

## A Study of Pulmonary Vein Variations and Their Drainage Pattern into the Left Atrium

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### ABSTRACT

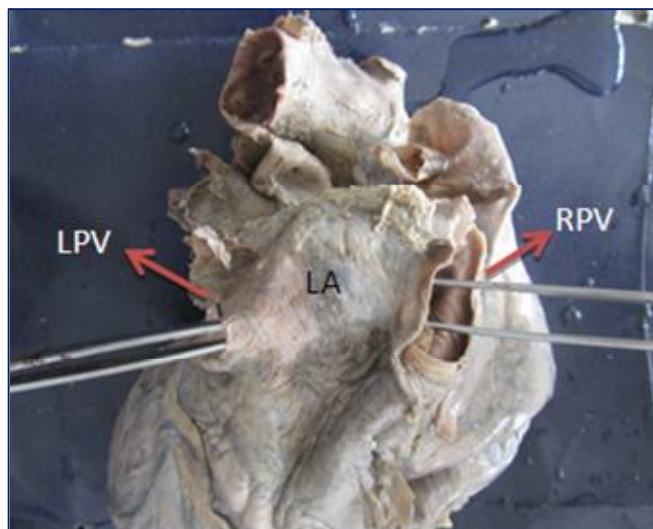
Pulmonary veins carry oxygenated blood from the lungs to the left atrium. Variations are quite common in the number and pattern of drainage. Clinically Pulmonary veins have been demonstrated to often play an important role in generating atrial fibrillation. The knowledge of variations is of importance in cardio-thoracic surgeries and radiological procedures. The present study was undertaken to evaluate the incidence of variation in the number of pulmonary veins and their drainage pattern into the left atrium. A total of 41 human hearts were studied irrespective of sex. The hearts were procured from formalin fixed adult cadavers from the dissection hall of SIMS, Hyderabad. Out of 41 specimen studied, variation in the no of pulmonary veins and the number of ostia was found in 12 (29.3%) cases. The normal pattern of drainage was observed in 32 (78.04%) hearts in right pulmonary veins and 34 (82.9%) in left pulmonary veins. Variations found in the present study helped us to come to a conclusion on an anatomical classification depending on the number and drainage pattern of Pulmonary veins into the left atrium.

**Keywords:** Pulmonary veins, pulmonary ostia, radiofrequency ablation, Atrial fibrillation

**Abbreviations:** PV - Pulmonary veins, PO - Pulmonary ostia, RPV - Right pulmonary vein, LPV - left pulmonary vein

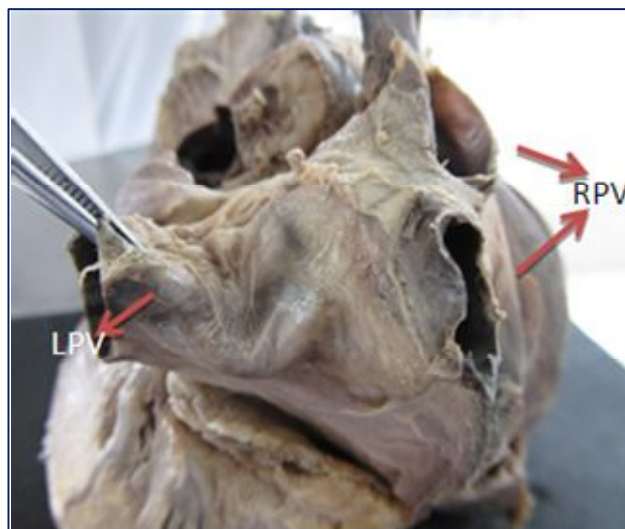
### 1. INTRODUCTION

The oxygenated blood is returned to left atrium by four pulmonary veins, two from each lung and these veins open into the left atrium via two separate ostia, on either sides (Standring, 2000). Initially during the development of left atrium, a single embryonic pulmonary vein develops as an outgrowth from its posterior wall. On further development,



