Morphological Findings in Ebstein's Anomaly

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Summary

This is a report on the anatomical findings of 6 cases of typical Ebstein's anomaly found in a review of 1300 autopsy specimens. In addition 2 cases with pulmonary atresia and 1 with atresia of the malformed tricuspid valve showing morphologically similar anomalies were found, as well as 29 cases with tricuspid valvular dysplasia (21 of them coexisting with pulmonary atresia with intact ventricular septum).

The right ventricle was divided, in each case, in 2 parts separated by the abnormal valvular leaflets. The infundibular septum was very hypoplastic, its antero-medial prolongation forming a morphologically abnormal band superimposed upon the right side of the interventricular septum, ending inferiorly at the base of the anterior papillary muscle. The interventricular septum was thinner than normal, and so was the right ventricular free wall.

A constant finding was a superiorly placed valvular orifice, limited by anterior and septal leaflets. In three cases an apical orifice was found, limited by the septal and posterior leaflets and by a zone of the posterior wall of the right ventricle with no recognizable leaflet insertion.

The leaflets were rather easily identified. The anterior leaflet was demarcated by the 2 commissures of the superior orifice. The septal leaflet attached to the septum along an oblique line. The posterior leaflet, the least differentiated, inserted in the annulus, with its inferior border adherent to the ventricular muscular wall, forming a blind cavity in which chordae tendineae in different stages of development were found.

Microscopic findings included: myocytolysis, substitution of muscle fibers by connective tissue with some small scars, a great deal of capillaries and disorganization of muscle bundles, none of them being constant.

Additional Indexing Words:
Congenital heart disease  Ebstein’s anomaly

The anomaly described by Wilhelm Ebstein in 18661 is a rare congenital heart malformation, the incidence of which has been estimated about 0.5% of all congenital heart anomalies2, although percentages as low as 0.03%...
have been reported.\textsuperscript{31} This anomaly is compatible with a long and relatively symptomless life in many cases,\textsuperscript{4,5} surgical treatment not being indicated.

It has usually been considered that Ebstein's anomaly is only a valvular anomaly, but more recently other authors\textsuperscript{6,7} suggested that Ebstein's anomaly was a part of a general abnormality of the right ventricle and sometimes of the left ventricle. The pathologic anatomy of Ebstein's anomaly has been reported as extremely variable\textsuperscript{8} and it has been suggested\textsuperscript{9} that there may be a spectrum of anomalies of the tricuspid valve in which downward displacement of the valve and valvular dysplasia formed the end points, with a number of combinations of these features forming intermediate lesions.

Review of our cases revealed macroscopic architectural anomalies, some previously not described to our knowledge, and occasional microscopic anomalies confirming the previous findings of other authors pointing to the more general nature of Ebstein's anomaly.

\textbf{Materials}

A review of 1300 autopsy specimens of congenital heart disease in the collections for C.S. "La Paz" (Madrid) and Killingbeck Hospital (Leeds), revealed 9 cases with Ebstein's anomaly (2 of them with pulmonary atresia and one third with atresia of the malformed tricuspid valve). In addition there were 29 cases with findings of tricuspid valvular dysplasia, 21 of them coexisting with pulmonary atresia and intact interventricular septum. Other lesions found in these cases were: pulmonary stenosis (2 cases), TGA (3 cases), VSD (1 case), double outlet right ventricle (1 case), and truncus arteriosus communis (1 case). Most of these cases had varying degrees of adherence of tricuspid valvular structures to the ventricular wall, mainly involving the septal leaflet.

In this paper the 6 cases without pulmonary or tricuspid atresia are reviewed. All showed the typical findings described by Ebstein. All of our patients had died during childhood.

