Quadricuspid Pulmonary Valve with Fenestration: Cadaveric Findings

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Abstract

Quadricuspid pulmonary valves are rare. Such valves can be associated with other cardiac anatomical anomalies. Here, we present a case of a quadricuspid valve with an additional variant and provide the morphometrics of this anatomical variation. During the routine dissection of an adult male body two anatomical variations were found within the pulmonary trunk. This individual contained a quadracuspid pulmonary valve. In addition, one of the leaflets of this valve contained fenestrations. No additional cardiac anomalies were identified. Knowledge of a quadricuspid pulmonary valve is important to clinicians who review imaging of the heart or treat patients with cardiac conditions.

Keywords: clinical, anatomy, congenital cardiac disease, anatomical variation, pulmonary trunk, quadricuspid pulmonary valve

Introduction

While more attention is usually given to bicuspid semilunar valves in medical literature due to their propensity to stenose, quadricuspid or quadrivalent pulmonary valves (QPVs) are also anatomical irregularities with which physicians have been familiar for a long time; Leonardo da Vinci, in fact, included both bicuspid and quadricuspid sketches of valves alongside the more common three-leaflet variety in the 16th century based off the bodies he evaluated [1]. Previously, it was hard to ascertain actual incidence rates of supernumerary aortic and pulmonary valves because they are often completely functional or subclinical, but now, with improved echocardiography techniques, studying noncomplicated patients is more accessible, and measured incidence rates are becoming more accurate [2]. Current estimates of the incidence of QPVs are about 0.1-0.2% of the general population [3, 4]. QPVs can be categorized by the sizes of the four leaflets: ~60% have three similarly sized leaflets with one smaller leaflet (Hurwitz type-b), ~15% have two similarly sized larger leaflets and two similarly sized smaller leaflets (Hurwitz type-c), ~12% have four equally sized leaflets (Hurwitz type-a), and the rest of the cases have various other relationships between the leaflets’ sizes (Hurwitz types d-g) [3, 5]. Although Hurwitz type-b QPVs are the most common, Hurwitz type-a cases are more often clinically diagnosed and are more associated with pulmonary regurgitation [6]. Interestingly, combining data from two studies, Hurwitz and Davia, it can be seen that of 193 QPVs found at necropsy, only 8 (4%) of them were not fully functional [7]. This is in contrast to quadricuspid aortic valves (QAVs), which while rarer, are insufficient valves about half of the time [7]. However, while QPVs are generally isolated or asymptomatic, sometimes they can be associated with other congenital cardiac abnormalities such as patent ductus arteriosus, atrial or ventricular septal defects, and bicuspid aortic valves [8]. In fact, compared with quadricuspid aortic valves, QPVs are more often coexistent with congenital heart anomaly and valvular stenosis (but less frequently coexistent with coronary artery anomalies and infectious endocarditis) [9].

Case Presentation

During the routine dissection of the heart in an 87-year-old male body, an unusual finding of the pulmonary valve was observed. The individual was formalin fixed and died of natural causes. There was no known history of cardiac pathology. After removing the heart from the thorax, four pulmonary valve leaflets were found. Specifically, a posterior leaflet was present (Figure 1). The arrangement and measurements of each leaflet are seen in Figures 1, 2.
FIGURE 1: Superior view of the internal aspect of the pulmonary trunk noting the four semilunar leaflets and the measurements for each of these. L=left leaflet, A=anterior leaflet, R=right leaflet, P=posterior leaflet.

FIGURE 2: Anterosuperior view of the fenestrated pulmonary valve leaflet (left) and zoomed in view (right).