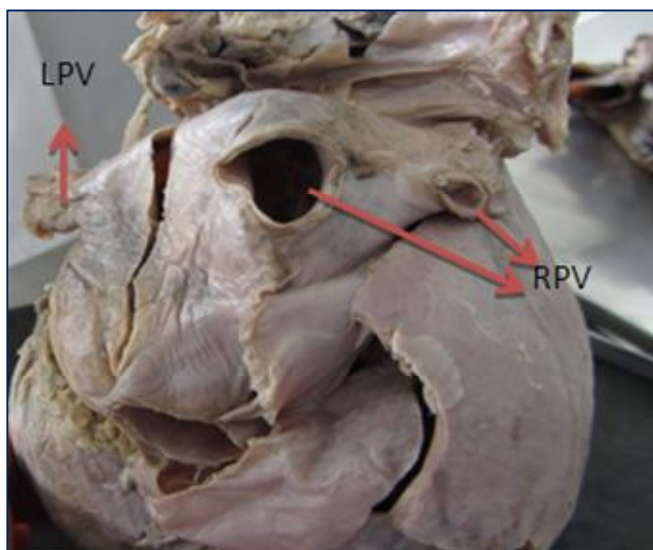
**Figure 1**

2 PV: 1 on right, 1 on left; 2 PO: 1 on right, 1 on left



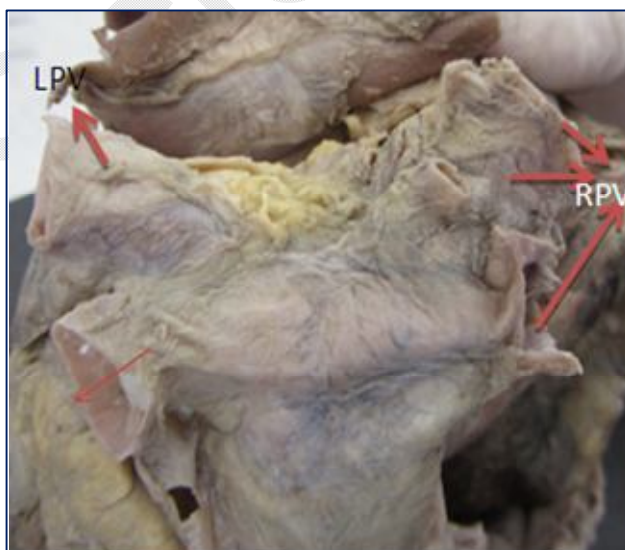
**Figure 2**

3 PV: 2 on right, 1 on left; 3 PO: 2 on right, 1 on left



**Figure 3**

4 PV: 3 on right, 1 on left; 3 PO: 2 on right, 1 on left



**Figure 4**

5 PV: 3 on right, 2 on left; 5 PO: 3 on right, 2 on left

**Table 1**

Shows the number of pulmonary veins draining into left atrium

|       | NUMBER OF PULMONARY VEINS |           |          |         |
|-------|---------------------------|-----------|----------|---------|
|       | 1                         | 2         | 3        | 4       |
| RIGHT | 3 (7.3%)                  | 31(75.6%) | 6(14.6%) | 1(2.4%) |
| LEFT  | 5 (12.1%)                 | 35(85.3%) | 1(2.4%)  | NIL     |

the pulmonary veins and its branches are incorporated into the left atrium. So at the end of the embryonic period independent four pulmonary veins drain into left atrium (Sadler, 2004). However variations in the number and drainage pattern of pulmonary veins are often observed. Pulmonary venous anatomy and relationship between pulmonary veins and left atrium is of importance in cardiothoracic surgeries and procedures like radiofrequency

**Table 2**

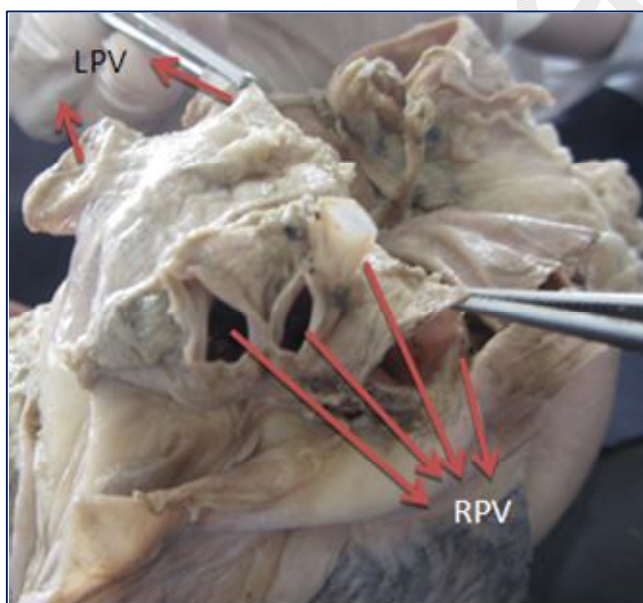
Shows the drainage pattern of pulmonary veins into left atrium

