Variations in pulmonary venous drainage into the left atrium. a case report with clinical implications

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SUMMARY

The pulmonary veins, responsible for carrying oxygenated blood from the lung to the left atrium for gaseous exchange, often exhibit variations. Understanding and mapping these variations is crucial for diagnosing atrial fibrillations and pulmonary arteriovenous malformations. This study, aimed at reporting the variations in the number of pulmonary veins and drainage patterns, presents findings from the dissection of a female cadaver in our Department of Anatomy. Notably, we observed variations in the drainage pattern of pulmonary veins on the left atrium. On the right side of the left atrium, three veins (Superior pulmonary vein, Accessory vein and Inferior pulmonary vein) were draining via three pulmonary ostia. On the left side, the common trunk of a single pulmonary vein drains via a single pulmonary ostium. These findings hold significant potential to benefit medical professionals, aiding in planning various procedures involving pulmonary veins and catheter-based interventions like radiofrequency ablation.

Key words: Pulmonary vein – Pulmonary ostia – Left atrium – Atrial fibrillation

ABBREVIATIONS

AF – Atrial fibrillation

ILV – Inferior lobar vein

IPV – Inferior pulmonary vein

LA – Left atrium

MLV – Middle lobar vein

PV – Pulmonary vein

SLV – Superior lobar vein

SPV – Superior pulmonary vein

INTRODUCTION

The pulmonary veins carry oxygenated blood from the lungs to the heart's left atrium for gaseous exchange. Four pulmonary veins have two superior and two inferior drains into the left atrium on either side via two separate pulmonary ostia. The joining of two lobar veins forms the right superior pulmonary vein (SPV), the superior

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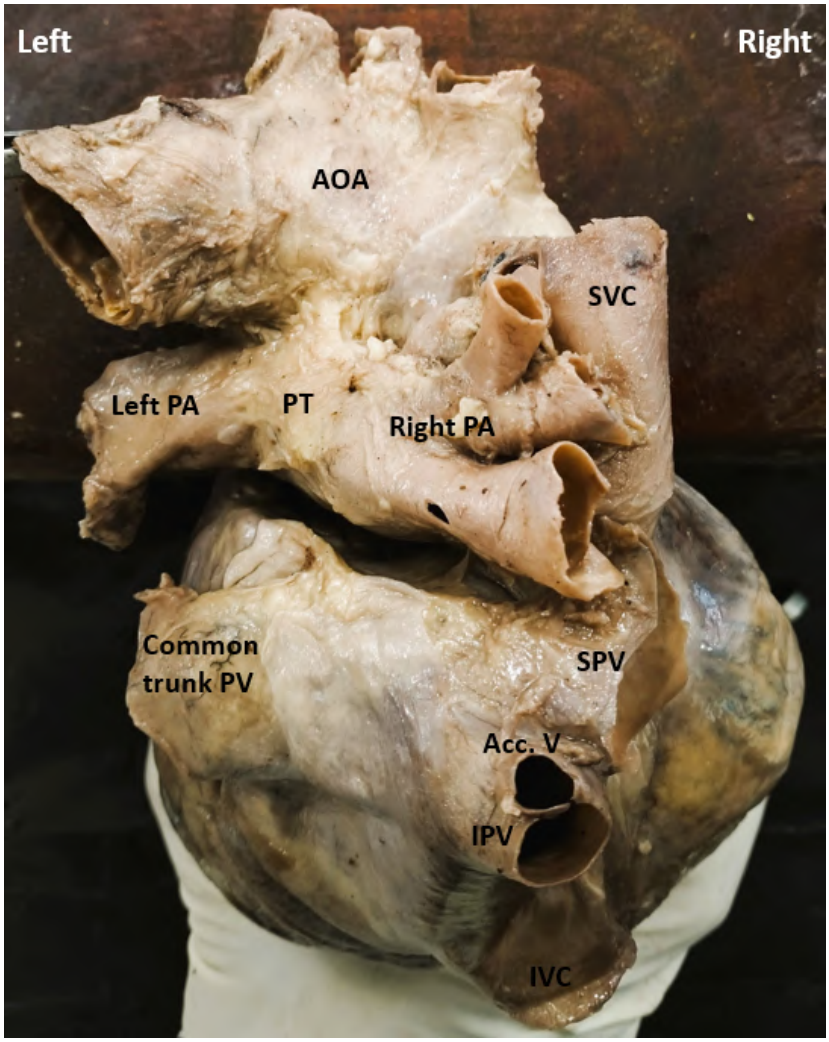

