CASE REPORT

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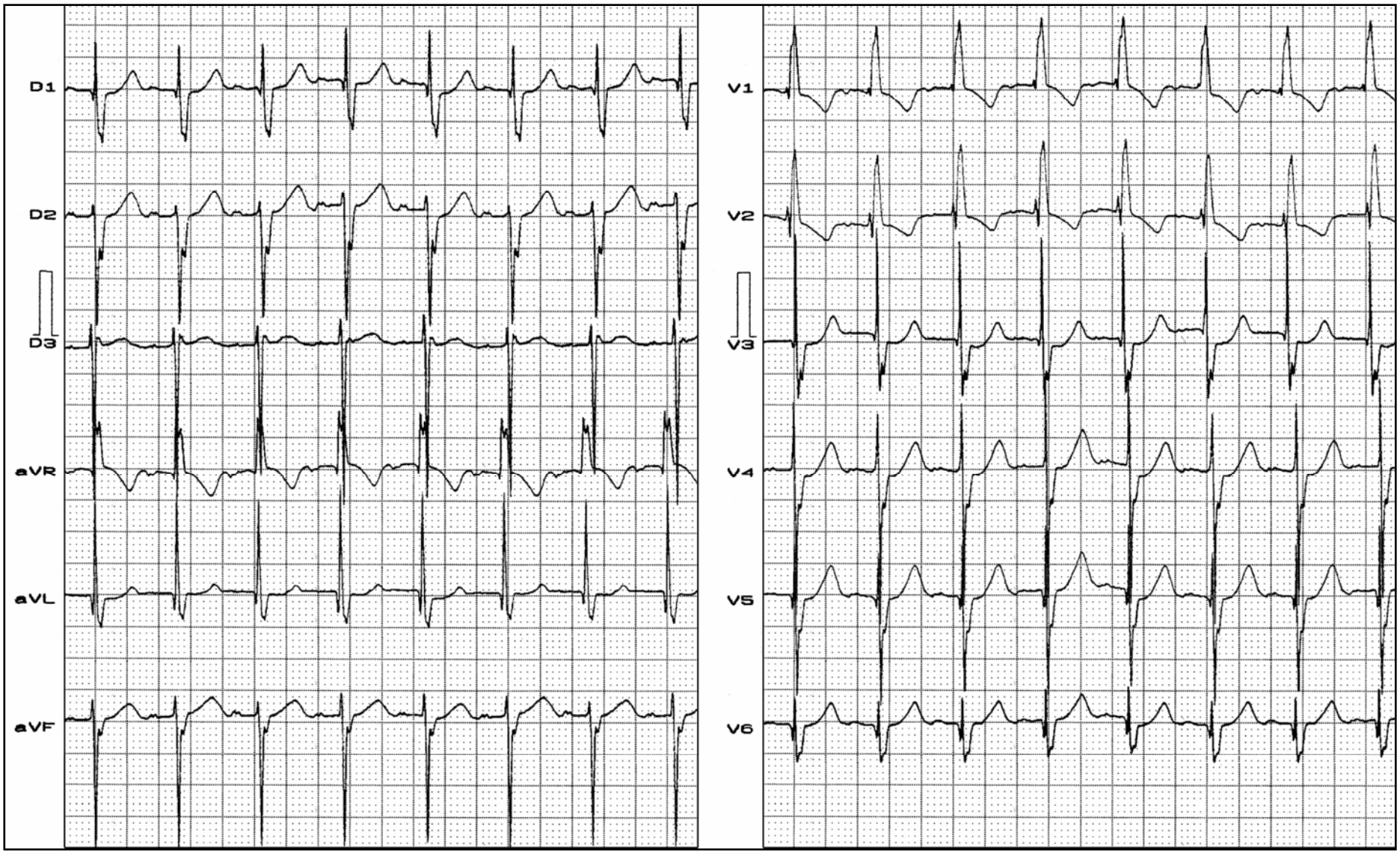
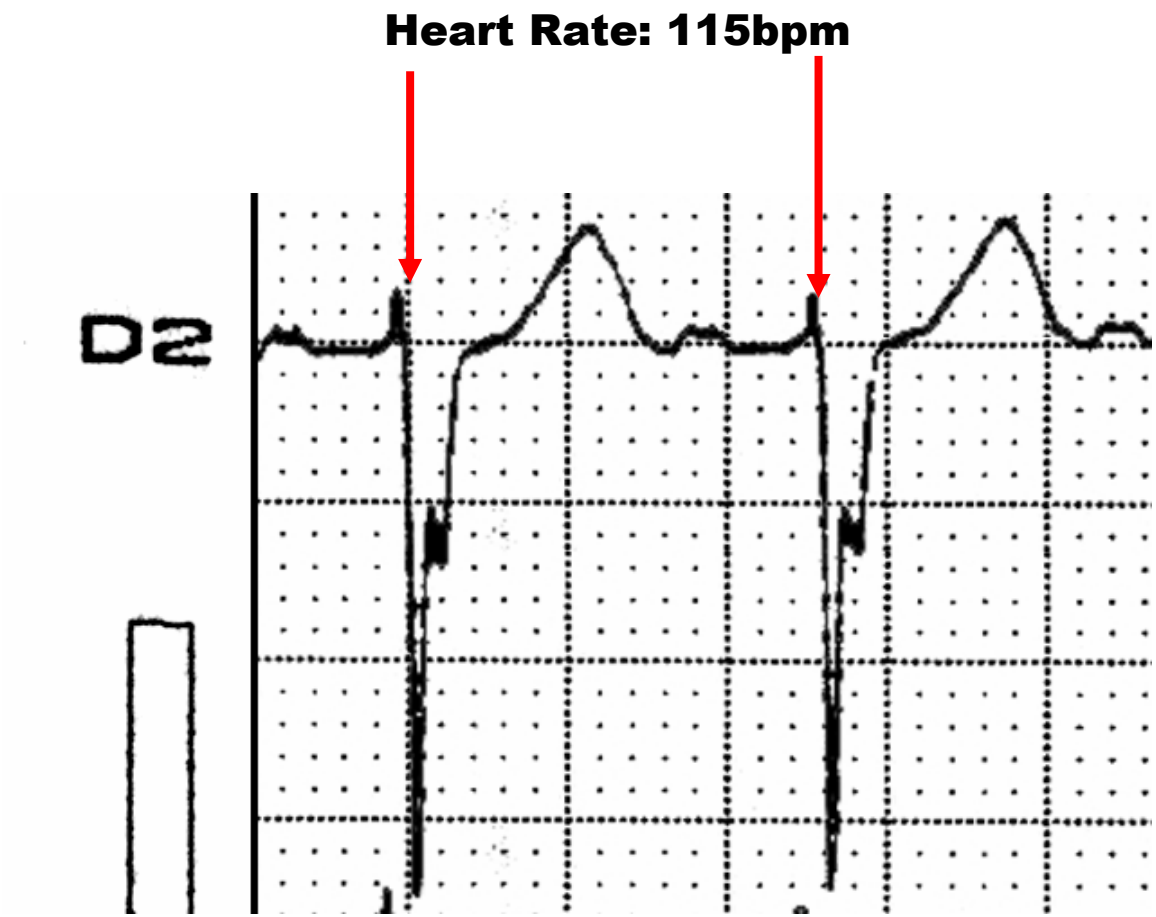
Clinical History

Masculine, Asian, baby 11 Months old, natural from Santo André – São Paulo – Brazil..
Positive history of murmur diagnosis from two Months of his life.
Antecedent of two episodes of past pneumony during four and eight Months of his life.
His mother refers profuse sweat with the suction and easy fatigability.

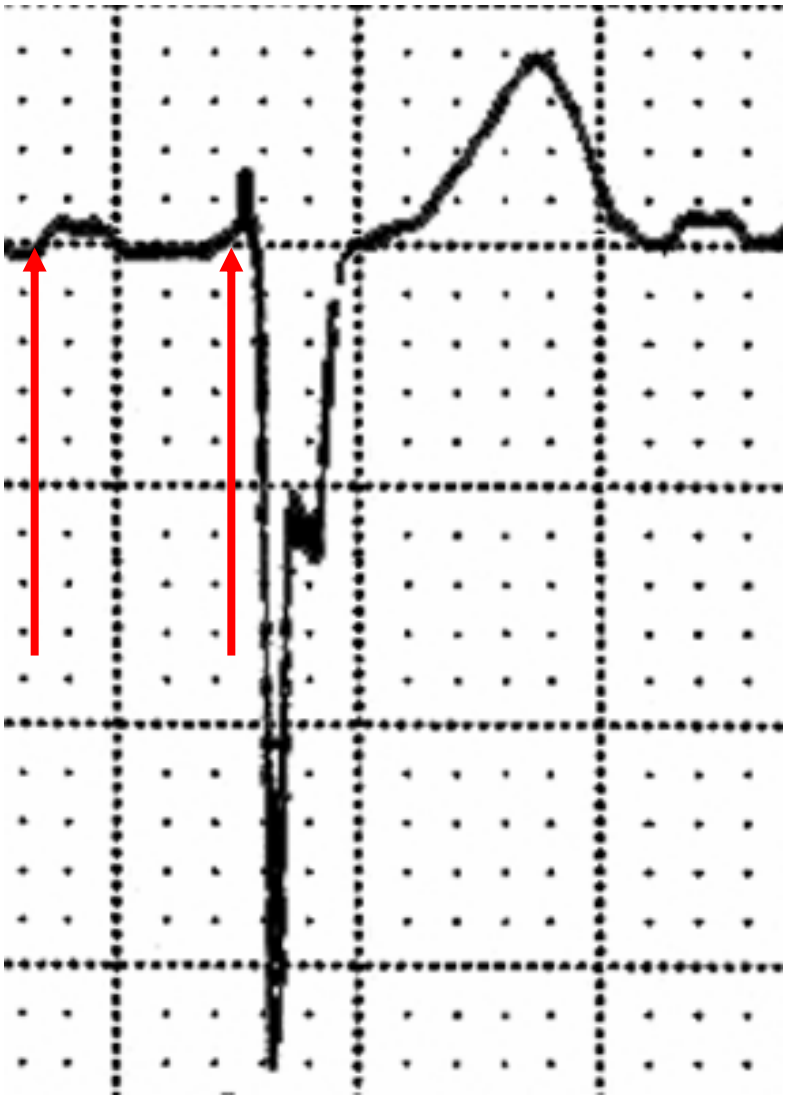
Physical
increased right ventricular impulse, evidence of mitral incompetence: palpable thrill in apical region and holosystolic murmur of mitral insufficiency is high-pitched, and loudest at the apex radiated to the sternal edge.
The first heart sound is faint.
A systolic ejection murmur is heard loudest at the upper left sternal border, following by a second heart sound widely fixed splitting.
A tricuspid mid-diastolic rumble is appreciated at the lower left sternal border.
The ECG see next slide. X-ray cardiothoracic ratio >65%

