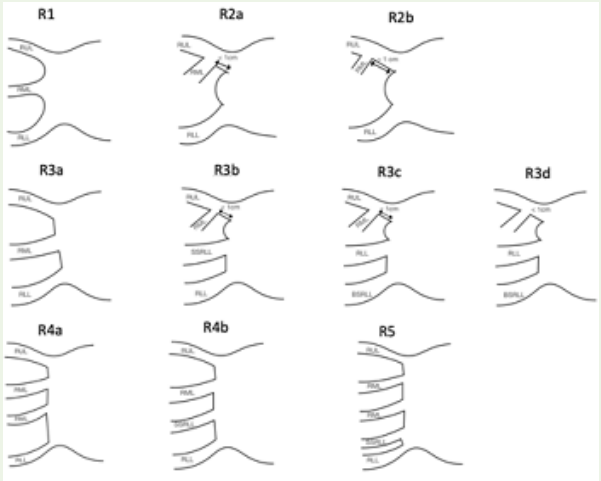

Figure 1a: Modified illustration of right sided pulmonary venous origin category, originally proposed by Marom, et al.
BSRLL = basilar segment right lower lobe pulmonary vein, RLL = right lower lobe pulmonary vein, RML = right middle lobe pulmonary vein, RUL = right upper lobe pulmonary vein, SSRLL = superior segment right lower lobe pulmonary vein, LUL = left upper lobe pulmonary vein, LLL = left lower lobe pulmonary vein, 1cm = distance from the ostium.

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Left pulmonary venous drainage patterns (Table 1): There were 107 (35.66%) patients with two ostia for the upper and lower lobe veins. A common trunk forming one ostium in the left atrium was seen in 190 (63.33%) patients, which was a slightly higher percentage than the patients with two ostia. 1 cases (1%) differed from the original Maroms classification in having three ostia for upper lobe, lower lobe and linguilar segment. We propose a new category for this variation as L3. (Figures 2 – 5).

Right pulmonary venous drainage patterns (Table 2): Most patients (232, 77.33%) had the expected anatomy of two atrial ostia for upper and lower lobe veins, with the middle lobe vein joining the upper lobe vein. 11 cases (3.67%) had a single common ostium opening into the left atrium. 5 cases (1.67%) had 4 ostia opening into the left atrium for the upper, middle, superior segment, and lower lobe veins. 52 cases (17.33%) had 3 ostia opening into the left atrium for upper and middle lobe veins and a variable vein. Out of these 52 cases, 5 cases have anatomy which differed from the original Maroms classification having three atrial ostia for the lower, lateral segment of middle and upper lobe veins, with upper lobe veins being accompanied by medial segment of middle lobe vein forming a common channel. We propose a new category here as R3d in which we found three atrial ostia for the lower, lateral segment of middle and upper lobe veins, with upper lobe veins being accompanied by medial segment of middle lobe vein forming a common channel (Figures 6 - 9).

Table 3 discusses permutations and combinations of all the categories of left sided and right sided drainage. Majority cases (145, 48.33%) had two ostia draining from the right side and one common ostium draining from the left side, with the most common combination being R2b with L1a having 40 cases (13.33%) followed by R2a with L1b with 37 cases (12.33%).

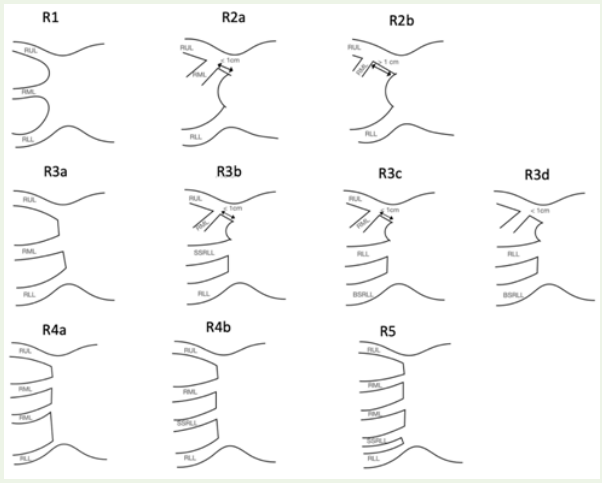

Figure 1b: Modified iillustration of left sided pulmonary venous origin category, originally proposed by Marom, et al.
LIN = Lingular vein, LUL = left upper lobe pulmonary vein, LLL = left lower lobe pulmonary vein, 1cm = distance from the ostium.

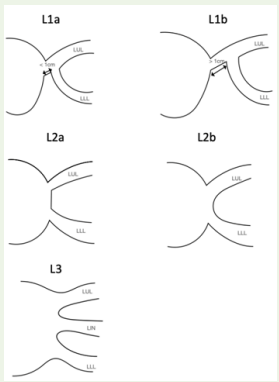

Figure 2: L1b pattern: Oblique coronal image shows lower lobe vein (LLL) joining the upper lobe vein (ULL) to form a common trunk vein more than 1 cm long that drains into the left atrium.

Figure 3: L2a pattern: An oblique coronal image showing the two different ostia of left upper lobe vein (LUL) and left lower lobe vein (LLL) separated by atrial tissue.

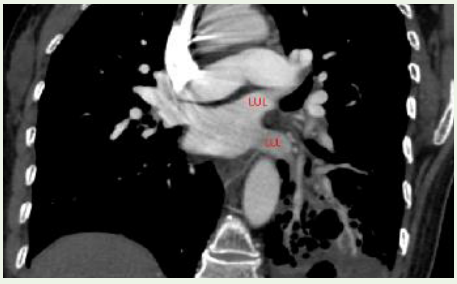

Figure 4: L2b pattern: An oblique coronal image showing the two different ostia of left upper lobe vein (LUL) and left lower lobe vein (LLL) which are not separated by left atrial tissue.