\textbf{Anatomical Findings}

1. \textit{Right ventricle}:

In all cases the right ventricle was divided in 2 parts, separated by the abnormal valvular leaflets: I. The inlet or atrialized chamber, freely communicated with the right atrium but separated from it by a distinct annulus corresponding to the expected location of the basal insertion of the tricuspid valve. This atrialized chamber was very dilated and had a smooth endocardial surface, without trabeculations and with significant fibrosis of the endocardium. Only a small part of its wall is formed by the muscular wall of the right ventricle (at the level of downward displacement of the insertion of the leaflets), the larger part being formed by the abnormal valvular leaflets (Fig. 1). II. The distal chamber was composed of 2 parts: one had the characteristics of an infundibulum (always small in our cases) and the other was placed between the mural aspect of the abnormal leaflets
Fig. 1. Right ventricle has been opened showing the abnormally positioned leaflets separating the proximal, atrialized, chamber of the right ventricle (freely communicated with the right atrium) from the distal chamber, which can be divided in 2 parts: the infundibulum and the cavity shown in the picture, placed between the leaflets and the internal surface of the right ventricular wall, surrounding the lateral and posterior walls of the proximal chamber. AL, SL, and PL: anterior, septal, and posterior leaflets. pm: papillary muscle. Solid triangles mark the expected “normal” line of implantation of the leaflets.

Fig. 2. The infundibular septum was usually hypoplastic and its anterior prolongation formed an abnormal band superimposed upon the right side of the most anterior part of the interventricular septum. Chordae tendineae arose from the septal commissure of the superior orifice and inserted on the inferior end of the abnormal band. i-v: infundibulo-ventricular septum or parietal band. ab: anterior prolongation of the infundibular septum. arrow: chordae tendineae from the septal commissure of the superior orifice inserted onto the infundibular septum.
and the internal surface of the right ventricular muscular wall, thus forming an outer cover for the atrialized chamber in most of its surface (Fig. 1).

The infundibulum was small. The infundibular septum, demarcated by the orifices of the coronary arteries, was hypoplastic, being much shorter and shallower than normal in 5 cases and mildly in 1. No clear limit between infundibular septum and trabecula septomarginalis was found, the anterior prolongation of the infundibular septum forming an abnormal band superimposed upon the right side of the most anterior part of the interventricular septum, and clearly detached from it in 4 cases, whose posterior border received chordae tendineae or direct insertions from the septal leaflet tissue. This abnormal morphology created a symmetrical aspect of both branches of the infundibular septum.

In all cases chordae tendineae from the antero-septal commissure inserted directly or through a small papillary muscle onto the infundibular septum. The anterior prolongation of the infundibular septum received insertions from the septal leaflet in its posterior border and ended inferiorly at the base of a well-defined anterior papillary muscle.

The pulmonary valve was always smaller than the aortic valve and the pulmonary trunk was mildly hypoplastic.

2. Interventricular septum and ventricular walls:

The interventricular septum was thinner than normal, without trabeculations on its right-sided aspect except in the most anterior part, where the abnormal band previously described was found. The thickness of interventricular septum was 3 to 4 mm in each case, while the free wall of the right ventricle measured 2 to 4 mm (being thinner than expected for normal in all except 1 case) and the wall of the left ventricle 7 to 9 mm (considered normal).

In some places of the right ventricle the muscle was hypoplastic and it was possible to transilluminate the wall. These zones of muscle atrophy were absent from the outlet chamber though this also was thinner than normal.

3. Right atrioventricular annulus:

The theoretical location was easily recognized in all cases but a fibrotic annulus was absent in 3, and then the atrial musculature was macroscopically continuous with the ventricular muscle. Over about two-thirds of its length a valve leaflet was inserted, while on a short segment of the posteromedial part and on the septum, the "annulus" was free from leaflet attachment.