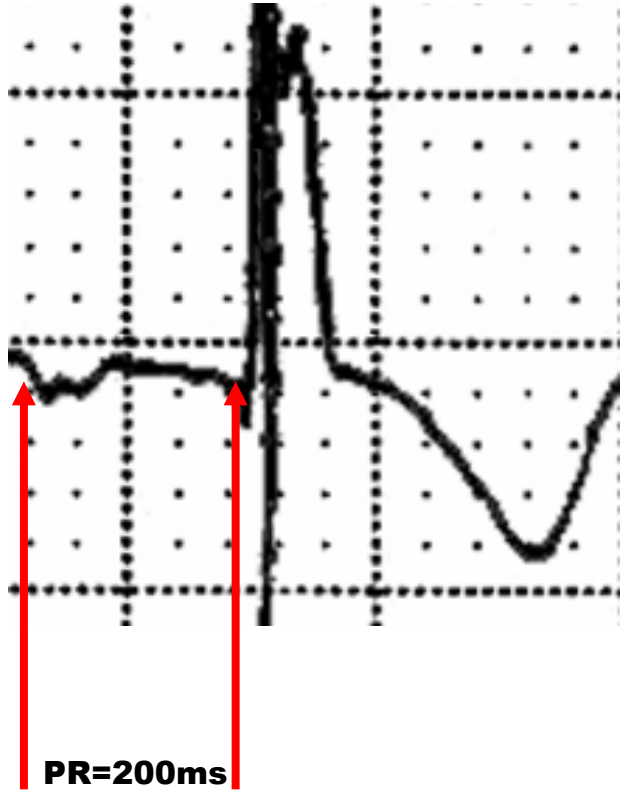
Name: AYW; **Gender:** Male; **Age:** 11 months; **Ethnic Group:** Asian; **Weight:** 7 Kg; **Height:** 68 cm;
Date: 19/02/2010





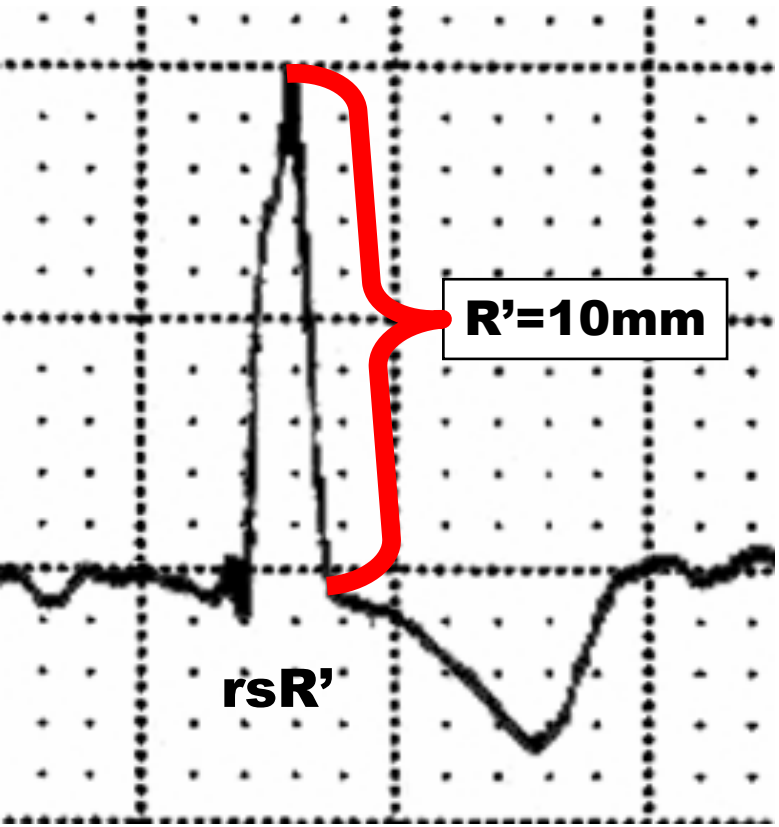
Sinus Rhythm. This children has not sinus tachycardia, because in children from six months to three years old the normal HR is between 90 to 120bpm.





In children from six months to three years old the PR interval has it inferior limit is still 90 ms and the superior one is up to 150 ms (0.15 s) for rates between 100 and 120 bpm.

ELEMENTS THAT SUGGEST RVH IN V_1 IN PREESENCE OF THE RBBB

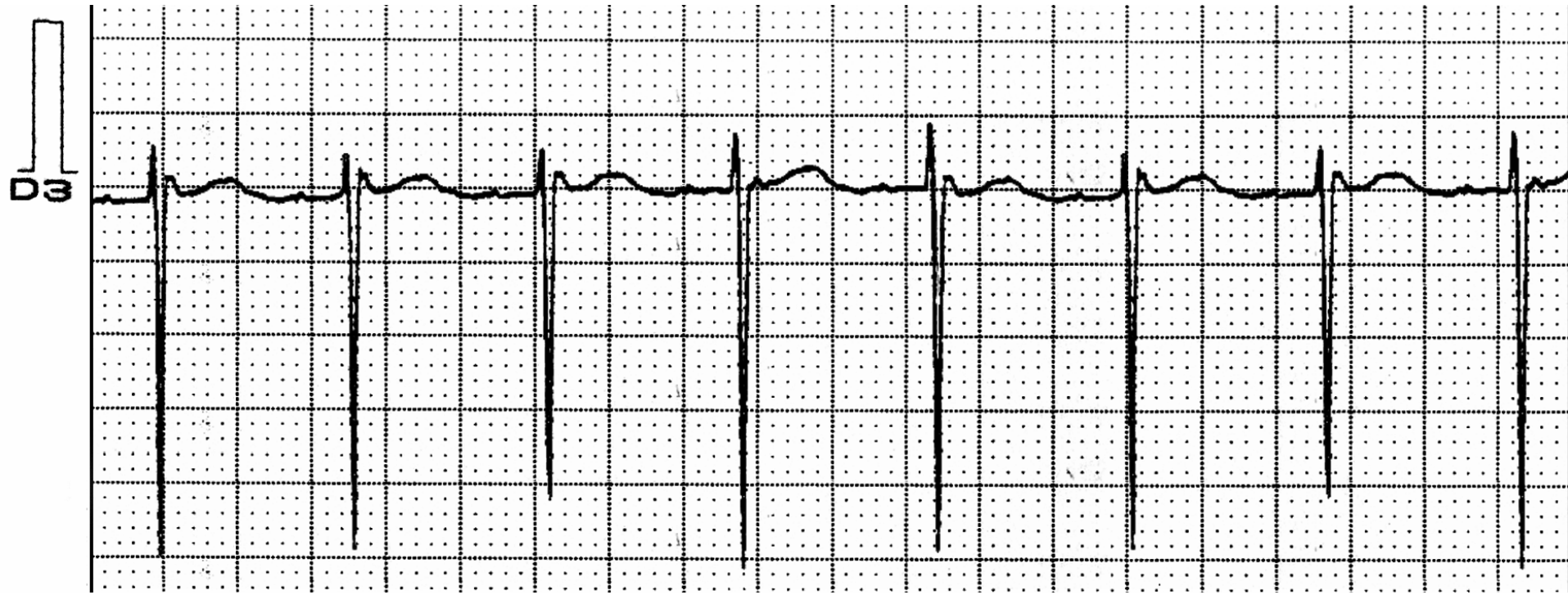


INCOMPLETE RIGHT BUNDLE BRANCH BLOCK
IRBBB = R'>10mm = RVH

COMPLETE RIGHT BUNDLE BRANCH BLOCK
CRBBB = R'>15mm = RVH

Conclusion: it has not voltage criteria for RVH because R' voltage has not 15mm.

Complete RBBB: QRSd = 112ms V1-V2 rsR´ triphasic pattern. Is considered complete with QRS duration≥ 120 ms in adults, > 100 ms between 4 to 16 years old and > 90 ms < 4 years old1



Electrical QRS alternans visible in III lead. The reported causes of electrical QRS alternans are: myocardial ischemia, AF, WPW-S, rheumatic heart disease , acute pulmonary embolism, myocardial contusion, left ventricular dysfunction, cardiac motion, large pericardial effusion and HCM.

ECG Diagnosis

Sinus Rhythm. This children has not sinus tachycardia, because in children from six months to three years old the normal HR is between 90 to 120bpm.

First-degree AV block. PR interval 200ms. In children from six months to three years old the PR interval: the inferior limit is still 90 ms and the superior one is up to 150 ms (0.15 s) for rates between 100 and 120 bpm.

Extreme left axis deviation (> - 30°) with counterclockwise loop in the frontal plane (qR pattern in I and aVL). **Left Anterior Fascicular Block like-pattern**

Complete RBBB: QRSd = 112ms V1-V2 rsR´ triphasic pattern. Is considered complete with QRS duration≥ 120 ms in adults, > 100 ms between 4 to 16 years old and > 90 ms < 4 years old[1].