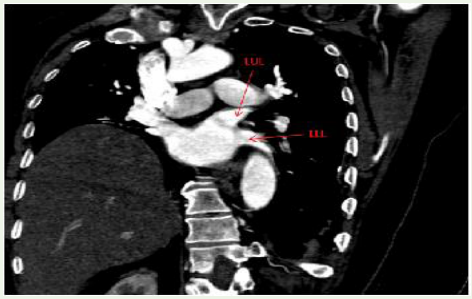

Figure 5: L3 pattern: An oblique coronal image showing three separate ostia for left upper lobe (LUL), left lower lobe (LLL) and lingular segments (LLS).

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Figure 6: R2c pattern: An oblique coronal image showing two atrial ostia for the upper (RUL) and lower lobe (RLL) veins with the middle lobe vein (RML) the lower lobe vein to form a common channel.

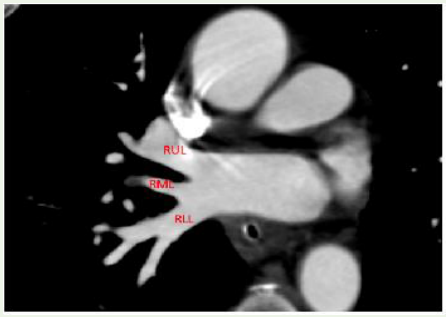

Figure 7: R3a pattern: An oblique axial image showing three separate ostia of right upper lobe (RUL), right middle lobe (RML) and right lower (RLL) lobe veins opening into the left atrium.

Figure 8: R3a pattern: An oblique coronal image showing three separate ostia of right upper (RUL) middle (RML) and lower (RLL) lobe veins opening into the left atrium.

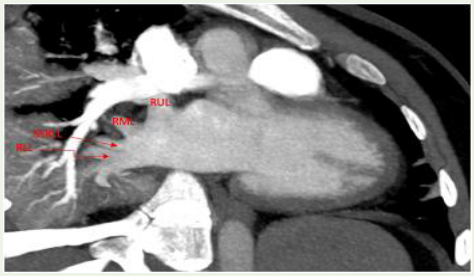

Figure 9: R4b pattern: An oblique sagittal image showing four atrial ostia for the upper lobe (RUL), middle lobe (RML), superior segment of right lower lobe (SSRLL), and right lower lobe veins (RLL).

Table 3: Combined patterns of pulmonary venous drainage.

	L1a	L1b	L2a	L2b	L3	Grand Total
R1	2	4	3	2	0	**11**
R2a	32	37	15	26	1	**111**
R2b	40	29	25	13	2	**109**
R2c	4	3	2	3	0	**12**
R3a	15	6	9	5	0	**35**
R3b	5	3	2	1	0	**11**
R3c	0	0	1	0	0	**1**
R3d	2	3	0	0	0	**5**
R4a	0	0	0	0	0	**0**
R4b	1	4	0	0	0	**5**
R5	0	0	0	0	0	**0**
Grand Total	**101**	**89**	**57**	**50**	**3**	**300**

Discussion

Embryology and Development

Around 4th week of intrauterine development, a primitive common pulmonary vein originates from a greater splanchnic capillary network that extends from the heart to the liver and connects to the cardinal and umbilicovitelline veins [4,5]. A small strand arises from this network to connect with the left atrium which makes its connection and forms a venous lumen, a sleeve of myocardial tissue envelops the new vein from the surrounding mesenchymal tissues [6]. This primitive pulmonary vein connects the lung bud's venous network to the left atrium close to the atrioventricular junction. Along with the development of the primary atrial septum on their right side the final positions of the pulmonary vein orifices are determined in the morphologic left atrium. The left atrium drains the tributaries of the primitive pulmonary vein as they develop and along with the atrophy of the connections to the cardinal and umbilicovitelline systems, which forms separate pulmonary and systemic venous systems.

Anatomy

Pulmonary venous anatomy shows variations in the number and the arrangement of drainage pattern and because of this fact [3,7], It is best to consider pulmonary vein arrangement in terms of commonality. In most people (57%-82%), four separate and distinct pulmonary vein ostia arise from the left atrium [8,9]. Two of these ostia are on the right, draining the right superior pulmonary vein and the right inferior pulmonary vein; and two ostia are on the left, draining the left superior and inferior pulmonary veins. Commonly, left atrial tissue separates these ostia on the right but is not separated from each other on the left. It can be tedious to delineate a common ostium from separate ostium without connecting atrial tissue. However, extrapolating the shape of the left atrium as it nears the pulmonary vein ostia provides help with the same, to determine the expected location of the pulmonary venoatrial junction [10,11]. Along with different ostial patterns, numerous branching and drainage patterns have been identified, with several investigators attempting to group and categorize the patterns [12]. The most accepted classification system for pulmonary venous drainage was produced by Marom et al [3].

Radiological Approach for Pulmonary Vein Evaluation

CT and MR imaging, both depict the pulmonary venous anatomy

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well. However, CT offers a speed advantage, compared with MR imaging which has greater spatial resolution. Electrocardiographically gated cardiac CT should be ideally used for a detailed assessment of pulmonary veins. For identification of the pulmonary venous number and branching patterns, multiplanar reformatted images should be preferred.

Conclusion

At chest imaging, the pulmonary veins are an often overlooked part of the anatomy that can become directly or indirectly involved in a wide array of pathological and non pathological processes. Detailed knowledge of the pulmonary veins is a necessity, because imaging can play a critical role in differentiating normal findings from serious conditions involving the pulmonary veins and hence having vital application in multiple areas of cardiothoracic surgery and interventional cardiology.

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