Acquired unilateral pulmonary vein atresia in a 3-year-old boy

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Abstract While unilateral pulmonary venous atresia (UPVA) most commonly presents as an extremely rare late embryological defect resulting in complete occlusion or absence of the PV pathway, it may also be an acquired pathology. We present a 3-year-old boy who presented with mild respiratory distress. Neonatal echocardiographic investigations revealed normal mediastinal anatomy and pulmonary vasculature with a bicuspid aortic valve. However, follow-up Doppler investigation revealed a pulmonary artery size difference with minimal forward flow and reverse flow during diastole. Absence of the left pulmonary veins and the presence of collaterals draining to the innominate vein confirmed the diagnosis of acquired UPVA. Our case represents the first case of acquired UPVA in conjunction with a normally functioning bicuspid aortic valve. The Doppler flow patterns discussed might be of significant interest to pediatricians, cardiologists and imaging specialists. These findings suggest that acquired UPVA should be considered in the differential diagnosis of

such patients when radiographic and echocardiographic findings may rule out other more common diagnoses. While the management of such a condition remains unclear and conservative management was agreed upon for our patient, the vulnerability of such cases warrants timely diagnosis and routine monitoring.

Keywords Acquired unilateral pulmonary vein atresia · Vanishing vein · Partial anomalous venous drainage · Bicuspid aortic valve

Riassunto Mentre l'atresia polmonare venosa unilaterale (UPVA) più comunemente si presenta come un rarissimo difetto di ritardo embriologico, con conseguente occlusione completa o assenza della PV, può essere anche una patologia acquisita. Presentiamo il caso di un bambino di 3 anni con distress respiratorio lieve. L'ecocardiografia neonatale ha rivelato normale anatomia del mediastino e della vascolarizzazione polmonare, con una valvola aortica bicuspidale. Tuttavia, il follow-up Doppler ha rivelato una differenza di dimensioni dell'arteria polmonare con portata minima e flusso inverso durante la diastole. L'assenza delle vene polmonari di sinistra e la presenza di collaterali con drenaggio nella vena anonima hanno confermato la diagnosi di UPVA acquisita. Il nostro caso rappresenta il primo di UPVA acquisita in combinazione con il normale funzionamento di una valvola aortica bicuspidale. I modelli di flusso Doppler discussi potrebbero essere di interesse significativo per pediatri, cardiologi e specialisti di imaging. Questi risultati suggeriscono che l'UPVA acquisita dovrebbe essere considerata nella diagnosi differenziale di tali pazienti quando i reperti radiografici ed ecocardiografici possano escludere altre diagnosi più comuni. Mentre la gestione di tale condizione non è chiara ed è stato concordato il trattamento conservativo per il nostro paziente, la

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vulnerabilità di tali casi richiede diagnosi tempestiva e monitoraggio di routine.

Introduction

Pulmonary veins (PV) typically drain oxygenated blood from the lungs and follow the course of the pulmonary intersegmental septae before entering the left atrium (LA) of the heart. They typically emerge as four well-differentiated channels at the hilum in 60–70 % of the population; however, atypical anatomical patterns have been documented in approximately 38 % of the population [1, 2].

The severity of pulmonary venous obstructive abnormalities varies based on the timing of failure during embryological development of the cardiovascular system. A failure during very early stages of development of the common pulmonary vein may result in the development of alternative pathways via the umbilico-vitelline or the cardinal systems causing an anomalous pulmonary venous return. Abnormalities at later stages of development may result in cor triatriatum sinister, where either of the atria is divided by a thin membrane resulting in three atrial chambers. Disruptions to the cardiovascular development at very late stages might result in atresia of individual or the common PV [3–6].

Unilateral pulmonary venous atresia (UPVA) is one such extremely rare late embryological defect resulting in complete occlusion or absence of the PV pathway. UPVA is primarily congenital in nature, but may also be acquired [7, 8]. While the severity of symptoms may vary, recurrent pneumonia on the affected side, hemoptysis, pulmonary hypertension and mortality rates of approximately 50 % in untreated patients have been previously reported [9–11]. Timely diagnosis and management are thus crucial. A standard practice in the management of acquired UPVA does not appear to have been adopted, given the variability in case presentation, symptomatology and complexity of the pathology. Here, we aim to discuss one of the first cases of acquired UPVA, and its associated differential diagnosis and management strategy which might be of significant value to imaging specialists, pediatricians and cardiologists. Notably, to the best of our knowledge, this case also represents the first report of acquired UPVA presenting in conjunction with a normally functioning bicuspid aortic valve.