RVH: The hypertrophied portion of the RV is predominantly the crista or RVOT. It is typically found in ASD (in 93% of cases), moderate pulmonary stenosis and mitral stenosis with pulmonary hypertension. In VCG correspond to RVH type D in the HP. It shows the efferent branch of counterclockwise rotation and the afferent one of clockwise rotation. The initial forces are located in the right anterior quadrant and do not present delay. In isolated RBBB, without RVH, the final forces located in the right anterior quadrant with “glove-finger” shape, present characteristic end conduction delay.

Electrical QRS alternans visible in III lead. The reported causes of electrical QRS alternans are: myocardial ischemia, AF, WPW-S, rheumatic heart disease , acute pulmonary embolism, myocardial contusion, left ventricular dysfunction, cardiac motion, large pericardial effusion and HCM.

1. **Surawicz B, Childers R, Deal BJ, et al. American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; American College of Cardiology Foundation; Heart Rhythm Society. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part III: intraventricular conduction disturbances: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. Endorsed by the International Society for Computerized Electrocardiology. J Am Coll Cardiol. 2009 Mar 17; 53:976-981.**

Clinical diagnosis

Large **O**stium **P**rimum **A**trial **S**eptal **D**efect (**OP-ASD**) or partial atrioventricular septal defect.

Atrioventricular canal defect

Ostium Primum (OP), a type of Atrial Septal Defect (ASD), occurs at the base of the interatrial septum and is the result of failure of fusion of the septum primum with the endocardial cushions. It is the simplest form of atrioventricular (AV) canal or AV septal defect. These defects are often associated with trisomy 21.

During fetal development, the rudimentary atrium is divided by the septum primum, except for an anterior and inferior space that is the ostium primum. The ostium primum is sealed by fusion of the superior and inferior endocardial cushions around 5 weeks' gestation. Failure to do so results in an ostium primum ASD. The endocardial cushions also contribute to the complete formation of 2 separate AV valves and the inlet interventricular septum. For this reason, ostium primum ASDs commonly are associated with malformations of these structures.

Ostium primum ASDs may occur in isolation but most commonly present with a cleft in the anterior leaflet of the mitral valve. This is sometimes termed a partial AV canal defect or a partial AV septal defect. In this case, a 5-leaflet AV valve is arranged so that separate right and left components (a tricuspid valve and a mitral valve) are present. The leaflets connect to each other and then adhere to the crest of the interventricular septum. This results in obligatory shunting at the atrial level with no ventricular level shunting. Generally, a commissure is observed between the left superior and inferior bridging leaflets because of abnormal fusion of the left tubercle of the superior and inferior cushions, which results in a cleft in the anterior leaflet of the mitral valve.

Pathophysiology

Shunting is predominantly left-to-right in the absence of pulmonary vascular disease or significant right ventricular outflow tract obstruction. This results in volume overload of the right atrium and ventricle and pulmonary overcirculation. If the mitral valve cleft causes significant mitral regurgitation, the left side of the heart also becomes volume overloaded. A left ventricle to right atrium shunt can be present, which further overloads both the right and left heart.

Frequency United States

Ostium primum ASDs are most commonly associated with Down syndrome (trisomy 21). The incidence of trisomy 21 is 1 per 800 live births, with an increased prevalence noted in children born to older mothers. The overall risk of congenital heart disease in patients with Down syndrome is 40-50%. Approximately 65% of those affected have some form of AV septal defect.

The inherited risk for children of parents who have an AV septal defect is reported as 9-14%.

Mortality/Morbidity

The presence and degree of associated mitral regurgitation and/or left ventricle to right atrium shunting generally determine symptoms.

Those with either no cleft or a cleft with a mild degree of mitral regurgitation are often asymptomatic. Patients typically are referred for evaluation of a heart murmur in childhood and generally survive well into adulthood. However, adults who have not had the condition repaired often become symptomatic from congestive heart failure (CHF) by age 45 years. Rarely, patients are reported to present in the seventh decade of life. Dyspnea on exertion and fatigue are usual adult complaints. Palpitations secondary to atrial fibrillation or flutter also are common.

Those with more severe mitral regurgitation or left ventricle to right atrium shunting often present in the first 2 years of life. Mortality has been reported to be as high as 30% in this subpopulation in the first year of life.

Although relatively rare, pulmonary vascular obstructive disease may occur in patients with long-standing substantial shunts and significant mitral regurgitation.

Children with trisomy 21 are at higher risk than the general population of developing pulmonary vascular obstructive disease at a younger age. Potential reasons for this include chronic upper airway disease, tonsillar and adenoid hypertrophy, and inadequate alveolarization of the terminal bronchioles, leading to a decreased surface area of the vascular bed.

History

Children with smaller ostium primum atrial septal defects (ASDs) and little or no mitral regurgitation or left ventricle to right atrium shunting are usually asymptomatic. Those with significant pulmonary overcirculation and/or significant mitral regurgitation tend to present in infancy with congestive heart failure (CHF). Tachypnea and tachycardia are noted at rest and are exacerbated with crying or exertion. Feeding is accompanied by dyspnea, diaphoresis, and an increased work of breathing. The combination of feeding difficulties and increased metabolic demands results in failure to thrive, which may be severe and/or intractable.

The size of the septal openings will affect the type of symptoms noted, the severity of symptoms, and the age at which they first occur. The larger the openings, the greater the amount of blood that passes through from the left side of the heart to the right and overloads the right heart and the lungs. Symptoms occur in infancy. The following are the most common symptoms of AVC. However, each child may experience symptoms differently. Symptoms may include:fatigue, sweating, pale skin, cool skin,rapid breathing,heavy breathing, rapid heart rate congested breathing, disinterest in feeding, or tiring while feeding poor weight gain

As the pressure in the lungs rises, blood within the heart will eventually "shunt" through the septal openings from right heart to the left. This allows oxygen-poor (blue) blood to reach the body, and cyanosis will be noted. Cyanosis gives a blue color to the lips, nailbeds, and skin. The symptoms of AVC may resemble other medical conditions or heart problems.

Physical Examination

Characteristic features of trisomy 21 may be detected. These include the following: hypotonia and hyperflexibility , short, flat nose with a flat nasal bridge, oblique palpebral fissures, abundant neck skin, large and protuberant tongue, short, broad hands with a shorter fifth finger (clinodactyly), simian crease Inner epicanthal fold extending onto the lower lid, brushfield spots or speckled iris. Infants and children with partial AV septal defects and significant mitral regurgitation have poor development and are tachypneic and tachycardic at rest. A hyperinflated thorax, bulging precordium, and Harrison grooves are often present. Most children, however, have a milder degree of mitral regurgitation and, in general, appear normally developed and thriving on examination. The cardiac examination in isolated ostium primum ASDs or partial AV canal defects with minimal mitral regurgitation is similar to that in other forms of ASDs. Patients typically have an increased right ventricular impulse secondary to volume overload. The first heart sound is normal. The second heart sound is fixed or at least widely split. A systolic ejection murmur is heard loudest at the upper left sternal border, with radiation to both lung fields. A click is not present. A tricuspid mid-diastolic rumble is present in children with larger shunts (pulmonary-to-systemic flow ratio > 2:1) and is appreciated at the lower left sternal border. The murmur of mitral insufficiency is typically high-pitched, holosystolic, and loudest at the apex. The murmur usually radiates to the axilla but may radiate preferentially to the sternal edge secondary to streaming of the regurgitant flow across the atrial septum. If pulmonary hypertension is present, significant changes are noted in the physical examination. The pulmonary component of the second heart sound becomes loud. The splitting of the second heart sound narrows and eventually may become single. The diastolic tricuspid rumble disappears. A holosystolic murmur of tricuspid regurgitation becomes noticeable as the right ventricle dilates. This murmur is usually loudest at the lower left sternal border and becomes higher pitched as the right ventricular pressure increases. A short midsystolic murmur may be present secondary to flow into a dilated pulmonary artery. A Graham-Steell pulmonary insufficiency murmur may be appreciated as an early diastolic decrescendo murmur at the mid left sternal border.

Anatomical Variants

1. **Isolated Ostium Primum Atrial Septal Defect (OP-ASD)** An OP-ASD is located in the most anterior and inferior aspect of the atrial septum. It is the simplest form of atrioventricular (AV) canal or AV septal defect.

2. **OP-ASD with Mitral Valve Cleft**

3. **OP-ASD with Mitral Cleft and Tricuspid of valve cleft**

4. **Common Atrium and Cleft Mitral Valve:** the single atrium found in a form of three-chambered heart associated with Mitral valve cleft.. It is frequently associated with heterotaxy syndrome.
5. **Atrioventricularis Communis, Common AV Canal, complete atrioventricular septal defect, Complete AV Canal (CAVD) defect:** congenital cardiac anomaly in which the endocardial cushions fail to fuse, the ostium primum persists, the atrioventricular canal is undivided, a single atrioventricular valve has anterior and posterior cusps, and there is a defect of the membranous posterior portion of interventricular septum. is characterized by an OP-ASD, a common atrioventricular valve and a variable deficiency of the ventricular septum inflow. CAVC is an uncommon congenital heart disease, accounting for about 3% of cardiac malformations. Occurs in two out of every 10,000 live births.

Both sexes are equally affected and a striking association with Down syndrome was found.

Depending on the morphology of the superior leaflet of the common atrioventricular valve, 3 types of CAVC have been delineated (type A, B and C, according to Rastelli's classification[1]).

CAVC results in a significant interatrial and interventricular systemic-to-pulmonary shunt, thus inducing right ventricular pressure and volume overload and pulmonary hypertension.

