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Atypical Pulmonary Venous Drainage Associated with Patent Foramen Ovale of Heart: A Case Report

Lorenzo Martin*, Joaquín Silva & Augusto Garrido

Departamento de Anatomía
Facultad de Medicina
Universidad de la República
del Uruguay

Correspondence
Lorenzo Martin
Departamento de Anatomía
Facultad de Medicina de la
Universidad de la República
del Uruguay
Uruguay

E-mail:martinlorenzo262@gmail.com

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ABSTRACT: Pulmonary venous drainage can exhibit anomalies of significant clinical relevance, often associated with interatrial septal defects. During a cadaveric dissection at the Facultad de Medicina, Universidad de la República, an anomalous pulmonary venous pathway was identified. This variant replaced the right superior pulmonary vein and drained into the superior vena cava (SVC) instead of the left atrium. The anomalous pulmonary veins at the right hilum of lung were carefully dissected, along with the heart (right and left atria), in a female cadaver weighing 45 kg and preserved in formaldehyde. Dissection tools, a digital caliper for measurements, and a Nikon D500 camera for photographic documentation were employed. Five anomalous pulmonary venous branches were identified from the right lung lobe, with lengths ranging from 5 mm to 18 mm, draining into the SVC. Additionally, a patent foramen ovale of heart was observed in the cardiac anatomy. Anomalies in pulmonary venous drainage have critical implications in clinical and surgical settings. A thorough anatomical understanding is essential for any intervention involving the pulmonary vasculature. Several classifications exist for anomalous pulmonary venous drainage, with that of Kirklin and Barret-Boyes being among the most widely referenced. The findings in this case correspond to Type I of this classification, though notably associated with a patent foramen ovale of heart rather than a venous sinus, which is more commonly observed in Type I cases.

KEY WORDS: pulmonary veins; anomalous pulmonary; atrial septal defects; anatomy; foramen ovale of heart.

INTRODUCTION

The pulmonary veins, which converge at the level of the hilum of lung, primarily drain oxygenated blood resulting from gas exchange in the lungs, as well as partially deoxygenated blood from subpleural veins and peripheral bronchial veins, into the left atrium. Typically, there are two pulmonary veins on each side, superior and inferior, both on the right and left.

Pulmonary veins originate as continuations of the intrasegmental and perisegmental perialveolar and perilobular venous networks, ultimately merging to form the intersegmental veins. These veins drain blood from more than one segment and run along the periphery of the pulmonary segments. The intersegmental veins then join to form the lobar veins, which, through anastomoses, contribute to the formation of the pulmonary veins (Testut *et al*., 1988; Latarjet & Ruiz Liard, 2005).

Anomalous pulmonary veins were first described by Winslow in 1739 (Muñoz Castellanos *et al*., 2008). Since then, and with the advent of various diagnostic techniques, the identification of different types of pulmonary venous anomalies has increased significantly.

Several pathogenic mechanisms have been proposed, all related to abnormal embryological development due to three primary causes (Muñoz Castellanos *et al*., 2008). One of the most accepted theories involves the failure or absence of formation of the common pulmonary vein from the left atrium, which is the secondary connection of the pulmonary veins during development. This failure results in the persistence of primary connections between the pulmonary veins and the right cardinal vein (which gives rise to the superior vena cava and the azygos arch), the left cardinal vein, or the umbilico-vitelline venous system (Muñoz Castellanos *et al*., 2008) Two other

possible mechanisms have also been suggested: in one, the pulmonary venous trunk originates from the roof of the right atrium; in the other, described by Wilson (Muñoz Castellanos *et al*., 2008), the sinus venosus becomes integrated into the roof of the right atrium due to ectopic formation of the interatrial septum, which is deviated to the left.

The presence of anomalous pulmonary veins can be associated with congenital heart defects, most notably interatrial septal abnormalities, and may lead to high morbidity and mortality both prenatally and postnatally, especially when the anomalous connection involves both lungs (Michielon *et al*., 2002).

Understanding the incidence and anatomical arrangement of anomalous pulmonary veins is essential for cardiac and thoracic surgeons when approaching procedures involving the pleuropulmonary fields. Awareness of these variations is critical in selecting the appropriate surgical technique, as certain approaches are more likely to result in conduction disturbances or potentially severe hemorrhages if these anomalies are inadvertently injured due to unrecognized anatomical variations (Michielon *et al*., 2002).