| NO. OF PULMONARY VEINS | NO OF OSTIA | RIGHT PULMONARY VEINS | LEFT PULMONARY VEINS |
|------------------------|-------------|-----------------------|----------------------|
| 1                      | 1           | 3(7.2%)               | 5(12.1%)             |
| 2                      | 1           | NIL                   | 1(2.4%)              |
| 2                      | 2           | 31(75.6%)             | 35(82.9%)            |
| 3                      | 1           | 1(2.4%)               | NIL                  |
| 3                      | 2           | 3(7.2%)               | NIL                  |
| 3                      | 3           | 2(4.8%)               | 1(2.4%)              |
| 4                      | 2           | 1(2.4%)               | NIL                  |

**Table 3**

comparison of number of pulmonary veins on right &amp; left side

| NUMBER OF PULMONARY VEINS | Shukla et al. (2012) | Present study  |
|---------------------------|----------------------|----------------|
|                           | Percentage (%)       | Percentage (%) |
| RIGHT                     |                      |                |
| 1                         | 3.4                  | 7.3            |
| 2                         | 75.9                 | 75.6           |
| 3                         | 17.2                 | 14.6           |
| 4                         | 3.4                  | 2.4            |
| LEFT                      |                      |                |
| 1                         | 17.2                 | 12.1           |
| 2                         | 79.3                 | 85.3           |
| 3                         | 3.4                  | 2.4            |
| 4                         | NIL                  | NIL            |

**Figure 5**

6 PV: 4 on right, 2 on left; 6 PO: 4 on right, 2 on left

ablation for treatment of atrial fibrillation, cardiac valve replacement, pulmonary lobectomy etc. Earlier pulmonary vein approach for catheter ablation of atrial fibrillation was an experimental procedure but over a last decade it has emerged as the most common ablation performed in many electrophysiology laboratories throughout the world (Calkins, 2008). In the initiation and maintenance of atrial fibrillation pulmonary veins and posterior part of left atrium play a critical role. So these reasons necessitate detailed and thorough knowledge of pulmonary venous anatomy. Few studies are available on these variations and that too radiological and it has several limitations. Post-mortem examination is considered so far as the best standard for this type of study, but such data are rarely available (Marom, 2004). Therefore, the present study was undertaken on cadavers with the aim to evaluate and classify the variations in the number of pulmonary veins draining into the left atrium and also to compare the variations on right and left side.

## 2. MATERIAL AND METHODS

A total of 41 human hearts were studied irrespective of sex. The hearts were procured from formalin fixed adult cadavers from the dissection hall of SIMS, Hyderabad. The number of Pulmonary veins was seen close to the heart from external aspect and the drainage pattern was studied by giving a midline incision along posterior wall of left atrium.

**Table 4**

Shows the comparison of drainage pattern of right pulmonary veins

| NO. OF PULMONARY VEINS | NO. OF OSTIA | Marom et al. (2004) | Shukla et al. (2012) | Present study |
|------------------------|--------------|---------------------|----------------------|---------------|
|                        |              | Percentage(%)       | Percentage(%)        | Percentage(%) |
| 2                      | 2            | 50                  | 75.9                 | 75.6          |
| 3                      | 2            | 21                  | 10.3                 | 7.2           |
| 1                      | 1            | 2                   | 3.4                  | 7.2           |
| 3                      | 3            | 24                  | 6.9                  | 4.8           |
| 4                      | 2            | NIL                 | NIL                  | 2.4           |
| 3                      | 1            | NIL                 | NIL                  | 2.4           |
| 4                      | 4            | 3                   | 3.4                  | NIL           |
| 6                      | 5            | 1                   | NIL                  | NIL           |