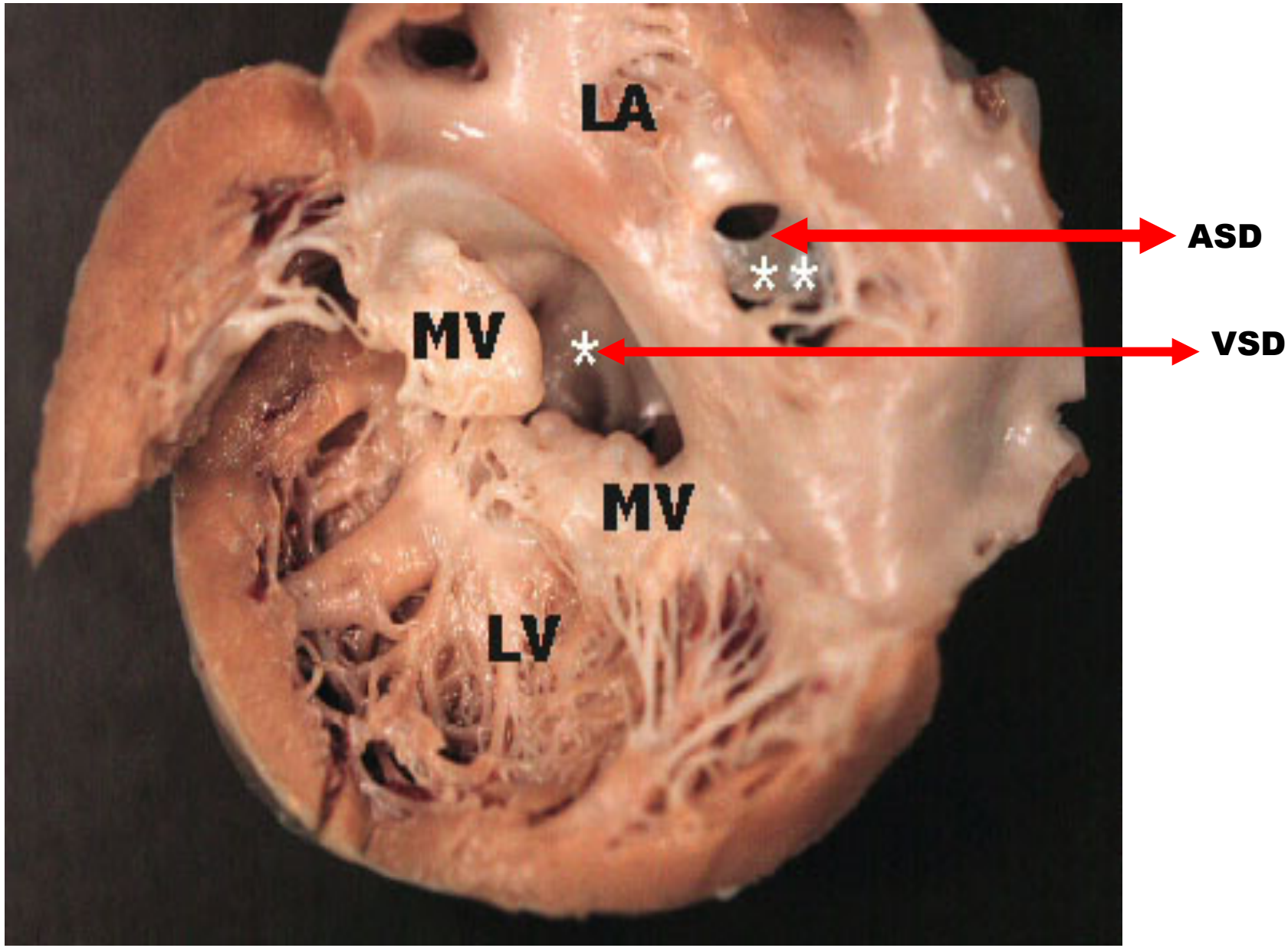
It becomes symptomatic in infancy due to congestive heart failure and failure to thrive. Diagnosis of CAVC might be suspected from ECG and chest X-ray findings. Echocardiography confirms it and gives anatomical details.

Over time, pulmonary hypertension becomes irreversible, thus precluding the surgical therapy. This is the reason why cardiac catheterization is not mandatory in infants (less than 6 months) but is indicated in older patients if irreversible pulmonary hypertension is suspected.

Medical treatment (digitalis, diuretics, vasodilators) plays a role only as a bridge toward surgery, usually performed between the 3rd and 6th month of life.

1. Rastelli G, Kirklin JW, Titus JL. **Anatomic observations on complete form of persistent common atrioventricular canal with special reference to atrioventricular valves.**Mayo Clin Proc. 1966 May;41:296-308.
2. Calabrò R, Limongelli G. **Complete atrioventricular canal.** Orphanet J Rare Dis. 2006 Apr 5;1:8.

Complete AV canal defect



Pathology: ASD Types

There are many types of atrial septal defects (**ASDs**), these are:

1. **Secundum ASDs** is due to a defect in the foramen ovale membrane **(OS-ASD)**

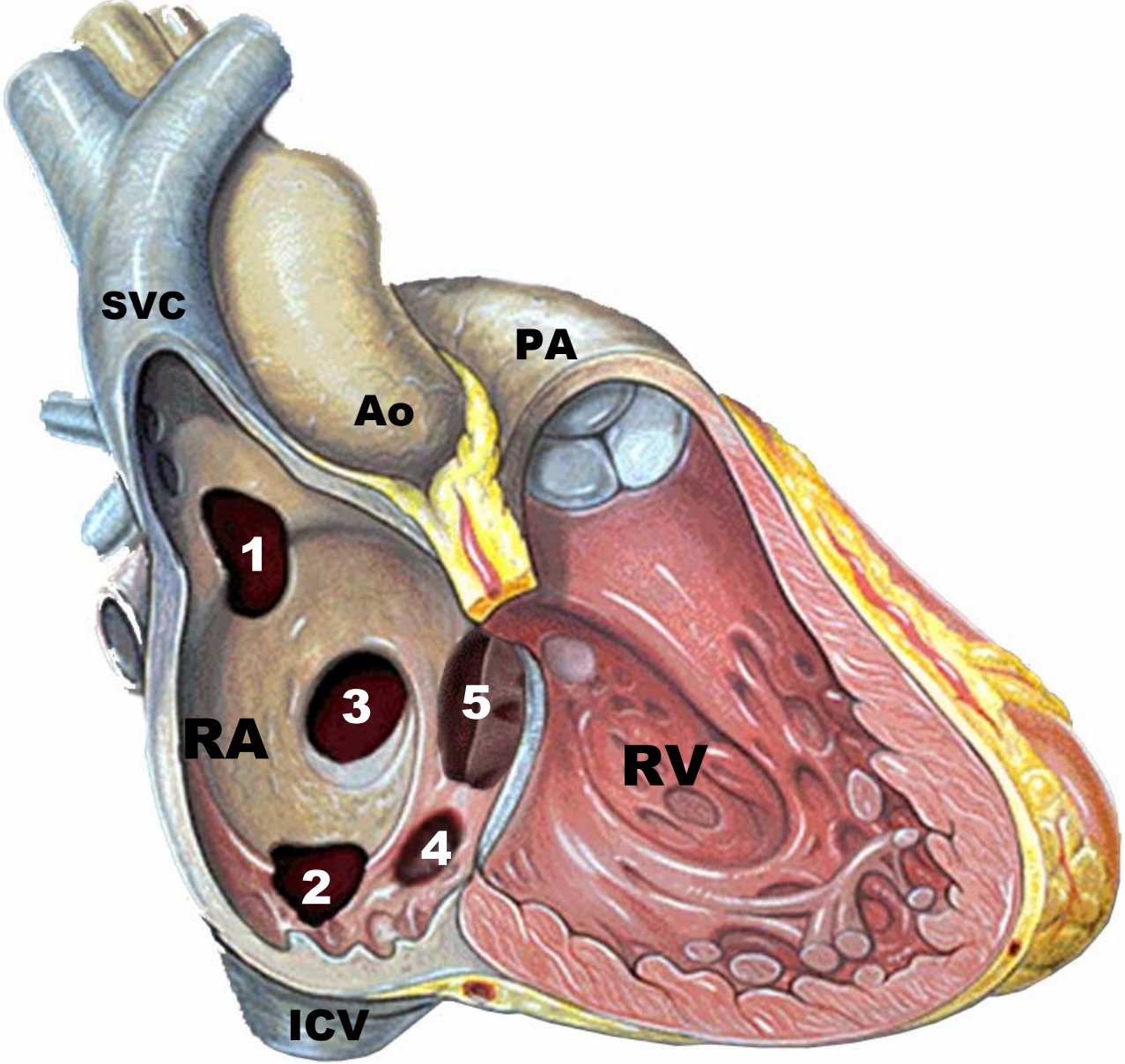
2. **Primum ASD defect (OP-ASD)**

3. **Sinoseptal defect** is involves the atrial septum between the sinus venosus component of the two atria, this could be:

   3 A. Upper Sinus Venosus ASD defect (USV-ASD), a defect of the atrial septum adjacent to the superior vena cava entrance into the right atrium. The right upper pulmonary vein typically would drain into the right atrium. It may or may not be aberrant in its communication to the left atrium A sinus venosus ASD that involves the superior vena cava makes up 2 to 3% of all interatrial communication. It is located at the junction of the superior vena cava and the right atrium. It is frequently associated with anomalous drainage of the right-sided pulmonary veins into the right atrium (instead of the normal drainage of the pulmonary veins into the left atrium)

   3 B. Lower Sinus Venosus ASD or Inferior Vena Cava Sinus Venosus ASD(LSV-ASD) is when the defect is inferior & closer to the right atrium-inferior vena cava junction

4. **ASD involving Coronary Sinus (CS-ASD) Unroofed coronary sinus,** this will lead to a communication (and shunting) between the LA and the coronary sinus.