MATERIAL AND METHOD

During a routine dissection at the Department of Anatomy, Faculty of Medicine, Universidad de la República, Montevideo, Uruguay, anomalies in the pulmonary venous drainage were identified in a female cadaver, 80 years of age and weighing 45 kg. This cadaver, like all those used in the Department of Anatomy at the Faculty of Medicine of Universidad de la República, was obtained through voluntary body donation for educational and research purposes.

The dissection was performed using dissection forceps (standard, iris, and curved), Metzenbaum and straight scissors, a grooved probe, and Farabeuf retractors. For measurements, a digital caliper and microrulers were used. Photographic documentation was carried out with a Nikon D500 camera. Data were compiled using Microsoft Excel 2010.

A sternotomy was performed to access the thoracic cavity. Dissection then proceeded to the pulmonary hila, where venous anomalies were observed exclusively on the right side. The number of anomalous main pulmonary veins was recorded, along with their origin and terminal drainage site. These veins were carefully skeletonized, and their lengths and calibers were measured. They were numbered sequentially from superior to inferior.

In a second step, an incision was made in the right atrium, extending from the superior vena cava (SVC) to the inferior vena cava (IVC), to assess the presence of any abnormalities in the interatrial septum.

A literature search was conducted on April 6, 2025, using the databases PubMed, Scopus, Google Scholar, and SciELO. The search included both MeSH terms ("pulmonary veins", "scimitar syndrome", "atrial septal defects") and non-MeSH terms such as "partial anomalous pulmonary veins", "total anomalous pulmonary veins", and "anomalous pulmonary venous return".

RESULTS

Five venous branches were identified arising from the right hilum of lung, draining oxygenated blood from the upper and middle lobes of the right lung into the superior vena cava (SVC), and subsequently into the right atrium. The first three veins drained the upper lobe, while the last two drained the middle lobe (Figs. 1 to 5).

It was observed that the third and fourth branches converged into a common trunk, which ultimately drained into the SVC. The fifth branch corresponded to a common trunk that trifurcated into three branches, each draining separately into the SVC.

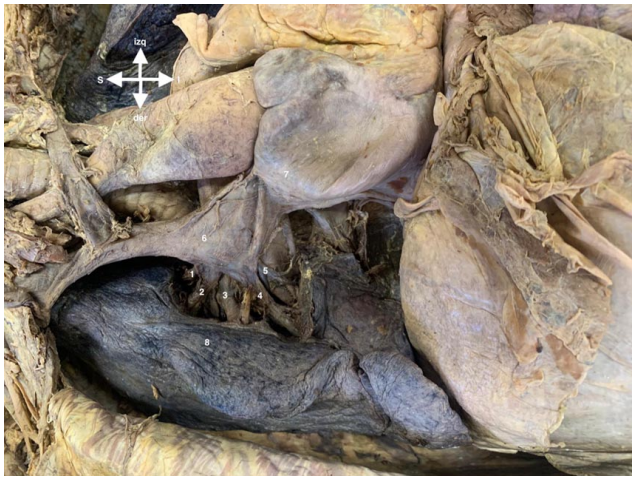


Fig. 1. Anterior view of the right hilum of lung. 1: first branch of the right superior pulmonary vein (RSPV). 2: second branch of RSPV. 3: third branch of RSPV. 4: common trunk formed by the confluence of branches 3 and 4 of RSPV. 5: common trunk or fifth branch of RSPV. 6: superior vena cava. 7: right atrium. 8: right lung.