Fig. 1.- Posterior view of cadaveric heart shows 3 pulmonary veins (PV) drains into right side of left atrium via 3 pulmonary ostia. (SPV – Superior pulmonary vein, Acc. V – Accessory vein, IPV – Inferior pulmonary vein). On left side, a common trunk of single pulmonary vein opens into left atrium. AOA – Arch of Aorta, SVC – Superior vena cava, IVC – Inferior vena cava, PT – Pulmonary trunk, PA – Pulmonary artery

lobar vein (SLV) draining the upper lobe, and the middle lobar vein (MLV) draining the middle lobe. The right inferior pulmonary vein (IPV) drains the right lower lobe of the lung. Similarly, the left superior pulmonary vein is formed by the superior lobar vein (SLV), draining the upper lobe, and the lingular vein (LV), draining the lingular lobe, while the left inferior pulmonary vein drains the left lower lobe of the lung. The ostia of IPV are more posterior and medial to SPV, and the ostia of the left pulmonary veins are higher than the right pulmonary veins (Standring, 2016). This is the regular drainage pattern reported in 82% of the population (Cronin, 2007).

The most common variants seen in pulmonary veins are conjoined and accessory veins. In the conjoined or common vein, the superior and inferior pulmonary veins unite on the same side before draining into the left atrium, resulting in a single atrial-pulmonary venous junction. It is commonly seen on the left side (Lyen, 2017). The accessory vein, the supernumerary vein, is separate from SPV or IPV, with independent drainage into the left atrium. These veins are usually small and often drain only one pulmonary segment, particularly the superior segment of the lower lobe (Cronin, 2007). The prevalence of accessory veins was documented in 30% of the cases, and it is more commonly seen on the right side (Schwartzman, 2003; Marom., 2004).

Much literature is available about the variations in pulmonary venous drainage radiologically and, as a case report in cadaveric specimens, and it has been reported that the variations were seen in 36% of the cases (Marom, 2004; Shukla, 2012). Pulmonary veins play an important role in atrial