The location of different types of ASD, the view is into an opened right atrium (RA), *RV* Right Ventricle; *SCV*: Superior Caval Vein; *ICV*: Inferior Caval Vein; *1*: Upper SV-ASD; *2*: Lower SV-ASD; *3*: OS-ASD; *4*: CS-ASD; *5*; OP-ASD.

ASD Prevalence Etiology/ CIA

CIA-OS 10% to 15% of all congenital heart diseases.
Atrioventricular septal defects account for 2-9% of congenital heart disease.
ASDs make up 30 to 40% of all congenital heart disease that is seen in adults.
Sporadic: due to environmental causes.
Hereditary and familial: dominant autosomal, linked to the Holt-Oran Syndrome. Mutations in the TBX5 gene cause Holt-Oram syndrome, located in chromosome 5q and 5q35. The gene of cardiac transcription factor Nkx2.5 was identified. Holt-Oram syndrome is characterized by skeletal abnormalities of the hands and arms (upper limbs) and heart problems. Holt-Oram syndrome is estimated to affect 1 in 100,000 individuals. The OS-ASD accounts for 7% of all congenital heart diseases.
The OS-ASD shows a female preponderance, with a male : female ratio of 1:2. The male-to-female distribution of atrioventricular septal defect is approximately equal[1].

1. **Rosenthal GL, Wilson PD, Permutt T, Boughman JA, Ferencz C. Birth weight and cardiovascular malformations: a population-based study. The Baltimore-Washington Infant Study. *Am J Epidemiol*. Jun 15 1991;133: 1273-1281.**

The Holt-Oram Syndrome or Heart-Hand syndrome

The Holt-Oram syndrome[1] (HOS) is an autosomal dominant genetic disease characterized by mild-to-severe congenital cardiac defects(75%of cases) and skeletal abnormalities of the upper limb. The most common cardiac disorder is an OS-ASD(34% of cases[2]), followed by VSD and OP-ASD. In addition, hypoplastic peripheral vessels of the upper limbs have been observed[3]. Mutations in T-box transcription factor 5 (TBX5) underlie this syndrome. official full name T-box 5 Long arm of chromosome 12. Location: 12q24.gene have been associated with HOS. Several transcript variants encoding different isoforms have been described for this gene. This gene is a member of a phylogenetically conserved family of genes that share a common DNA-binding domain, the T-box. T-box genes encode transcription factors involved in the regulation of developmental processes. This gene is closely linked to related family member T-box 3 (ulnar mammary syndrome) on human chromosome 12. The encoded protein may play a role in heart development and specification of limb identity.

Frequency

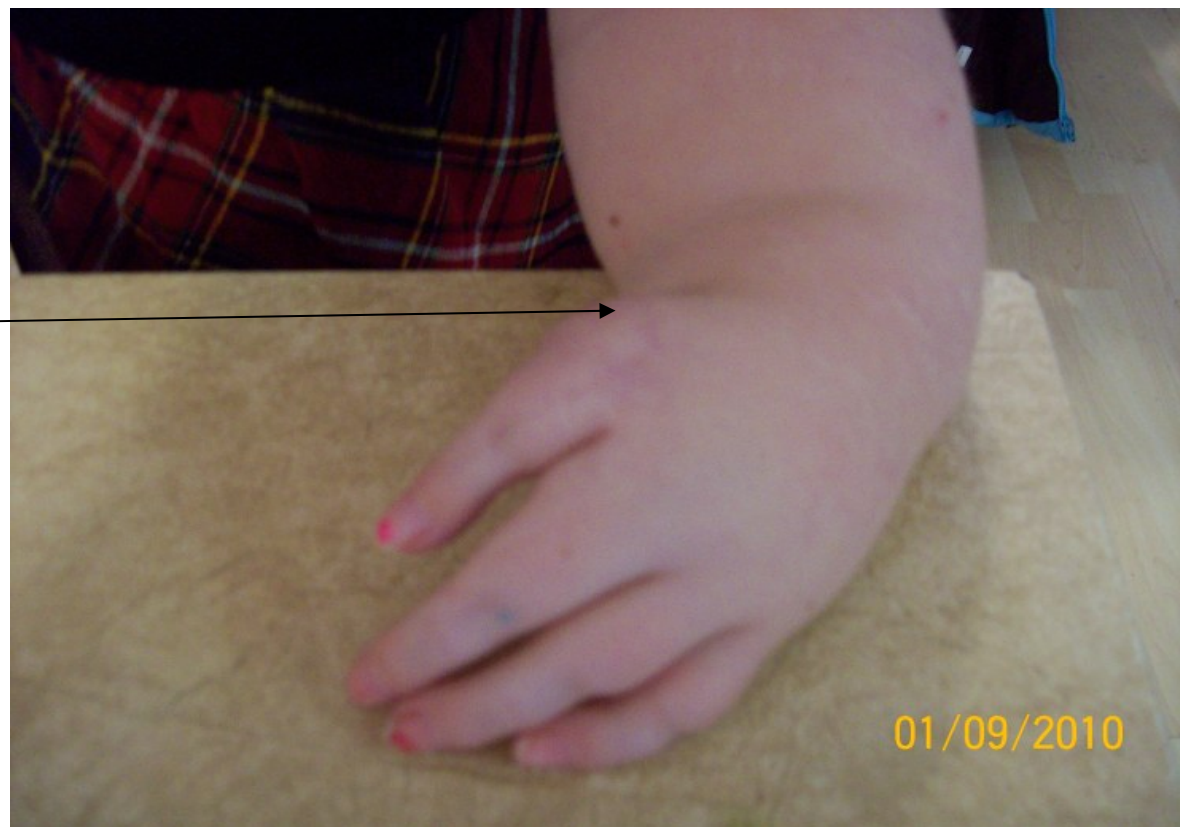
HOS is the most common form of heart-hand syndrome, with prevalence estimated at 0.95 cases per 100,000 total births. Approximately 85% of cases are attributed to new mutations.
Sporadic disease may represent a de novo germline mutation in *TBX5*.
Patients may have a family history of cardiac and/or limb malformation. may present in infancy with obvious limb malformations and/or signs of cardiac failure secondary to ASD, VSD, or cardiac conduction disease.

1. **Holt M, OramS. Familial heart disease with skeletal malformations. *Br Heart J*. Apr 1960;22:236-42**
2. **Newbury E, Leanage R, Reaburn JA, et al. Holt-Oram syndrome: a clinical genetic study. Genet Couns 1996; 7: 323-324.**
3. **Bossert T, Walther T, Gummert J, Cardiac malformations associated with the Holt-Oram syndrome--report on a family and review of the literature. Thorac Cardiovasc Surg. 2002 Oct;50:312-314.**

UPPER LIMB MUSCULOSKELETAL DEFORMITIES

Although the clinical manifestations are variable, upper limb abnormalities are always present. Abnormalities may be unilateral or bilateral and asymmetric and may involve the radial, carpal, and thenar bones. Aplasia, hypoplasia, fusion, or anomalous development of these bones produces a spectrum of phenotypes, including triphalangeal or absent thumbs. Occasionally, upper limb malformation can be sufficiently severe to produce phocomelia (a malformation in which the hands are attached close to the body); this has been termed pseudothalidomide syndrome. The most prevalent findings in persons with HOS are malformations or fusions of the carpal bones. Carpal bone abnormalities are the only findings present in every affected individual, although these anomalies may be evident only radiographically in some patients.

ABSENT THUMB



ECG FEATURES

Bradycardia, P pulmonale, right axis deviation, and qR pattern in V1 and V2, thus being compatible with RAE and RVH1.
Cardiac cardiac conduction defects such as progressive atrioventricular block and various degrees of AV block. Cardiac conduction disease is progressive with aging. Middle-aged individuals often present with significant atrioventricular block or AF.
Paroxysmal atrial fibrillation2;3 consequence of a gain-of-function mutation5,

GENETIC COUNSELING

It is important that once an individual has been diagnosed with HOS, his family members should be screened for the syndrome. The individual with HOS should also be aware that the disorder is inherited in an autosomal dominant manner, meaning that each of his/her children will have a 50% chance of inheriting the disorder.

1. **McDermott DA, Hatcher CJ, Basson CT.Atrial Fibrillation and Other Clinical Manifestations of Altered TBX5 Dosage in Typical Holt-Oram Syndrome. Circ Res. 2008 Sep 26;103:e96.**
2. **Brockhoff CJ, Kober H, Tsilimingas N, Holt-Oram syndrome. Circulation. 1999 Mar 16;99:1395-1396.**
3. **Postma AV, van de Meerakker JB, Mathijssen IB, A gain-of-function TBX5 mutation is associated with atypical Holt-Oram syndrome and paroxysmal atrial fibrillation. Circ Res. 2008 Jun 6;102:1433-1242.**

The ECG abnormalities in OP-ASD

1) **P wave:** normal, Left Atrial Enlargement (**LAE**) Right Atrial Enlargement (**RAE**) or Biatrial Enlargement (**BAE**). With significant mitral regurgitation, LAE may be present, demonstrated by a P wave duration of more than 80ms and/or terminal and deep inversion of the P wave in lead V1 or V3R. RAE is often detected, demonstrated by a peaked P wave measuring more than 2.5 mm (standard 10 mV/mm). It is best seen in leads II, III, V1, and V3R.
2) **PR interval:** prolonged in ≈ 50% of the cases by increase of AV conduction time; The ECG abnormalities are predominantly caused by abnormalities of the conduction system. Specifically, the AV node is displaced posteriorly and inferiorly, and atrial and/or AV nodal conduction often is delayed. Delayed conduction through the atria or through the AV node may lead to prolongation of the PR interval (ie, a first degree AV block).