**TABLE 5**

Shows the comparison of drainage pattern of left pulmonary veins

| NO. OF PULMONARY VEINS | NO. OF OSTIA | Marom et al. (2004) | Shukla et al. (2012) | Present study  |
|------------------------|--------------|---------------------|----------------------|----------------|
|                        |              | Percentage (%)      | Percentage (%)       | Percentage (%) |
| 2                      | 2            | 86                  | 79.3                 | 82.9           |
| 1                      | 1            | 14                  | 17.2                 | 12.1           |
| 2                      | 1            | NIL                 | NIL                  | 2.4            |
| 3                      | 3            | NIL                 | NIL                  | 2.4            |
| 3                      | 2            | NIL                 | 3.4                  | NIL            |

**Table 6**

Classification of drainage pattern of pulmonary veins

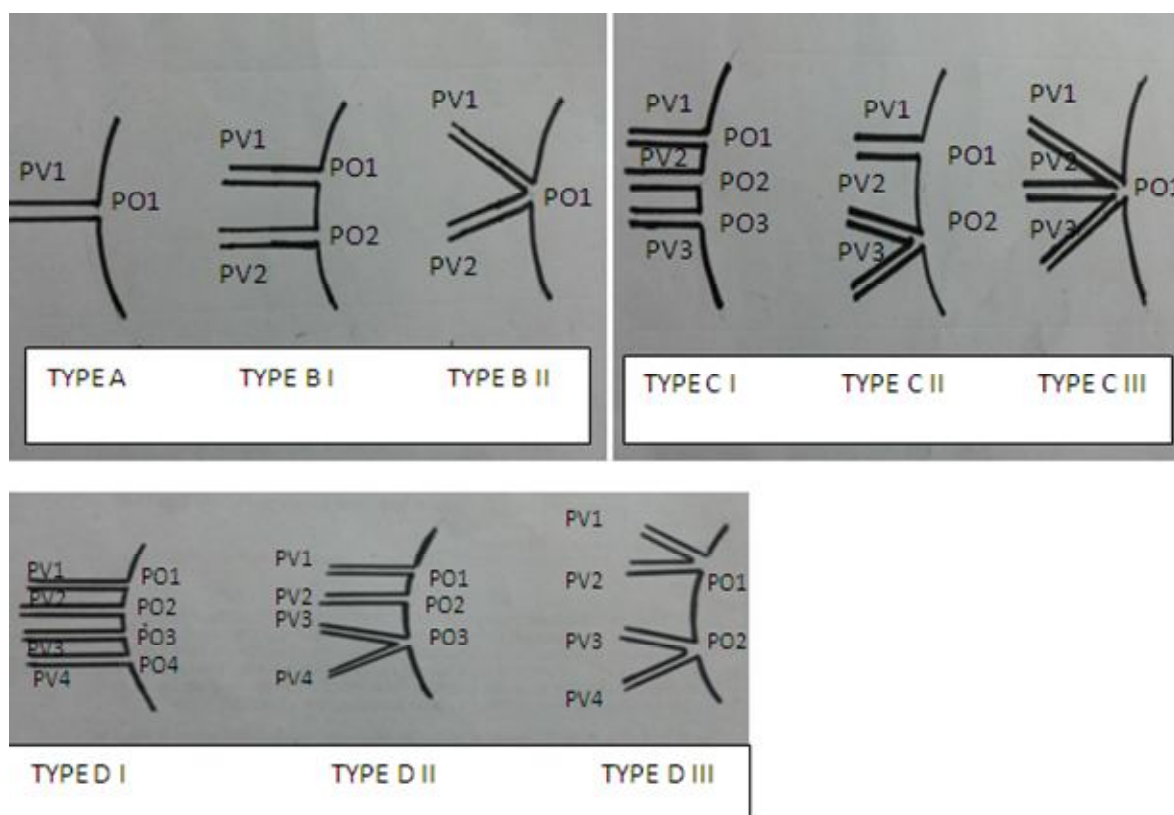
(PV=pulmonary veins, PO=pulmonary ostia)

| RIGHT/LEFT | TYPE           |
|------------|----------------|
| TYPE A     | 1 P WITH 1 PO  |
| TYPE B I   | 2 PV WITH 2 PO |
| TYPE B II  | 2 PV WITH 1 PO |
| TYPE C I   | 3 PV WITH 3 PO |
| TYPE C II  | 3 PV WITH 2 PO |
| TYPE C III | 3 PV WITH 1 PO |
| TYPE D I   | 4 PV WITH 4 PO |
| TYPE D II  | 4 PV WITH 3 PO |
| TYPE D III | 4 PO WITH 2 PO |

