DOI: 10.7860/JCDR/2026/88367.24695

Original Article

Anatomy Section

# Variations in the Pulmonary Venous Ostia of the Left Atrium: A Cross-sectional Study

GL JYOTHI LAKSHMI[1], JOSHUA P AJITH[2], HS SARALA[3]

BY-NC-ND


## ABSTRACT

**Introduction:** The left atrium typically receives the terminations of two pulmonary veins from each lung. The pulmonary veins are an important source of ectopic beats, initiating frequent paroxysms of atrial fibrillation. There is a paucity of data on the variations in the number of pulmonary veins in population of Karnataka.

**Aim:** To assess the variations in the number of right and left pulmonary veins draining into left atrium and to classify the variations in pulmonary veins according to the pulmonary vein and ostial number-based classification system.

**Materials and Methods:** A cross-sectional study was undertaken on 40 normal adult cadaveric human hearts aged 18-70 years belonging to the Department of Anatomy of Sri Atal Bihari Vajpayee Medical College and Research Institute in Bengaluru, Karnataka, India. The study was conducted from July 2024 to December 2024. The left atrium was observed from the outer aspect after removing the heart from the cadaver according to Cunningham's dissection manual. Pulmonary ostia were observed from the inner aspect after incising the posterior wall of the left atrium. The variations noted were classified according to the pulmonary vein and ostial number-based classification system. The observations made were presented using descriptive statistics such as frequencies and percentages. Statistical analysis was made using the software Statistical Package for Social Sciences (SPSS) version 24.0.

**Results:** Out of 40 specimens, the normal pattern of two right pulmonary veins draining through two separate ostia into left atrium was reported in 39 (97.5%) specimens and the normal pattern of two left pulmonary veins draining through two separate ostia into left atrium was seen in 38 (95%) of specimens. Two specimens had single left pulmonary vein with single ostium in the left atrium and they belonged to type 1A. An accessory middle pulmonary vein along with typical two right pulmonary veins draining through 3 independent ostia into the left atrium was observed in a heart specimen which belonged to type 3A.

**Conclusion:** The present study reported that the most common pulmonary vein drainage pattern was two pulmonary veins draining through two separate ostia into left atrium on each side.


**Keywords:** Accessory pulmonary vein, Arrhythmic foci, Atrial fibrillation, Cadaveric study, Drainage pattern, Early branching

## INTRODUCTION

The posterior aspect of the left atrium is quadrangular and forms most of the anatomical base of the heart. It typically receives the terminations of two pulmonary veins from each lung. The four pulmonary veins open into the superior posterolateral surfaces of the left atrium, two on each side [1].

The left atrial musculature extends from the atrium and envelopes the proximal pulmonary veins. The superior pulmonary veins have more conspicuous sphincter-like atrial-pulmonary venous junctions and better developed myocardial venous sleeves than the inferior pulmonary veins [2]. The superior veins, which have longer muscular sleeves, have been reported to be more arrhythmogenic than the inferior veins. The pulmonary veins are an important source of ectopic beats, initiating frequent paroxysms of atrial fibrillation. These foci respond to treatment with radiofrequency ablation [3].

Skowerski M et al., observed that the anomalies of pulmonary vein anatomy occurred more often in patients with atrial fibrillation. They can be defined as an image biomarkers of atrial fibrillation. Right additional (middle) pulmonary vein was the most important anomaly detected in patients with AF, along with enlarged diameters of the left atrium and pulmonary vein ostia [4]. Harbi A et al., retrospectively evaluated the incidence of variability of the anatomy of pulmonary venous ostium in a Saudi cohort and reported that the association between anatomically varied venous ostia and atrial arrhythmia was significant [5].

The present study was undertaken to assess the variations in the number of pulmonary veins draining into left atrium.

## MATERIALS AND METHODS

The present study was a cross-sectional study undertaken in the Department of Anatomy of Sri Atal Bihari Vajpayee Medical College and Research Institute in Bengaluru, Karnataka, India, from July 2024 to December 2024. The study was conducted on 40 normal adult cadaveric human hearts from individuals aged 18-70 years obtained from the Department of Anatomy. The gender of the specimens under study could not be established. The study was done on cadavers donated to the Department of Anatomy for medical education and research purposes. The study was done on specimens obtained from cadavers donated for the purpose of medical education and research.

**Inclusion criteria:** The cadaveric human hearts available in the Department of Anatomy were included in the study.

**Exclusion criteria:** Hearts that were damaged during preservation, surgically operated on, and those with congenital anatomical defects were excluded.