Case report

We present a 3-year-old boy, born at 36 weeks weighing 2,541 g, whose delivery was induced due to oligohydramnios

and pericardial effusion on prenatal ultrasonographic investigation. The patient was monitored in the neonatal intensive care unit after birth due to mild respiratory distress, for which he received continuous positive airway pressure. Routine echocardiographic investigations during this period clearly showed normal bilateral pulmonary artery (PA) and PV anatomy, a non-obstructive bicuspid aortic valve with a small atrial septal defect and normal ventricular function (Figs. 1, 2). The patient did not present with any significant cardiac complications and underwent minimal local surgical intervention over the next 3 years.

Upon follow-up echocardiographic examination to assess bicuspid aortic valve function, the left pulmonary artery (LPA) was incidentally noted to be smaller than the right pulmonary artery (RPA) (6.4 vs. 10.1 mm). Doppler investigation also revealed minor forward flow with significant reverse flow from the LPA to the RPA during diastole, suggestive of high left-sided pulmonary vascular resistance (Fig. 3). Contrary to neonatal echocardiographic findings, the right pulmonary veins (RPVs) had normal drainage into the LA with normal flow, but the left pulmonary veins (LPVs) were not visualized at any angle. A chest radiograph (CXR) revealed engorged appearance of perihilar vessels and a mildly enlarged cardiothymic silhouette. A decrease in left lung size, compensatory hyperinflation of the right lung, and a left mediastinal shift of the heart were noted. Some patchy areas of increased attenuation in the left lung apex were observed as well (Fig. 4). Normal right-sided pulmonary drainage and the absence of the LPVs were further confirmed by magnetic

Fig. 1 A neonatal echocardiogram demonstrating normal pulmonary artery anatomy, with equally sized branches. *PT* pulmonary trunk, *LPA* left pulmonary artery, *RPA* right pulmonary artery

Fig. 2 Color flow image demonstrating normal return and flow pattern through all four pulmonary veins into the left atrium

Fig. 3 Colour flow of pulmonary arteries at follow-up at 3 years of age, showing hypoplastic left-sided pulmonary artery with diastolic flow reversal in the left pulmonary artery. *PT* pulmonary trunk, *LPA* left pulmonary artery, *RPA* right pulmonary artery

resonance angiography (MRA) and cardiac catheterizations (Fig. 5a, b).

Additionally, small bronchial collateral vessels in the left perihilar region were visualized. Angiographic investigation revealed collaterals supplying the left lung from the aorta and the right subclavian artery. Selective artery

wedge angiography showed small collaterals draining to the innominate vein.

Following consultation with the parents, the patient was managed conservatively without administration of any medical or surgical intervention, and remains asymptomatic.

Fig. 4 Chest radiograph demonstrating: **a** a decrease in left lung size; **b** right lung hyperinflation; **c** left mediastinal shift of the heart; and **d** an abnormally low right diaphragmatic dome

Discussion

There are several proposed mechanisms for the obstruction or atresia of PV. Sade et al. [6] reported that venous atresia can be unilateral and can be due to a diaphragm in the hilar region completely occluding all the PVs in the venoatrial junction. The obstructing diaphragm may consist of muscle fibers, connective tissue, and significant intimal fibrous thickening. Individual PVs may also get occluded and

undergo atresia due to localized stenotic segments or the presence of a partially obstructing hilar diaphragm. Histologically, atria of the PVs in such a pathology are often associated with medial hypertrophy and significant intimal fibrosis [12].

The majority of previously reported UPVA cases have been congenital in nature, which is supported by the following considerations [3, 6, 13, 14]:

1. The majority of UPVA presentations are pediatric.
2. There is typically little histological evidence of active inflammation in UPVA cases.
3. The condition often presents alongside other congenital cardiac anomalies (Pourmoghadam et al. [10] reported that 32 % of congenital UPVA patients have accompanied cardiac defects).
4. Similar individual PV obstruction is seen in other anomalous pulmonary venous drainage conditions (e.g., Scimitar syndrome).