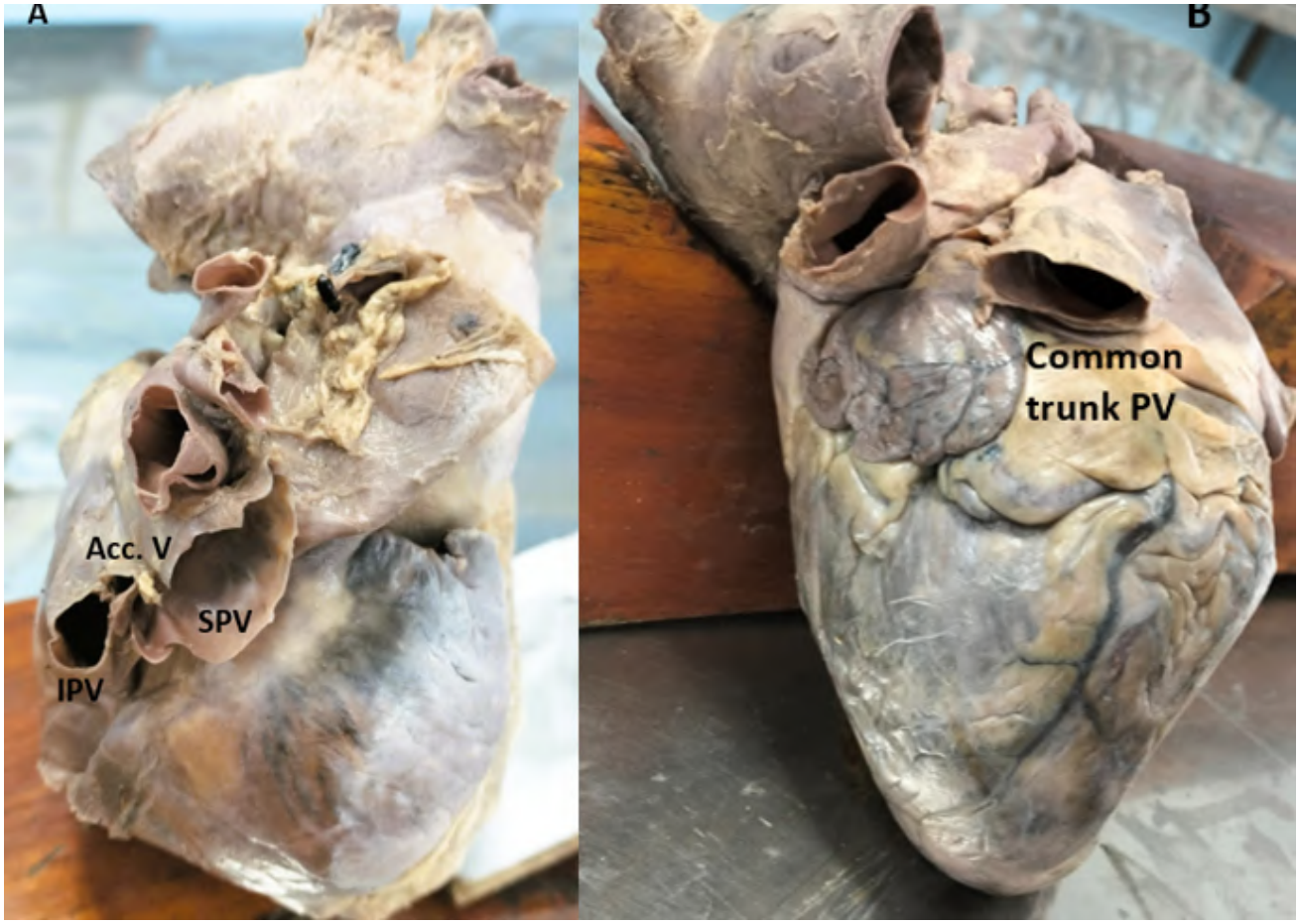

Fig. 2.- A – Right lateral view of cadaveric heart shows 3 pulmonary veins (PV) drains into right side of left atrium via 3 pulmonary ostia. (SPV – Superior pulmonary vein, Acc. V – Accessory vein, IPV – Inferior pulmonary vein). **B** – Left lateral view shows a common trunk of single pulmonary vein opens into left side of the left atrium.

fibrillation, as they are the primary source of ectopic depolarization in patients presenting with paroxysmal atrial fibrillation (Cronin, 2007). In addition to that, it may often present with intraoperative complications like hemorrhage, as well as misinterpretation of radiographic images due to its anatomical variations (Yamashita, 2000). Therefore, thorough knowledge of the pulmonary veins is essential for cardio-thoracic surgeons and radiologists to properly diagnose and manage cardio-pulmonary cases to minimize the risk of operative complications.

CASE REPORT

Dissection of the thoracic region was carried out per Cunningham's manual of practical anatomy. During the routine cadaveric dissection for medical undergraduates, variation in the pulmonary veins that drain into the left atrium of the heart was encountered in a 65-year-old female cadaver in the Department of Anatomy at Vinayaka Mission's Medical College, Karaikal. After careful dissection of the pericardium, variations in the pulmonary veins were noted, as in Figs. 1 and 2. The schematic representation of the number of pulmonary veins and their drainage pattern were showed on the Fig. 3. On the right side of the left atrium, 3 PV drains via three pulmonary ostia (PO); on the left, a common trunk of a single pulmonary vein drains via a single PO.