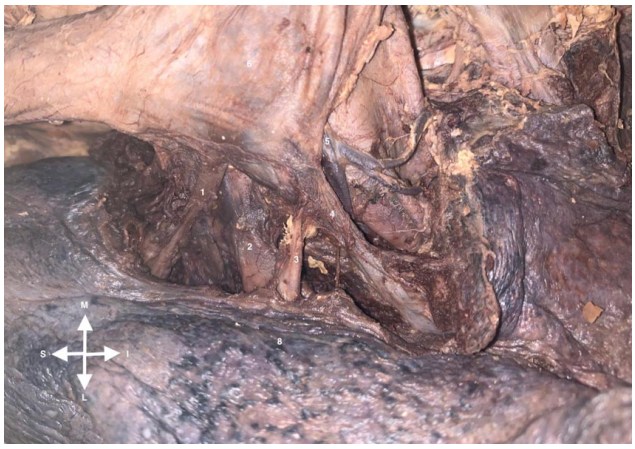
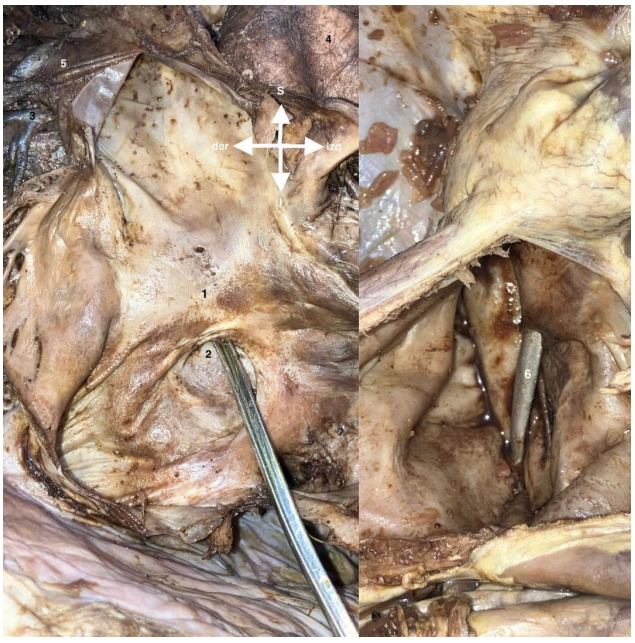


Fig. 2. Anterior view of the right hilum of lung. 1: first branch of RSPV. 2: second branch of RSPV. 3: third branch of RSPV. 4: common trunk formed by the confluence of branches 3 and 4 of RSPV. 5: common trunk or fifth branch of RSPV. 6: superior vena cava. 8: right lung.

Fig. 3. Right anterolateral view of the right hilum of lung. 1: first branch of RSPV. 2: second branch of RSPV. 3: third branch of RSPV. 4: common trunk formed by the confluence of branches 3 and 4 of RSPV. 5: common trunk or fifth branch of RSPV. 6: superior vena cava. 8: right lung.

Fig. 5. Anterior view showing the interior of the right atrium on the left; on the right, demonstration of a patent foramen ovale of heart via probe passage. 1: right atrium. 2: patent foramen ovale of heart. 3: common trunk or fifth branch of RSPV. 4: ascending aorta. 5: superior vena cava. 6: grooved probe passing through the patent foramen ovale of heart.

Fig. 4. Right anterolateral view of the right hilum of lung, exposing its intrapulmonary segments. 1: first branch of RSPV. 2: second branch of RSPV. 3: third branch of RSPV. 4: common trunk formed by the confluence of branches 3 and 4 of RSPV. 5: common trunk or fifth branch of RSPV. 6: superior vena cava. 8: right lung.



Regarding measurements, the longest branch was the second, measuring 18 mm in length, while the branch with the greatest diameter was the fifth (the common trunk), with a diameter of 6 mm (Table 1).

At the level of the interatrial septum, a patent foramen ovale of heart was observed, with no other interatrial septal defects noted.

Table 1. Number and measurements of anomalous pulmonary veins. Veins were numbered in ascending order from superior to inferior.

Vein description	Length (mm)	Diameter (mm)
1. First branch	7	3
2. Second branch	18	5
3. Third branch	1	4
4. Fourth branch	13	4
Common trunk from branches third and fourth confluence	5	3
5. Common trunk or fifth branch	14	6
First branch	7	2
Second branch	14	2

DISCUSSION

Several important studies have highlighted the frequency of pulmonary venous drainage anomalies in specific populations over time. Since the advent of cardiac catheterization and the surgical repair of interatrial septal defects, the diagnosis of such anomalies has increased (Hickie *et al*., 1956).

These anomalies are commonly associated with other cardiac malformations, such as atrial septal defects and conduction disturbances. In fact, they are frequently encountered during interatrial septal defect repair, as both conditions often present with similar clinical features (Gustafson *et al*., 1995).