4. Orifices and commissures:

In the 6 cases there was a superiorly placed orifice with an aperture varying between 4 and 18 mm in diameter. This orifice was always placed immediately below the infundibular septum, and was being limited by 2 leaflets, anterior and septal (Fig. 4). These leaflets were recognized by their insertion and formed 2 usually fairly well defined commissures from which dysplastic chordae tendineae rose and crossed to be inserted onto the infundibular septum (those from the superior commissure) and onto a papillary muscle placed at the inferior end of the previously described abnormal band (those coming from the inferior commissure). The chordae were of variable degrees of development. This orifice, by its location would allow the blood to flow from the atrialized chamber to the subpulmonary
Fig. 3. The infundibular septum, very hypoplastic, received chordae tendineae from the septal commissure of the superior orifice. Its anterior prolongation ended at the base of the well-differentiated anterior papillary muscle. The apical orifice, of large size, is easily recognized below the septal leaflet. P: pulmonary artery, IS: infundibular septum. AL, SL, and PL: anterior, septal, and posterior leaflets. ab: anterior prolongation of the interventricular septum, pm: anterior papillary muscle.

region (Figs. 3, 4).

In 3 cases there was an apical orifice of grossly triangular shape, limited by the septal and posterior leaflets and by a zone of the posterior wall of the right ventricle to which there was no recognizable leaflet insertion. This orifice allowed blood flow between the atrialized chamber and the distal chamber near to the apex of the right ventricle.

In 2 cases there were irregular small perforations in the leaflets, mainly related with traces of chordae tendineae.

In 1 case the superior orifice only was present. In this case the leaflets formed a curtain-like structure with no evidence of chordae tendineae present.

The 2 commissures described with the superior orifice were a constant finding. In 3 cases another possible commissure between anterior and posterior leaflets was found but it was poorly differentiated.

5. Leaflets:

In 5 of the 6 cases the findings were similar. The anterior leaflet, the most differentiated, rose from the annulus, was not adherent to the ventricular wall and it was clearly demarcated by the 2 commissures. Its free border formed the superior limit of the superior orifice.
Fig. 4. (left). The superior orifice was placed in a high position, below the infundibular septum, being limited by the anterior and septal leaflets. Chordae tendineae from septal and lateral commissures of this orifice were constantly inserted onto the infundibular septum and the inferior end of the abnormal band (usually through well-developed papillary muscles). AL, SL, and PL: anterior, septal, and posterior leaflets. Solid square: septal commissure. Solid triangle: lateral commissure.

Fig. 5. (right). Section of the posterior wall of the right ventricle near the septum showed the origin of the posterior leaflet from the annulus, its inferior border being adherent to the ventricular muscular wall (thus creating a false impression of low implantation), thus forming a blind ended cavity in which chordae tendineae were recognized (arrow). a: atrium, v: ventricle, L: posterior leaflet.

The septal leaflet was attached to the septum along an oblique line, from the infundibular septum to close to the ventricular apex. This leaflet met the anterior one at the commissure described. When an apical orifice was present, the septal leaflet formed, by its superior border the inferior margin of the superior orifice and by its inferior border the medial margin of the apical orifice.

The posterior leaflet was considered demarcated by the anterior papillary muscle and the most posterior site where a leaflet was recognized as being inserted into the annulus. It was usually the least differentiated, its inferior border being adherent to the ventricular muscular wall, thus forming a blind ended cavity, in which chordae tendineae in different stages of development were recognized inserted...
into small papillary muscles on the posterior right ventricular wall (Fig. 5). We could not identify leaflet tissue on the most medial part of the posterior wall or on the posterior part of the septum, there being a "gap" which formed the posterior boundary of the apical orifice if this was present.

In 1 case all the leaflets were fused in a curtain-like structure which was adherent to the ventricular wall over most of its surface. No chordae tendineae were identified in this case and there was only one high orifice with an aperture of 4 mm.

Thin sheets of muscular tissue were present in the anterior leaflets in 2 cases. The superior part of the anterior leaflet was muscular in 1 case (Fig. 6).

6. Coronary arteries:
Origin and distribution of the coronary arteries was considered normal in all cases, although the artery found in the posterolateral part of the right A-V sulcus and posterior interventricular septum (pattern of so-called "right dominance") was small in 3 cases, while the right marginal coronary artery seemed to be dilated.