COMMENTS

The developmental cause is one of the main reasons for pulmonary venous anomalies. During the fourth to fifth week of development, an outpouching develops from the middle of the posterosuperior wall of the primitive left atrium, which presents as a single pulmonary vein. With the growth of the second heart field mesenchymal cells, the single PV moves towards the left side, where they establish communication with the splanchnic plexus and systemic cardinal and umbilical-vitelline veins. Later, the single PV grow towards the bronchial buds and anastomose with the splanchnic

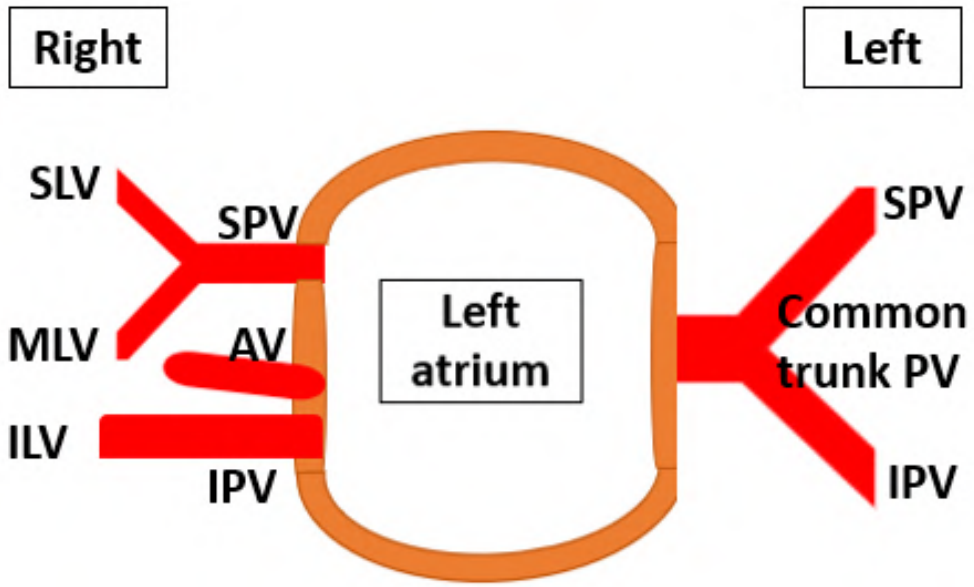

Fig. 3.- Schematic diagram showing the number and drainage pattern of pulmonary veins on right and left side of the left atrium. SLV – Superior lobar vein, MLV – Middle lobar vein, SPV – Superior pulmonary vein, AV – Accessory vein, ILV – Inferior lobar vein, IPV – Inferior pulmonary vein.

plexus surrounding the lung parenchyma. With the expansion of the left atrium, the PV is separated from the splanchnic plexus and is incorporated within the left atrium, where it branches to give four separate openings of pulmonary veins (Larsen, 2009). Failure of separation and atypical incorporation of PV into the left atrium results in variant anomalies like the common trunk of PV and accessory vein (Healey, 1952).

Pulmonary veins play a vital role in lung segmental anatomy, as they govern bronchopulmonary segments' surgical borders. Anatomical variations of PV are essential for performing surgical procedures like lobar resection and video-assisted thoracoscopic surgeries (VATS), as they require a better understanding of thoracic anatomy in the operating field. Variations in the number and drainage pattern of pulmonary veins were studied by few investigators in radiograph images (Marom, 2004; Cronin, 2007) and less in cadaveric specimens (Shukla, 2012; Rajeshwari, 2012).