Anomalous pulmonary venous drainage refers to the drainage of pulmonary veins into the right atrium or its tributaries. It is considered total when involving both lungs and partial when only one lung is affected (Alsoufi *et al*., 2007), as in our case.

These drainage anomalies can vary, including drainage into the coronary sinus or, as seen in scimitar syndrome, into the inferior vena cava (Muñoz Castellanos *et al*., 2007).

The modified Darling classification is useful for categorizing partial anomalous pulmonary venous connections into supradiaphragmatic (which can be further subdivided into supracardiac, draining into the SVC, azygos arch, or vertical vein; cardiac, into the coronary sinus or morphological right atrium; and infracardiac, into the suprahepatic portion of the IVC), infradiaphragmatic, and mixed types (Muñoz Castellanos *et al*., 2007, 2008). Our case represents a clear example of a supradiaphragmatic supracardiac anomalous pulmonary venous connection draining into the SVC.

The Kirklin and Barret-Boyes classification provides a more detailed categorization, identifying five types (Table 2). Type I, the most common, involves right pulmonary veins draining into the lower portion of the SVC or at its junction with the right atrium. This anomaly is often associated with persistent venous sinus defects in the interatrial septum. Interestingly, in our case, the right pulmonary veins drained into the inferior part of the SVC, but the interatrial septal defect consisted of a patent foramen ovale of heart, not a sinus venosus defect (Alsoufi *et al*., 2007).

The distribution of anomalous pulmonary veins is variable. Drainage anomalies most commonly involve the

Table 2. Kirklin and Barret Boyes classification (Alsoufi *et al*., 2007).

Type	Description
1	Partial anomalous pulmonary venous connection of the right pulmonary veins to the superior vena cava. The anomalous veins drain into the lower part of the SVC or at its junction with the right atrium. Frequently associated with sinus venosus defects in the interatrial septum.
2	Anomalous connection in which the pulmonary veins drain partially, but directly, into the right atrium.
3	Scimitar syndrome: the anomalous pulmonary veins drain partially or totally from the right lung into the inferior vena cava or at its junction with the right atrium.
4	Left pulmonary veins partially connect to the left brachiocephalic vein via an anomalous vertical vein.
5	Bilateral partial anomalous pulmonary venous drainage, usually with an intact interatrial septum. Some right superior pulmonary veins drain into the SVC, and some left pulmonary veins drain into the left brachiocephalic vein via an anomalous vertical vein.

upper lobe of the right lung, followed by the middle lobe, and, less frequently, the entire lung (Muñoz Castellanos *et al*., 2007). Our case is consistent with this pattern, as the anomalous veins drained the upper and middle lobes.

This topic is of crucial importance since different surgical techniques are employed to address these anomalies. For instance, in Type I of the Kirklin and Barret-Boyes classification, approaches may include division of the SVC with the placement of an autologous graft connecting the anomalous veins to the left atrium, or the use of a "double patch" technique (Alsoufi *et al*., 2007). These highly complex procedures, particularly the latter, often result in the need for pacemaker implantation (Alsoufi *et al*., 2007), due to the association with disruption and repair of the crista terminalis, which can lead to reentry arrhythmias (Michielon *et al*., 2002). Additionally, these procedures are associated with potential complications such as SVC or pulmonary vein obstruction (Alsoufi *et al*., 2007).

CONCLUSION

A thorough anatomical understanding of the pulmonary veins and their variations is essential for both pathological assessment and surgical planning in thoracic procedures.

In this case, the anomalous venous drainage was limited to the upper and middle lobes of the right lung, corresponding to a dependency on the right superior pulmonary vein.

This variation gains further relevance due to its drainage into the right side of the heart, disrupting the typical separation of systemic and pulmonary circulations, thus adding to the clinical interest of the case.

The interatrial septal defect observed, namely a patent foramen ovale of heart, does not theoretically align with current classifications of pulmonary venous drainage anomalies.

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Conflicts of Interest: The authors declare no conflicts of interest.

Ethical Considerations: The cadaveric material used in this study was obtained through the voluntary body donation program of the Faculty of Medicine, Universidad de la República, Uruguay. This program is approved and overseen by the institution's Department of Bioethics.

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