### Study Procedure

The hearts were removed from the cadavers by following the methodology described in Cunningham's Manual of Anatomy. A vertical cut was made through each side of the pericardium of the heart immediately anterior to the line of the phrenic nerve. The lower ends of the incision were joined by a transverse cut approximately 1 cm above the diaphragm. The flap of the pericardium was turned upwards. The attachment of the pericardium to the superior vena cava, aorta and pulmonary trunk was determined and cut through. A transverse cut was made through the superior vena cava and

aorta at the junction with the ascending part with the arch. The inferior vena cava and the pulmonary veins were cut through. The left atrium was observed from the outer aspect [6]. The variant anatomy noted in the hearts was photographed. The observations were done by two observers to enhance reliability.

The following parameters were assessed:

a. The number of pulmonary veins draining into the left atrium on each side.

b. The variations in the number of pulmonary veins draining into the left atrium were classified according to the classification proposed by Shukla L et al., [6]. Depending upon the number of pulmonary veins, it may be classified into Type I to Type V; and if the number of pulmonary ostia is equal to the number of pulmonary veins, it may be categorised into A subtype; and if the number of pulmonary ostia is less than the number of pulmonary veins, then it may be categorised into B subtype [6].

## STATISTICAL ANALYSIS

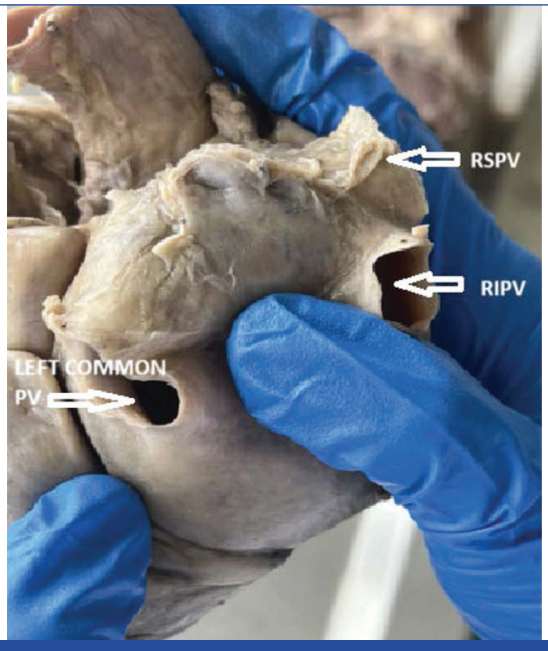
The observations made were presented using descriptive statistics such as frequencies and percentages. Statistical analysis was performed using SPSS version 24.0.

## RESULTS

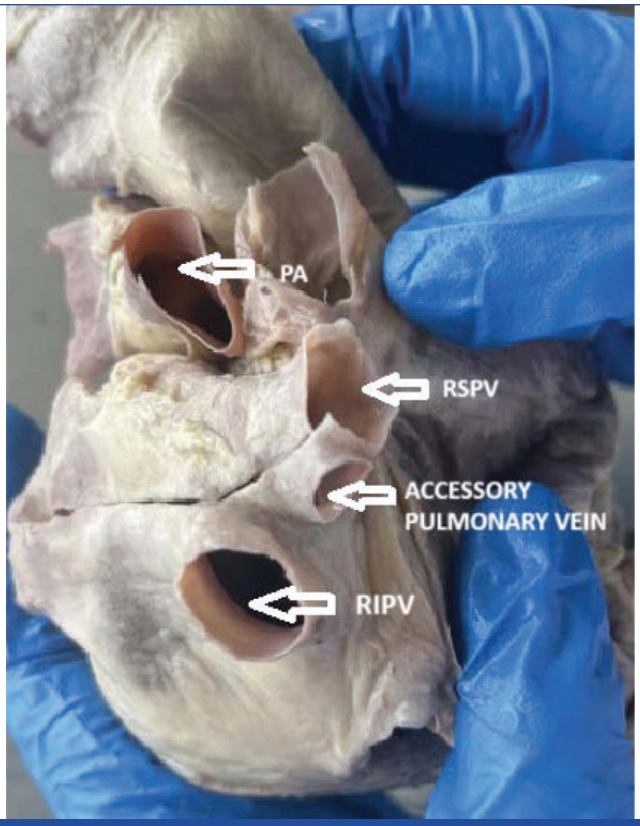
Out of 40 specimens, the normal pattern of two right pulmonary veins draining through two separate ostia into the left atrium was reported in 39 (97.5%) specimens and the normal pattern of two left pulmonary veins draining through two separate ostia into the left atrium was seen in 38 (95%) of specimens as shown in [Table/Fig-1]. None of the hearts showed variations on both sides simultaneously. Two of the specimens had a single common left pulmonary vein with single ostia as shown in [Table/Fig-2]. An accessory middle pulmonary vein along with typical two right pulmonary veins draining through three independent ostia into the left atrium was observed in a heart specimen as shown in [Table/Fig-3]. Right accessory middle pulmonary vein was smaller than the right superior and inferior pulmonary veins.

| Type of pulmonary veins draining into left atrium | 1A | 2A | 3A |
|---|---|---|---|
| Right (n=40) | - | 39 (97.5%) | 1 (2.5%) |
| Left (n=40) | 2 (5%) | 38 (95%) | - |

**[Table/Fig-1]:** Type of pulmonary veins draining into left atrium in the present study according to the classification by Shukla L et al., [6].