3) **QRS axis:** characteristic extreme shift in superior quadrants and counterclockwise rotation of QRS loop in the frontal plane. The QRS axis is outside the normal range for age, demonstrating either a left or far left axis, and Q waves are present in leads I and aVL. In II, III and aVF, rS-pattern with notch in the ascending ramp of S wave. qR complexes in I and aVL: LAFB-like-pattern. This extreme deviation of the QRS axis towards the left observed in endocardial cushion defects can be attributed to the anatomical distorsion of the intraventricular His system genetically conditioned.

1. **Boineau JP, Moore EN, Patterson DF. Relationship between the ECG, ventricular activation, and the ventricular conduction system in ostium primum ASD. Circulation. 1973 Sep;48(3):556-64.**

Endocardial Cushion Defects Characteristics of The Ventricular Conduction System in Comparison to the Normal Intraventricular His System

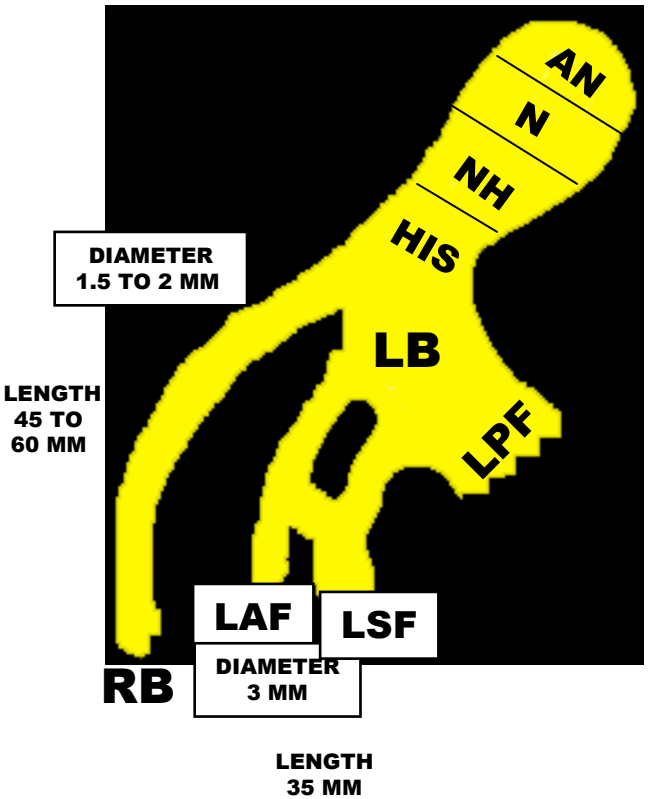
1. Posterior displacement of the atrioventricular (AV) node
2. Relatively short distance between the AV node and the beginning of the Left Bundle Branch (**LBB**)
3. Shorter and shifted backward and inferior of His bundle and the LBB.
4. Longer and hypoplasic Right Bundle Branch(80mm length) Normally **RBB** has 45 to 60mm
5. Left Posteroinferior Fascicle (**LPF**) with early onset
6. Left Anterosuperior Fascicle(**LAF**) hypoplasic(1mm) and longer than normally (70mm).

These anatomical features results in a counterclockwise (**CCW**) rotation loop in the FP in 95% of cases[1]. The posteroinferior displacement of the LBB seemed to be responsible (partially) for left axis deviation[2]. In OP-ASD early activation of the posterobasal region of the LV through an abnormally short LPF results in a minimal superior QRS axis which is then exaggerated in the presence of abnormal hemodynamics, ventricular hypertrophy, or RBBB. Thus, the superior axis in OP-ASD with associated RBBB does not represent a true bifascicular block and has a different natural history and clinical significance[3].

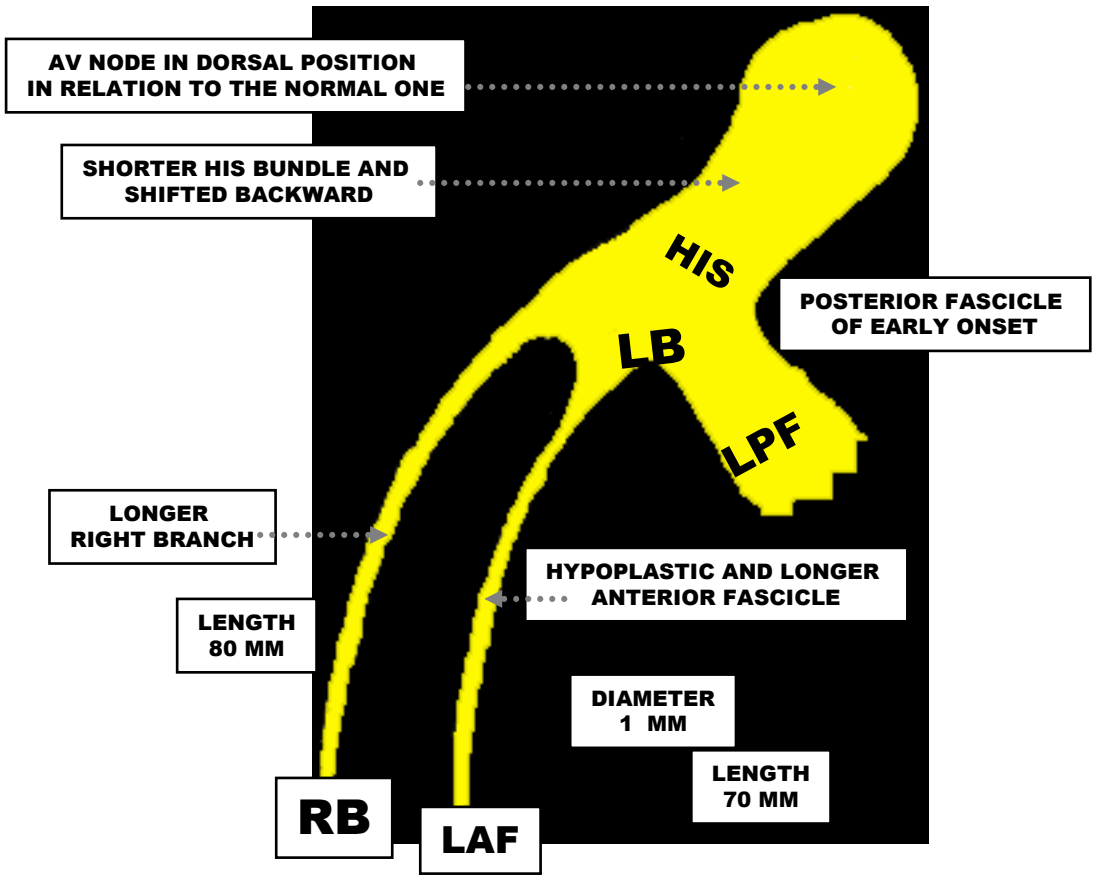
1. **Boineau JP, Moore EN, Patterson DF. Relationship between the ECG, ventricular activation, and the ventricular conduction system in ostium primum ASD. Circulation. 1973 Sep;48:556-564.**
2. **Ih S, Fukuda K, Okada R, et al Histopathological correlation between the QRS axis and disposition of the atrioventricular conduction system in common atrioventricular orifice and in its related anomalies Jpn Circ J. 1983 Dec;47:1368-1376.**
3. **Borkon AM, Pieroni DR, Varghese PJ,et al. The superior QRS axis in ostium primum ASD: a proposed mechanism. Am Heart J. 1975 Aug;90:215-221.**

COMPARISON BETWEEN THE NORMAL INTRAVENTRICULAR CONDUCTION SYSTEM WITH THE ATRIOVENTRICULAR SEPTAL DEFECT

NORMAL INTRAVENTRICULAR HIS SYSTEM



INTRAVENTRICULAR HIS SYSTEM IN ENDOCARDIAL CUSHION DEFECTS



IT EXPLAINS RBBB AND POSTERIOR EARLY ACTIVATION OF THE LAFB TYPE; DELAYED ANTERIOR REGION ACTIVATION.

1. Boineau JP, Moore EN, Patterson DF. Relationship between the ECG, ventricular activation, and the ventricular conduction system in ostium primum ASD. Circulation. 1973 Sep;48:556-564.

Another theory postulated that patients with OP-ASD have an imbalance in the positions of the left ventricular papillary muscles compared with healthy subjects, and that this anatomic imbalance correlates with left deviation of the QRS axis. 35 patients with OP-ASD and 35 healthy subjects were included in the study.

Echocardiographic images were used to determine the papillary muscle positions.

A 12-lead electrocardiogram was used to determine the QRS axis in the frontal plane in both patients and healthy subjects. An imbalance between papillary muscle positions in OP-ASD patients was defined as the position of the antererolateral papillary muscle (ALPM) closer to the septum and/or the position of the posterolateral papillary muscle(PLPM) further from the septum compared with the position of the papillary muscles in healthy subjects.

In OP-ASD patients compared with control subjects, there was significant imbalance in the positions of the papillary muscles. The imbalance of papillary muscles correlated with deviation of the QRS axis.

Abnormality in the position of the papillary muscles changes continuously with the abnormality of the QRS axis. Understanding the electroanatomic relationships provides important insight into developmental relationships between the conduction system and the trabecular structures in OP-ASD patients. These results may provide insights in understanding the continuity of OP-ASD abnormality, in estimating the best surgical approach, and predicting the prognosis of OP-ASD patients.

1. Hakacova N, Wagner GS, Idriss SF. Electroanatomic relationships in patients with primum atrioventricular septal defect. JACC Cardiovasc Imaging. 2009 Dec;2:1357-1365.

The portion of the LV endocardium activated earliest is directly supplied by the "fanlike" distribution of the anterior, middle, and posterior fascicles of the LBB.

The anterior and posterior fascicles course toward their respective mitral papillary muscles.

These structures could therefore serve as anatomical landmarks to indicate the borders of this fanlike distribution of primary "start points" of LV activation.