In our present case, we have seen variations in the drainage pattern of pulmonary veins in the cadaveric heart showing 3 PV (I. Superior pulmonary vein; II. Accessory vein drained independently; III. Inferior pulmonary vein) draining into the right side of the left atrium via three pulmonary ostia, and a common trunk of single pulmonary vein draining into the left side of left atrium via single pulmonary ostia, as shown in Figs. 1, 2A and 2B. On the right side, SPV drains the upper and middle lobes via the superior and middle lobar veins, whereas IPV drains the lower lobe of the lung. In addition, the accessory vein was present as a separate vein, emptied independently into the left atrium, as shown in Figure 2A. If more than one PV drains anomalously into LA, volume overload leads to right ventricular diastolic overload (Saha, 2019).

A similar finding was reported by Shukla et al. in 2012, which categorized the drainage pattern of pulmonary veins into four types. Our study results coincide with category 3, with a prevalence of 6.9% on the right side and 17.2% on the left side of the left atrium. Marom et al. (2004) did a study on pulmonary venous anatomy using computed tomography in 201 patients and reported that 26% of the patients presented with 3-5 PO on the right side and 14% with single PO on the left side.

The anatomical variation of the middle lobar vein (MLV) and its drainage pattern has surgical importance. In our case report, MLV emptied into SLV and drained as SPV into the left atrium. This is a common finding documented by many investigators. However, in some cases, the middle lobar

Table 1. Comparative incidence of common trunk of the left sided pulmonary vein among various studies.

Studies	No. of Cases	Number / Frequency (%)
Healey J.E, 1952	251 specimens	53 (21.11%)
Marom et al, 2003	201 CT Chest	21 (10%)
Saha Anubha, 2019	RL - 49, LL - 54	5 (9.26%)
Shukla et al, 2012	-	5 (17.2%)

CT – Computerized Tomography, RL – Right lobe, LL – Left lobe

vein has independent drainage into the left atrium as MPV, which was reported in 25% of the cases and MLV emptying into ILV, drained as IPV into the left atrium, which was documented in 11.53% (Marom, 2004; Rajeshwari, 2012). Due to its anatomical variations, improper ligation of the inferior lobar vessels during a lobectomy procedure may cause postoperative complications like hemorrhage, lung oedema and respiratory distress (Sugimoto, 1998).

Many literatures have reported that pulmonary venous morphology plays a vital role in the pathophysiology of atrial fibrillation (AF) due to the lengthening of myocardial sleeves from the left atrium to the proximal part of PV (Cronin, 2007). Its anatomical variations often affect the success rate of specific surgical procedures like radiofrequency ablation, as it is the dominant source of initiating ectopic foci, with 96% of patients presenting with atrial fibrillation. The frequency of AF was found to be more common in patients with independent drainage of middle lobar veins and accessory veins into the LA (Lyen, 2017). So, it is essential to do pre-ablation imaging studies to determine any variant vein and their drainage pattern.

The common trunk of a single pulmonary vein was noted on the left side of the LA. Many investigators reported similar findings, which are compared in Table 1. Brantigan et al. (1952), while performing surgery, observed a common trunk pulmonary vein more frequently on the left side eight times and six times on the right side. Patients that present with common trunk PV are asymptomatic and accidentally found during imaging studies and surgeries. Since it has a regular drainage pattern into the LA, no vascular shunt is produced and it does not require surgery. Few authors have reported that the common trunk vein mimics scimitar syndrome, pulmonary nodules, pulmonary varices and pulmonary arteriovenous malformations. (Benfield, 1971; Hasuo, 1981). Differentiating common trunk veins from other pathologies is essential, as anomalous veins do not require treatment.

Yamashita et al. (2000) reported that PV carries a high risk of spreading tumor cells from the primary site of lung carcinoma, which must be interrupted first during lobectomy to prevent metastasis. Misinterpretation of radiograph images may often be encountered due to anatomical variations, which may mislead clinical diagnosis. The dimensions of the hilar structures were primarily described by the pulmonary arteries, with little contribution by the superior pulmonary veins in the imaging studies. Therefore, anatomists and radiologists must know about the variant pulmonary vessels, which would be helpful for academic teaching and diagnostic and therapeutic procedures (Saha, 2019).