7. Associated anomalies:
An interatrial communication was constant (patent foramen ovale in 4 cases and an ostium secundum defect in 2). One case had a bicuspid pulmonary valve. One case had a large, subaortic ventricular septal defect partially covered by the abnormal septal leaflet, the anterior part of the VSD being directly related to the
superior orifice of the abnormal valve, thus creating a functional communication between the left ventricle and the atrialized chamber.

8. Microscopic findings:

Pieces of 1 cm² of the septum and right ventricular wall were stained with hematoxylin and eosin and PAS in 4 cases. Areas of myocytolysis, substitution of muscle fibers by connective tissue with some small scars, a large number of capillaries and dilatation of the lymphatic vessels, along with disorganization of the muscle bundles in the subendocardial layer of the right ventricle were the most consistent abnormal findings, although inconstant.

DISCUSSION

Ebstein's anomaly has been considered to be an exclusively valvular anomaly, but recent authors⁶,⁷ have emphasized the associated lesions. Our findings are considered supporting this more “general” concept of the anomaly.

It is usually thought¹⁰ that valvular anatomy cannot be described systematically, but our findings suggest that in many cases most of the structures can be identified, particularly the leaflets and commissures. In all our cases the anterior and septal leaflets had 2 constant points of insertion, one on the infundibular septum and the other on a papillary muscle, usually fairly well differentiated, situated at the inferior end of the abnormal anterior prolongation of the infundibular septum.

The superior orifice, therefore, was constantly located between the septal and anterior leaflets, while the inferior border of the septal leaflet and the free border of the posterior leaflet usually form an apical orifice when they are not completely adherent to the ventricular wall. Other irregular perforations can be found in any part of the leaflets, usually in zones in which chordae tendineae are present though these are not completely differentiated.

The superior orifice has been, in our cases, always smaller than the expected size of the tricuspid orifice (between 1.2 and 1 times the mitral orifice, in the absence of significant anomalies of this valve); this orifice was relatively larger in the presence of a big apical orifice. It seems logical to think that when only the superior orifice exists the probable functional anomaly will be stenosis of the valve, while when a big apical orifice is present regurgitation is almost constant, as this orifice cannot be occluded by the abnormal leaflets.

The leaflet anatomy is of particular interest. Usually this anomaly is thought to be characterized by low implantation of both septal and posterior leaflets, but our findings show that it is the septal leaflet which is abnormal in this respect as shown by Ebstein¹¹ and other authors.¹¹ The confusion
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may be due to the septal leaflet being normally inserted both on the septum and on the posterior wall of the right ventricle.\textsuperscript{12} However, in addition abnormal adherence of parts of other leaflets to the ventricular wall, mainly the inferior border of the posterior leaflet, exist and there is poor differentiation of valvular structures. Low implantation of the septal leaflet, adherence of leaflets to the ventricular wall and poor differentiation of valvular structures seem to be the findings which characterize the tricuspid valve in this anomaly.

The anterior prolongation of the infundibular septum in these cases presented particular characteristics. Usually the infundibular septum meets the trabecula septo-marginalis (its superior part, or septal band). In these cases the infundibular septum was hypoplastic and its anterior prolongation formed an abnormal band, morphologically similar to a structure described in cases of transposition of the great arteries\textsuperscript{13} and usual in cases with dextroposition of the anterior limb of the infundibular septum. This could suggest that the infundibular septum and the muscular interventricular septum are abnormally inter-related in Ebstein’s anomaly.

If the right bundle branch follows this abnormal band it is conceivable that its course is elongated which may relate to the abnormal right bundle branch block usually present in the electrocardiograms.

Edwards\textsuperscript{14} demonstrated the presence of muscular continuity between right atrium and right ventricle without clear evidence of the existence of a fibrous annulus and similar findings were observed in 3 of our cases. This muscular continuity may be related to some of the arrhythmias seen in these cases (WPW type B).

The variable development of the muscle of the right ventricular wall has been reported previously.\textsuperscript{14–16} When this wall is very atrophic the similarity with Uhl’s anomaly and “parchment heart”\textsuperscript{17} is clear and suggest a pathogenetic relationship.

\section*{References}