### 3. RESULTS

Out of 41 specimens studied, variation in the number of pulmonary veins and the number of ostia was found in 12 cases (29.3%). Out of 12 specimens with variations (Figures 1 to 5), 8 hearts (66.6%) showed variations either on right side or on left side and 4 (33.3%) hearts showed variations on both sides. On right side the most common variation observed in the number of pulmonary veins was 3 pulmonary veins in 6 cases(14.6%) followed by 1 pulmonary vein in 3 cases (7.3%). While on left side most common variation observed was 1 pulmonary vein in 5 cases (12.1%). Followed by 3 pulmonary veins in 1 case (2.4%), (Table 1). The normal pattern of drainage that is 2 pulmonary veins with 2 pulmonary ostia was observed in 31 hearts (78.1%) on right side and 34 hearts (82.9%) on left side. The most common variation in drainage pattern on right side was 3 pulmonary veins with 2 pulmonary ostia and 1 pulmonary vein with 1 pulmonary ostia in 3 cases each (7.2%). On left side the most common variation in drainage pattern was 1 pulmonary vein with 1 pulmonary ostia in 5 cases (12.1%), (Table 2).





**Figure 6**  
Schematic representation of drainage pattern of pulmonary veins

#### 4. DISCUSSION

Earlier the variations in pulmonary venous drainage were thought to be rare and only few cases were reported by Alfke (1995), Collins (1985), Benfield (1971), Hasuo (1981). Pulmonary veins play an important role as a triggering focus of the electrical activity in atrial fibrillation. So over last decade some radiological but very few cadaveric studies were conducted. In a study conducted by Shukla et al. (2012) on 29 hearts, 13 hearts showed variation in the number of pulmonary veins. The most common being 3 pulmonary veins in 17.2% cases on right side and 1 pulmonary vein in 17.2% cases on left side. This coincides with the present study where most common variation in number of pulmonary veins was 3 in 14.6% cases on right side and 1 in 12.2 % cases on left side (Table 3). Normal drainage pattern observed by Shukla et al. (2012) on right side was found in 75.9% cases and most common variation found was 3 pulmonary veins with 2 pulmonary ostia in 10.3% cases (Table 4). On left side normal drainage pattern was observed in 79.3% cases and most common variation found was 1 pulmonary vein with 1 pulmonary ostia in 12.1% cases (Table 5). The results of present study coincide with the findings of the study done by Shukla et al. (2012).

In present study on right side 4 pulmonary veins with 2 pulmonary ostia and 3 pulmonary veins with 1 ostia was found in 2.4% cases each. On left side 2 pulmonary veins with 1 ostia and 3 pulmonary veins with 3 ostia were observed in 2.4% cases each. All these observations were not reported in earlier studies. Marom et al. (2004) studied the anatomy of pulmonary veins in 201 patients by using computed tomography. This study revealed normal drainage pattern in 50% hearts on right side and 86% hearts on left side. Whereas the most common variation on right side is 3 pulmonary veins with 3 pulmonary ostia in 24% cases (table 4) and 1 pulmonary vein with 1 pulmonary ostia on left side in 14% cases (Table 5). Ho et al. (2001) dissected 20 human hearts and reported a single ostium for pulmonary veins in 2 hearts on right side and 3 hearts on left side. A study done by Niculescu et al. (2006) on 100 heart specimen showed normal drainage pattern in 70% of hearts and rarely 3 or 5 orifices were observed.

On the basis of observations in the drainage pattern of pulmonary veins found in the present study a flexible classification system is suggested. This classification easily describes the variations. It will be of great help to clinicians to evaluate pulmonary venous anatomy prior or during the procedure involving these veins and will also facilitate communication with clinical reference. Depending upon the number of pulmonary veins they are classified into type

A to type D. If the pulmonary ostia is equal to the number of pulmonary veins, it is placed under subtype I and if the pulmonary ostia is less than the number of pulmonary vein it is placed under subtype II, III & IV (Table 6 & Figure 6).

## 5. CONCLUSION

Results of the present study confirm that there are substantial variations in pulmonary venous anatomy but it needs a detailed study before performing any procedure involving pulmonary veins. These veins play a pivotal role in atrial fibrillation which is treated by ablation. Therefore, for successful ablations and surgeries without any complication, it is very important to have a detailed knowledge of pulmonary venous anatomy.

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