**[Table/Fig-2]:** Single pulmonary vein on the left-side and two pulmonary veins on the right-side.
PV: Pulmonary vein; RSPV: Right superior pulmonary vein; RIPV: Right inferior pulmonary vein




**[Table/Fig-3]:** An accessory pulmonary vein on the right-side .
PA: Pulmonary artery; RSPV: Right superior pulmonary vein; RIPV: Right inferior pulmonary vein

According to the classification by Shukla L et al., the specimen with three right pulmonary veins and three pulmonary ostia in the present study belongs to type 3A [6]. The specimens with a single left pulmonary vein and one pulmonary ostium belong to type 1A. The rest of the specimens with normal draining pattern with two pulmonary veins and two pulmonary ostia on each side belong to Type 2A.

## DISCUSSION

During the development of the pulmonary vein, a single primordial pulmonary vein develops from the dorsal atrial wall just to the left of septum primum. It grows into dorsal mesocardium, dividing into right and left pulmonary veins, each of which in turn is formed by the union of two pulmonary veins from the corresponding lung buds. Abnormalities in the development of the common pulmonary vein primordium and its tributaries and their incorporation into the left atrial wall can lead to variation in the number of pulmonary veins draining into the left atrium. During development, migration of atrial myoblasts into the wall of pulmonary veins may be the cause of arrhythmic foci that initiate atrial fibrillation [7].

The observations of the present study in comparison with previous studies are shown in [Table/Fig-4] [6,8-11].

In a study by Kocygit D et al., on 250 patients who underwent multidetector Computed Tomography (CT) before cryoballoon-based catheter ablation, the accessory right middle pulmonary vein was noticed to be smaller than the other veins, which correlates with the findings of the present study. Kocygit D et al., also observed that patients with a separate ostia for the right middle lobe pulmonary vein were prone to have a higher frequency of atrial arrhythmia than those with other patterns [12].

An accessory pulmonary vein needs to be differentiated from early branching of the pulmonary vein. This is a common diagnostic challenge and is particularly critical when planning procedures like radiofrequency ablation for atrial fibrillation [13].

| Variables | Number of pulmonary veins | Shukla L et al., 2012 [6] n (%) | Rajesh S et al., 2018 [8] n (%) | Lalitha Kumari MK et al., 2020 [9] n (%) | Bose P et al., 2021 [10] n (%) | Marom EM et al., 2004 [11] n (%) | Present study n (%) |
|---|---|---|---|---|---|---|---|
| Sample size | | 29 | 80 | 25 | 75 | 201 | 40 |
| Population | | Haryana, India | Tamil Nadu, India | Andhra Pradesh, India | Chhattisgarh, India | North Carolina, USA | Karnataka, India |
| Methodology | | Cadaveric study | Cadaveric study | Cadaveric study | Cadaveric study | CT scans | Cadaveric study |
| Right | 1 | 1 (3.4) | 6 (7.5) | - | - | 4 (2) | - |
| Right | 2 | 22 (75.9) | 72 (90) | 25 (100) | 63 (84) | 142 (71) | 39 (97.5) |
| | 3 | 5 (17.2) | 2 (2.5) | - | 7 (9.33) | 56 (28) | 1 (2.5) |
| | 4 | 1 (3.4) | - | - | 3 (4) | | - |
| | 5 | - | - | - | 2 (2.66) | | - |
| Left | 1 | 5 (17.2) | 8 (10) | 2 (8) | 2 (2.66) | 28 (14) | 2 (5) |
| | 2 | 23 (79.3) | 71 (88.75) | 23 (92) | 73 (97.33) | 173 (86) | 38 (95) |
| | 3 | 1 (3.4) | 1 (1.25) | - | - | | - |

**[Table/Fig-4]:** Observations of the present study compared with previous studies [6,8-11].

## Limitation(s)

The limitations of the present study are the small sample size, selection bias, lack of clinical correlation, embalming-related distortion, absence of radiological correlation, and inability to assess functional significance.