Hakova et al(1) test the hypothesis that location of both papillary muscles closer to the septum correlates with longer QRS duration. The secondary aim of the study is to test the hypothesis that the balance of the distances of the ALPM and PLPM from the septum is related to the direction of the frontal plane QRS axis.
The study population consisted of 16 healthy adult volunteers with a mean age of 26 +/- 9 years. Measurements were done on the magnetic resonance images from all study subjects. Positions of papillary muscles were assessed as a predictive variable of QRS duration.
A significant correlation was found between the closer position of both papillary muscles to the septum and longer QRS duration. Subjects with higher ratio of ALPM vs PLPM free wall angle correlates with inferior rotation of the average axis of QRS complex in the FP.
The positions of the papillary muscles in relation to the free wall and septum wall can be predictive of both QRS duration and the direction of the QRS axis. These results might provide a new basis for prediction of QRS complex characteristics of an individual and, thus, differentiate between real QRS complex abnormalities and variants of normal[1].

1. Hakacova N, Robinson AM, Olson CW, et al. The relationship between mitral papillary muscles positions and characteristics of the QRS complex.J Electrocardiol. 2008 Nov-Dec;41:487-490. 2008

4) aVR: qR complexes with broader final R wave and followed of negative T wave.
5) Abnormalities in the right precordial leads are similar to those in OS- ASDs. The QRS pattern typically is either an trhphasic QRS type rSr' or an rsR' nearly always present in right precordial leads V3R V1 and V2 and resulting from dilation and hypertrophy of the RVOT caused by volume overload of the right ventricle. Broader S wave in left leads I, aVL, V5 and V6.
6) More evident signs of RVH in its complete form (ostium atrium ventricularis comunis). There may be criteria for BVE or LVH.
7) After OP-ASD repair significant late postoperative arrhythmias are frequent (≈20%). The types of arrhythmias included isolated complete atrioventricular block in 5 of 14, complete atrioventricular block with sinus node dysfunction in 2 of 14, and isolated sinus node dysfunction in 7 of 14. Pacemakers have been implanted in 8 of 14 of these patients.

1. Portman MA, Beder SD, Ankeney JL, et al. **A 20-year review of ostium primum defect repair in children.** Am Heart J. 1985 Nov;110:1054-1058.

Congenital Heart Disease associated with extreme left axis deviation and CCW rotation on FP

Extreme left axis deviation (QRS axis between -30° and -90°) is one of the most commonly encountered ECG abnormalities. Its presence should alert physicians to the possibility of underlying structural heart disease. Many of the causes of left axis deviation are apparent from the clinical findings. Left anterior fascicular block is one of the commonest causes of left axis deviation and has specific ECG criteria for its diagnosis. A counterclockwise (CCW) frontal plane QRS loop that is oriented to the left and superiorly may be seen in others congenital heart diseases[1]:

1. Endocardial Cushion Defects partial and total (LAFB+BVH+RBBB); 3. Tricuspid Atresia (in ≈ 80% of cases RAE or BAE+LVH+LAFB+ cianosis); 4. in ≈ 15% of Uncomplicated Ventricular Septal Defect[2]; 5. Double-outlet Right Ventricle; 7. Complete Transposition of Great Arteries[3]; 8. Corrected Transposition of the Great Vessels; 9. Single Ventricle 22% ; 10. Coartation of the Aorta 18%; 11. Patent Ductus Arteriosus; 12. First degree relatives of patients with atrioventricular defects; 13. Anomalous origin of the left coronary artery from the pulmonary trunk; 14. large pulmonary AV fistula; 15. Aortic stenosis; 16. After surgery to correct Tetralogy of Fallot with septal apporach, VSD, or endocardial cushion defect[4]; 17. Normal variant. In the last one frequently, it is associated with incomplete right bundle branch block[5].

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1. MacKenzie R. Left axis deviation. J Insur Med. 2005;37:227-32.
2. Brink AJ, Neill CA. The electrocardiogram in congenital heart disease; with special reference to left axis deviation. Circulation. 1955 Oct;12:604
3. Shaher RM. Left Ventricular Preponderance And Left Axis Deviation In Cyanotic Congenital Heart Disease.Br Heart J. 1963 Nov;25:726-734.
4. Rautenburg HW, Wagner R. Left anterior hemiblock" or "extreme left axis deviation" in the ECG of childrenMonatsschr Kinderheilkd. 1983 Mar;131:150-156.
5. Calcaterra G, Puglisi R. Left axis deviation in healthy infants and children. Int Cardiol. 1989 Aug;24:236-238.

Three groups of patients were identified in the series of OS-ASD with extreme left axis deviation in an analysis of 910 patients of OS-ASD with or without other accompanying anomalies:

1) 12 patients with isolated ostium secundum atrial septal defect **OS-ASD** and extreme left axis deviation

2) 5 patients with OS-ASD associated prolapse of posterior leaflet of the mitral valve and extreme left axis deviation. The association of prolapse of the posterior leaflet of the mitral valve with OS-ASD is common and may be present in the absence of any clinical evidence of a mitral valve lesion[1].

3) 4 patients with OS-ASD associated HCM and/or single (left) coronary artery and extreme left axis deviation.

The combination of such anomalies should be considered in the differential diagnosis of OP-ASD endocardial cushion defect from the ECG viewpoints[2].

1. **Betriu A, Wigle ED, Felderhof CH, et al. Prolapse of the posterior leaflet of the mitral valve associated with secundum atrial septal defect. Am J Cardiol. 1975 Mar;35:363-369.**
2. Tan KT, Takao A, Hashimoto A, et al. **Electrocardiogram of secumdum type atrial septal defect simulating endocardial cushion defect.** Br Heart J. 1975 Feb;37:209-215.

The VCG in Endocardial Cushion defects

The ECG/VCG finding in endocadial Cushing defects depend of following factors:
1)The amount of blood that is shunted
2) The pulmonary artery pressure
3) The anatomical modifications of the intraventricular conductions system.
1 and 2 affect mainly the horizontal plane (HP) affected the QRS rotation reflected primarily the right ventricular systolic pressure and the anatomical modifications of the intraventricular conductions system alter the frontal QRS axis in frontal plane (FP) with extreme left axis deviation and CCW rotation on FP.

HORIZONTAL PLANE OR TRANSVERSAL PLANE

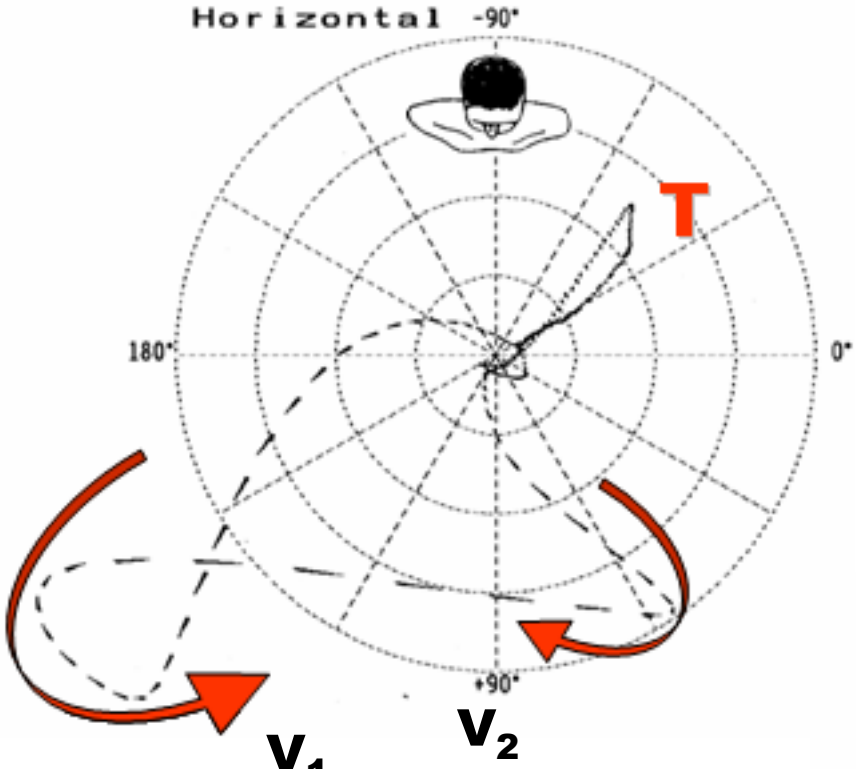
Low RV pressure: If right ventricular pressure < 40mm Hg: QRS loop CCW rotation and type C RVH pattern, III or SPECIAL

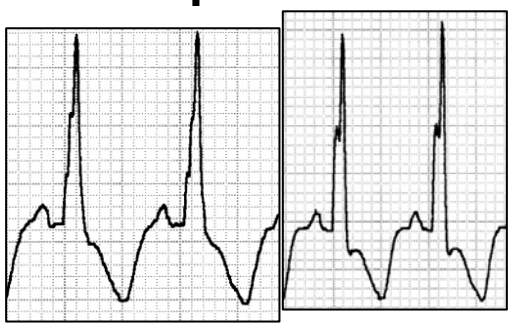
Intermediate RV pressure: RVH TYPE B or II QRS loop in the horizontal plane keeps a counterclockwise rotation or figure in eight intermediate intraventricular right pressure Right bundle branch block (RBBB) pattern.

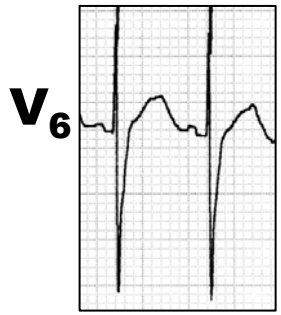
High RV pressure: RVH TYPE A or I. CWR intraventricular right pressure >100mm of Hg and located predominantly on right anterior quadrant. It indicates severe RVH, QRS loop of clockwise rotation in the horizontal plane and of location predominant in anterior quadrants, predominantly in the right anterior quadrant.