Our patient represents one of the few acquired cases of UPVA in the literature, presenting with normal PA and PV anatomy upon initial investigation and experiencing atresia of left-sided PVs upon follow-up. UPVA patients typically present with recurrent pneumonia on the lesioned side, hemoptysis and pulmonary hypertension [9–11]. Notably, our patient remained largely asymptomatic throughout follow-up. We hypothesize that anatomical variations in PV drainage may account for varying severity of signs and symptoms in UPVA patients. The visualization of a collateral system involving the aorta, the right subclavian artery

Fig. 5 a A three-dimensional MRI reconstruction showing the posterior of the heart and the great vessels. Aorta is seen in the midline. The left and right PAs are noted to have a significant size difference. The right PVs are clearly visualized whereas the left PVs

are absent. **b** Magnetic resonance angiograph (MRA) showing normal right-sided pulmonary drainage and the absence of the left PVs. The right lung's silhouette is seen whereas the left lung's silhouette is not, indicating minimal forward flow in the left PA

and the innominate vein in our case suggests adequate blood flow to and drainage from the lesioned lung parenchyma. This may also explain the lack of bronchial vein rupture and bronchial varix formation in our patient, which are considered typical in cases of PV obstruction [15]. Despite the benign course, our patient remains in critical condition, given the risk of collateral vessel rupture and significantly elevated pulmonary pressure. Moreover, although UPVA has been previously reported with various other cardiac anomalies, our patient represents the first ever case of this condition in conjunction with a normally functioning bicuspid aortic valve. The hemodynamic changes as a result of this bicuspid aortic valve with preserved function in conjunction with UPVA in our patient remain unclear, which may further complicate the prognosis.

Intrinsic or extrinsic obstruction of one of the PAs is likely to result in retrograde flow in the lesioned PA and accelerated flow in the other due to elevated unilateral pulmonary pressure. Such echocardiographic and Doppler flow patterns might serve as “red flags” for various differential diagnoses. For instance, postoperative complications, mediastinal tumors, pericardial or mediastinal infections, and intracardiac tumors or thrombi may also present similarly. Our patient did not undergo any surgical intervention prior to diagnosis, ruling out postoperative complications. No thromboembolic causes, mediastinal tumors, mediastinal infections, pericarditis or pericardial effusions were detected upon radiographic and ultrasonographic investigation either. It is important to note that such echocardiographic and angiographic findings may be indicative of other conditions such as bronchopulmonary dysplasia (e.g. right-sided Scimitar syndrome). However, contrary to our patient, the PVs are still likely to be visualized in such cases. Therefore, when other more common diagnoses can be ruled out based on radiographic and echocardiographic investigation, our case suggests that PV atresia should be considered as a plausible diagnosis in patients presenting with the aforementioned flow patterns. Furthermore, MRA, CXR, computed tomography angiography or cardiac catheterization may be used as confirmatory examinations to distinguish UPVA from other possible diagnoses.

Prognosis and appropriate management of such patients may be challenging and ambiguous. Pharmaceutical interventions such as inotropic support with dopamine or epinephrine and primary pulmonary vasodilators may be administered to address severe pulmonary hypertension or edema, respectively. Given the patient’s susceptibility to pulmonary hemorrhaging, especially in the collateral system, the administration of red blood cell transfusion may be crucial. Extreme pharmaceutical measures, such as chemotherapy for patients with pulmonary vein stenosis, have also been studied in infants and children as a means of

modulating intraluminal myofibroblastic cell proliferation at the Boston Children’s Hospital, but its efficacy remains largely unsupported [16].

Despite the aforementioned pharmaceutical interventions, a lack of definitive surgical intervention may leave the patient at a long-term risk of progressive pulmonary hypertension to the unaffected lung and lethal collateral hemorrhage. Various techniques such as anastomosis stenosis repair, traditional venoplasty and sutureless PV repair have been proposed previously, but with little success. While unilateral left-sided pneumonectomy may be considered for managing pulmonary hypertension, such a procedure may increase right-sided cardiac stress [17]. Unilateral or bilateral lung transplantation may facilitate pulmonary hypertension control without such adverse effects, but long-term prospects remain unconvincing [18].

Upon exploring several pharmaceutical and surgical alternatives and consulting with the parents, conservative management with regular monitoring was agreed upon as the most optimal strategy for the time being. Surgical intervention is to be considered at later stages of the patient’s follow-up.

Conclusion

Our case indicates that acquired UPVA should be included in the differential diagnosis of patients presenting with a unilateral PA size difference, retrograde flow in the lesioned PA and accelerated flow in the other. Such Doppler and ultrasonographic observations are especially pertinent to pediatricians, cardiologists and imaging specialists when radiographic and echocardiographic findings may rule out other more common diagnoses. While the management of such a condition remains unclear, timely diagnosis and routine monitoring are critical.

Conflict of interest Mohammed Firdouse, Arnav Agarwal, Lars Grosse-Wortmann, and Tapas Mondal declare that they have no conflict of interest.

Ethical standards The authors confirm that all human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the Helsinki Declaration of 1975 and its late amendments. Additional informed consent was obtained from all patients for which identifying information is not included in this article.

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