CONCLUSIONS

The variations seen in our case report would be additional data for the existing document and helpful in academic teaching. Mapping of pulmonary venous anatomy is essential for clinical diagnosing and planning surgical and catheter-based interventions like radiofrequency ablation, pulmonary resections and pulmonary vein catheterizations. Knowledge of pulmonary venous variations before surgical procedures helps decrease the incidence of unexpected intraoperative complications.

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REFERENCES

BENFIELD JR, GOTS RE, MILLS D (1971) Anomalous single left pulmonary vein mimicking a parenchymal nodule. *Chest,* 59(1): 101-103.

BRANTIGAN OC (1952) Anomalies of the pulmonary veins: their surgical significance. *Diseases of the Chest,* 21(2): 174-178.

CRONIN P, KELLY AM, DESJARDINS B, PATEL S, GROSS BH, KAZEROONI EA, ORAL FMH, CARLOS RC (2007) Normative analysis of pulmonary vein drainage patterns on multidetector CT with measurements of pulmonary vein ostial diameter and distance to first bifurcation. *Acad Radiol*, 14(2): 178-188.

HASUO K, NUMAGUCHI Y, KISHIKAWA T, IKEDA J, MATSUURA K (1981) Anomalous unilateral single pulmonary vein mimicking pulmonary varices. *Chest*, 79(5): 602-604.

HEALEY Jr JE (1952) An anatomic survey of anomalous pulmonary veins: their clinical significance. *J Thorac Surg,* 23: 433-444.

LARSEN'S (2009) *Human Embryology*. 5th edition. Churchill Livingstone, New York, pp 280-284.

LYEN S, WIJESURIYA S, NGAN-SOO E, MATHIAS H, YEONG M, HAMILTON M, MANGHAT N (2017) Anomalous pulmonary venous drainage: a pictorial essay with a CT focus. *J Congenit Heart Dis,* 1: 7.

MAROM EM, HERNDON JE, KIM YH, MCADAMS HP (2004) Variations in pulmonary venous drainage to the left atrium: implications for radiofrequency ablation. *Radiology,* 230(3): 824-829.

RAJESHWARI MS, RANGANATH P (2012) Variations in draining patterns of right pulmonary veins at the hilum and an anatomical classification. *Int Schol Res Network*, (2012): 786549.

SAHA A, SRIMANI P (2019) Comprehensive study of pulmonary hilum with its clinical correlation. *Ann Anat*, 222: 61-69.

SCHWARTZMAN D, LACOMIS J, WIGGINTON WG (2003) Characterization of left atrium and distal pulmonary vein morphology using multidimensional computed tomography. *J Am Coll Cardiol*, 41(8): 1349-1357.

SHUKLA L, GAUR N, SONI G, DHAL U (2012) Variation in number and drainage pattern of pulmonary veins draining into the left atrium. *J Anat Soc India,* 61(1): 5-8.

STANDRING S (2016) *Gray's Anatomy. The Anatomical Basis of Clinical Practice.* 41st edition. Elsevier, UK, pp 960-961.

SUGIMOTO S, IZUMIYAMA O, YAMASHITA A, BABA M, HASEGAWA T (1998) Anatomy of inferior pulmonary vein should be clarified in lower lobectomy. *Ann Thorac Surg,* 66(5): 1799-1800.

YAMASHITA JI, KURUSU Y, FUJINO N, SAISYOJI T, OGAWA M (2000) Detection of circulating tumour cells in patients with non–small cell lung cancer undergoing lobectomy by video-assisted thoracic surgery: A potential hazard for intraoperative hematogenous tumour cell dissemination. *J Thorac Cardiovasc Surg*, 119(5): 899-905.