As one leaflet (left leaflet) in this individual was slightly smaller than the others, it is classified as a Hurwitz type-b valve. Additionally, one of the leaflets (left leaflet) was found to be fenestrated (Figure 2). These fenestrations were found in the anterior most aspect of the valve at its attachment into the internal surface of the pulmonary trunk. The fenestration (entire defect in the leaflet and including each of the smaller windows) was roughly 5x3 mm. The length of the leaflets was made where the length was along the free edge and the width was the maximal length located at the leaflet’s midpoint. The remaining visible morphology of the heart was found to be within normal limits including some mild calcifications within the ascending aorta.
Discussion

Usually, the pulmonary valve has three semilunar leaflets (left, right, and anterior), but sometimes, it can have an abnormal number of leaflets, such as two, four, or more (one pentacuspid case reported in the literature to date) [11, 12]. Recently, Lis et al. [6] revisited the anatomy of the tricuspid pulmonary valve providing several morphometrical and geometrical descriptions. For instance, they reported that the mean intercommissural distance and geometric height (width and length in our study respectively) of the left anterior, right anterior, and posterior leaflets were 17.56±4.25 mm - 15.25±5.10 mm, 17.21±4.27 mm - 15.49±2.79 mm, and 17.62±3.61 mm - 15.69±3.38 mm respectively. Also, the authors identified the presence of fenestrations in all the leaflets of the pulmonary valve with an occurrence of 12.5% [6]. On the other hand, Soleswki et al. [12] documented the histomorphological analysis of a quadricuspid pulmonary valve presented in a 26-year-old male. They found that the leaflet length and height (width and length in our study respectively) of the left anterior, right anterior, posterior, and the additional leaflet were 14.6 mm - 15.0 mm, 13.5 mm - 11.6 mm, 15.3 mm - 13.6 mm, and 5.2 mm - 10.1 mm respectively. Additionally, in this study the thickness of the tissue was measured in selected valve regions obtaining slightly tickier measurements in comparison with ours [12]. The supernumerary leaflets are generally asymptomatic and isolated, also, they can rarely cause dysfunction and more commonly are associated with other congenital cardiac abnormalities [9]. Because of its association with other cardiac abnormalities, understanding the embryology of valvulogenesis and how these abnormalities might arise is critical. Some alleles, such as Egfr (epidermal growth factor receptor) and Ptpn11 (protein tyrosine phosphatase for Shp2 protein), have been demonstrated in animal models as important for only semilunar valvulogenesis, but not for atrioventricular valves [13]. However, QPVs are associated with congenital cardiac anomalies, including atrioventricular valve abnormalities and septal defects; this may be explained by the fact that they all arise from mesenchymal cardiac tissue [8]. Other animal studies have shown that bicuspid variations of the aortic valve are a result of fusion of the valve cushion primordia, and that the early existence of three valve primordia is the norm, even for bicuspid valves [14]. While this latter theory would perhaps explain why bicuspid semilunar valves are more common than quadricuspid valves, it does not in fact give a theory for the formation of quadricuspid valves.

The cushions that give rise to the leaflets of the pulmonary valve are made up of neural crest cells, but the mechanism by which these cushions actually develop into the leaflets of the semilunar valves remains unresolved [15]. While it was previously thought that late gestation signaling was more involved in the neural crest cells’ role, a more recent study involving RockDN and Wnt1 mutants in mouse models suggests that earlier signaling of neural crest cells may be responsible for both bicuspid and quadricuspid valves [16]. By interfering with RockDN signaling, well-defined outflow cushions do not form, or are misplaced: sometimes, the non-coronary leaflet does not form at all, and bicuspid valves appear to result; in other cases, neural crest cells aggregate inappropriately, producing extra cushions that may give rise to supernumerary valves [16]. Therefore, the organization of the neural crest cells may predict the semilunar valve structure, regardless of type.

Declaration

The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind’s overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude [17].

Conclusions

Quadricuspid pulmonary valves tend to be asymptomatic and are commonly related with other congenital cardiac anomalies. Knowledge about this anatomical variation which was also found in this case along with a fenestration in the left leaflet, and the embryological correlation discussed, is important to clinicians treating cardiac conditions or reviewing cardiac images, also, this case is of archival value for future descriptions of these concurrent variations or similar cases.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.
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Author Contributions

Conceptualization: GB, ML, RST. Data acquisition: GB, DS, JI. Data analysis or interpretation: JJC, AC, DS. Drafting of the manuscript: GB, JJC, AC. Critical revision of the manuscript: JI, ML, RST. Approval of the final version of the manuscript: all authors.

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