## CONCLUSION(S)

The present study reported that the most common pulmonary vein drainage pattern was two pulmonary veins draining through two separate ostia into left atrium on each side. The observations noted in the study serve as a guide for clinicians during radiological examinations and interventional procedures such as radiofrequency ablation to isolate pulmonary veins while treating atrial fibrillation.

## REFERENCES


[1] Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st Ed. Elsevier Ltd, 2016. p.1005.
[2] Nathan H, Eliakim M. The junction between the left atrium and the pulmonary veins. An anatomic study of human hearts. Circulation 1966;34(3):412-22.
[3] Haïssaguerre M, Jaïs P, Shah DC, Takahashi A, Hocini M, Quiniou G, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med. 1998;339(10):659-66.
[4] Skowerski M, Wozniak-Skowerska I, Hoffmann A, Nowak S, Skowerski T, Sosnowski M, et al. Pulmonary vein anatomy variants as a biomarker of atrial fibrillation - CT angiography evaluation. BMC Cardiovasc Disord. 2018;18(1):146. Doi: 10.1186/s12872-018-0884-3.
[5] Harbi A, Mhish H, Alshehri HZ, Das KM. Anatomical variation of pulmonary venous ostium and its relationship with atrial arrhythmia in the Saudi population. J Saudi Heart Assoc. 2014;26(2):81-85. Doi: 10.1016/j.jsha.2013.11.007.
[6] Shukla L, Gaur N, Soni G, Dhall U. Variation in number and drainage pattern of pulmonary veins draining into the left atrium. Journal of Anatomical Society of India 2012;61:05-08.
[7] Chimmalgi M, Rangsubhe P, Shanu S, Amalasmitha LV, Krishnan K, Dhanushia S, et al. Double superior vena cava and variation in pulmonary venous drainage – case report. National Journal of Clinical Anatomy. 2016;5(3):156-60.
[8] Rajesh S, Kumar, S Vijaya Reddy, V Manikanda. A study on pulmonary venous ostia pattern in the left atrium and its clinical applications. National Journal of Clinical Anatomy. 2018;7(4):201-04.
[9] Lalitha Kumari MK, Srivani D, Vinayak I, Sreekanth C, Prathiba K. Study of anatomical variations of number of pulmonary veins and its clinical significance. International Journal of Contemporary Medical Research. 2020;7(3):C1-C3.
[10] Bose P, Choudhary U, Singh P, Singh B, Singh R. Morphological variations of pulmonary veins draining into left atrium: A detailed cadaveric study. National Journal of Clinical Anatomy. 2021;10(4):236-39.
[11] Marom EM, Herndon JE, Kim YH, McAdams HP. Variations in pulmonary venous drainage to the left atrium: Implications for radiofrequency ablation. Radiology. 2004;230(3):824-29.
[12] Koçyiğit D, Gürses KM, Yalçın MU, Türk G, Evranos B, Canpolat U, et al. Pulmonary vein anatomy and its variations in a Turkish atrial fibrillation cohort undergoing cryoballoon-based catheter ablation. Turk Kardiyol Dern Ars. 2017;45(1):42-48.
[13] Bittner A, Mönnig G, Vagt AJ, Zellerhoff S, Wasmer K, Köbe J, et al. Pulmonary vein variants predispose to atrial fibrillation: A case-control study using multislice contrast-enhanced computed tomography. Europace. 2011;13(10):1394-400. Doi: 10.1093/europace/eur145.



**PARTICULARS OF CONTRIBUTORS:**
1. Assistant Professor, Department of Anatomy, Sri Atal Bihari Vajpayee Medical College and Research Institute, Bengaluru, Karnataka, India.
2. Undergraduate Student, Department of Anatomy, Sri Atal Bihari Vajpayee Medical College and Research Institute, Bengaluru, Karnataka, India.
3. Professor, Department of Anatomy, Rajarajeswari Medical College and Hospital, Bengaluru, Karnataka, India.

**NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:**
GL Jyothi Lakshmi,
74, FF2, Elegant Akshaya, 4th Cross, Ramarao Layout, Kathriguppe,
Banashankari 3rd Stage, Bengaluru-560085, Karnataka, India.
E-mail: jyothimanjappa11@gmail.com



**PLAGIARISM CHECKING METHODS:** [Jain H et al.]
- Plagiarism X-checker: May 22, 2026
- Manual Googling: Aug 08, 2026
- iThenticate Software: Aug 10, 2026 (16%)

**ETYMOLOGY:** Author Origin

**EMENDATIONS:** 6

**AUTHOR DECLARATION:**
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No (covered by cadaver donation consent)
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 19, 2026**
Date of Peer Review: **May 26, 2026**
Date of Acceptance: **Aug 12, 2026**
Date of Publishing: **Dec 01, 2026**