If significative mitral insufficiency and/or large IVS are observed signs of LVH: increase leftward maximal spatial voltage.

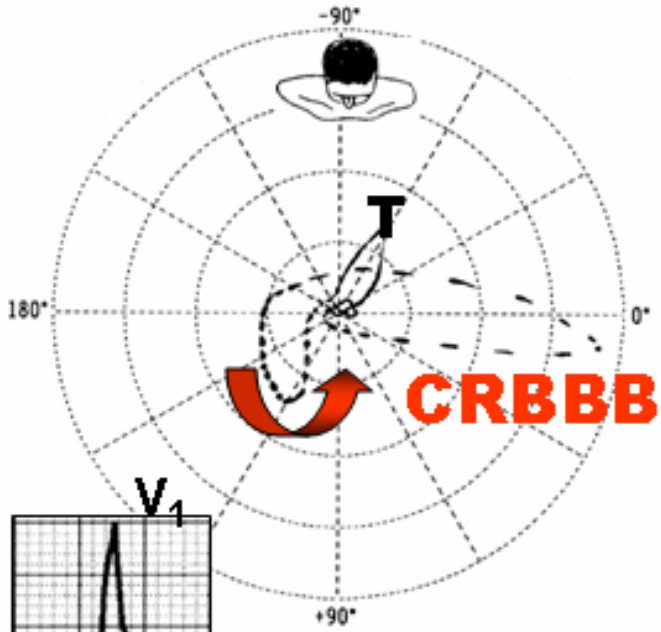
High RV pressure:

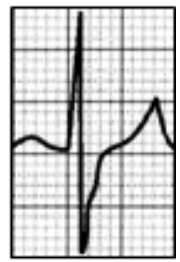






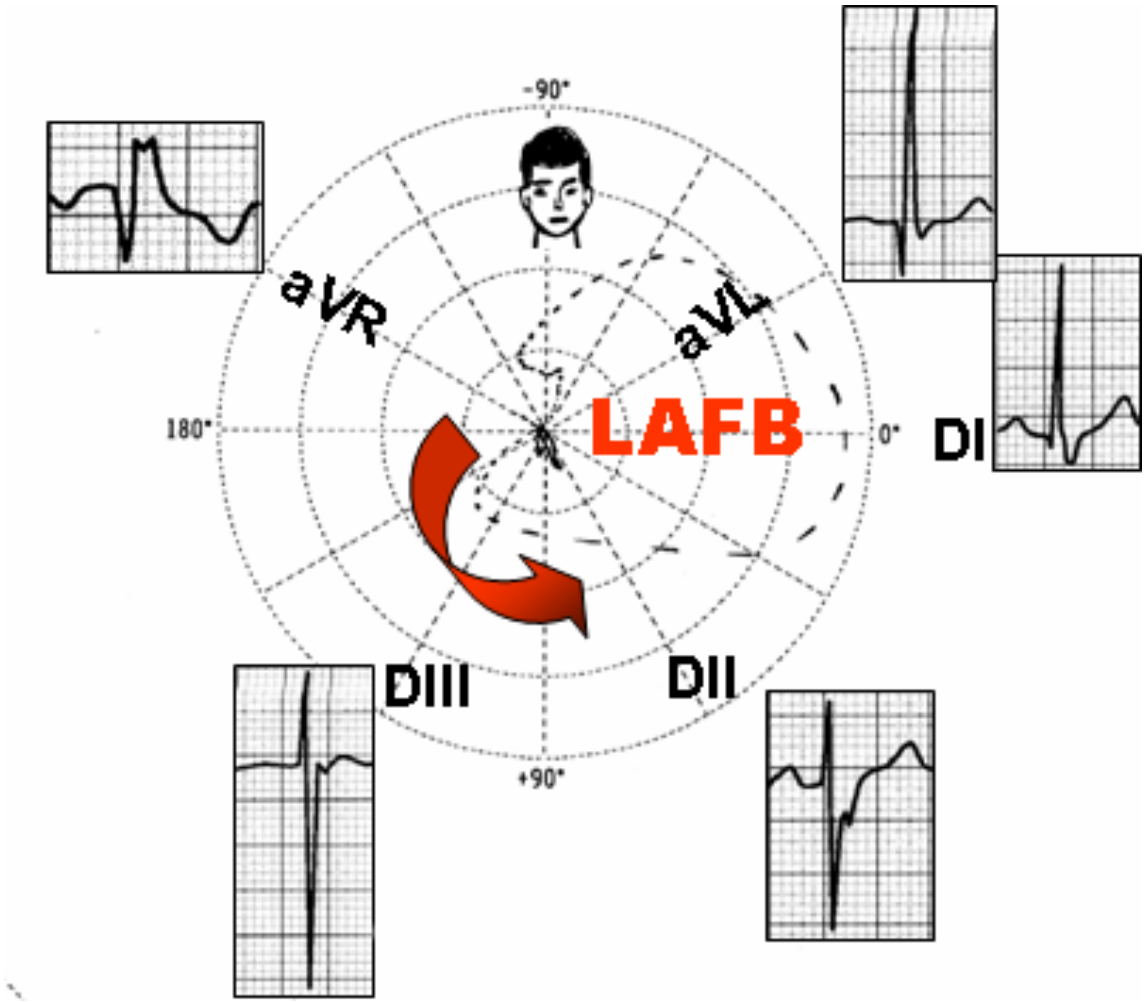
Low RV pressure:





FRONTAL PLANE

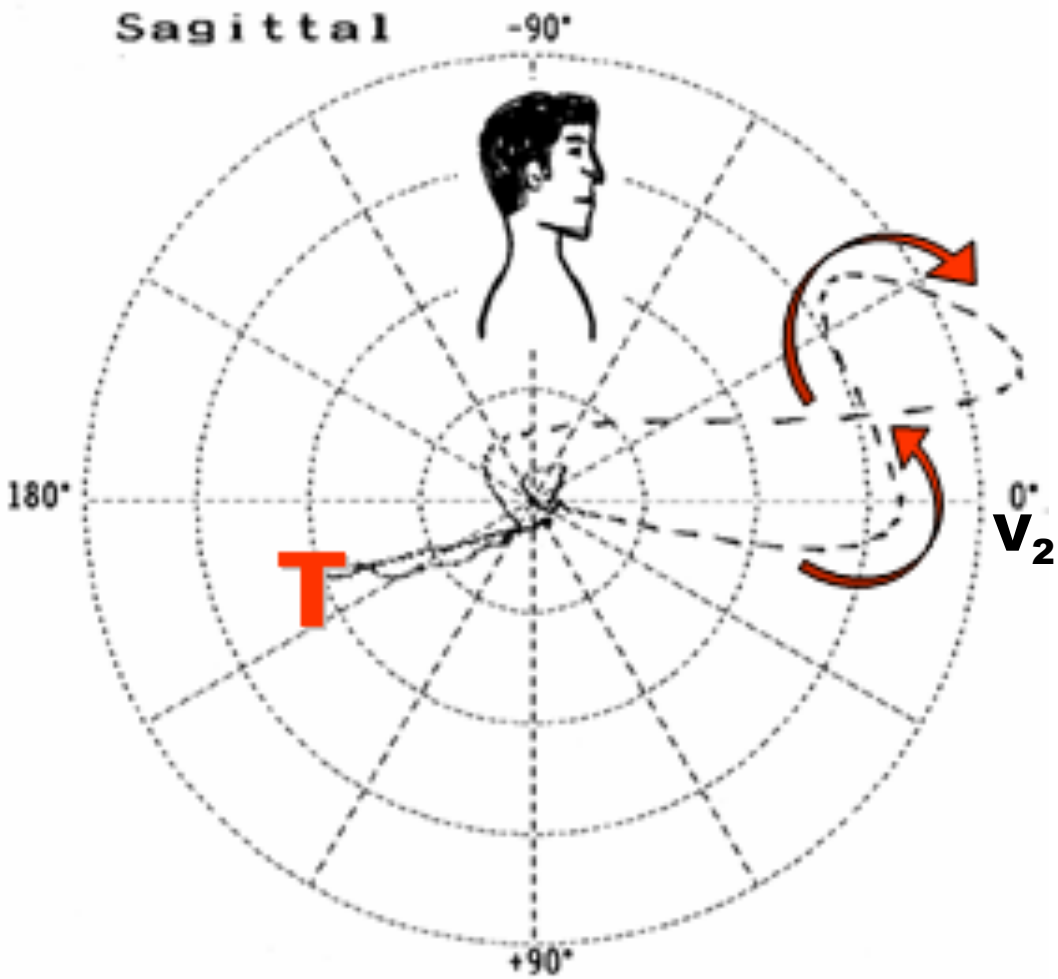
10-20ms initial vector directed inferiorly dependent of Left Posteroinferior fascicle
The loop is inscribed counterclockwise(CCW)
The maximal QRS vector being in the left superior quadrant in 95% of cases in OP-ASD an in all patients with common AV canal
In 5% of cases the loop is inscribed in a linear figure –eight manner that is slightly superior to the X lead 0° to + - 180°.



1. Coelho E, Sequerra Amran S, et al.. Electrocardiogram and vectorcardiogram of ostium secundum and ostium primum. Cardiologia. 1960;37:319-30
2. Brohet CR.. Special value of the vectorcardiogram in pediatric cardiology. J Electrocardiol. 1990;23 Suppl:58-62.

RIGHT SAGITTAL PLANE

10-20ms initial vector directed inferiorly and to front.
QRS loop in rotate CCW in a superior location.



Summary of Main ECG/VCG features in Endocardial Cushion Defects

1. **Normal P wave or signs of right atrial left atrial or biatrial enlargement may be observed**
2. **Atrial Arrhythmias are frequent:** atrial fibrillation or flutter are common.
3. **First degree V block is frequent (≈50% of cases)**
4. **Extreme left axis deviation is the rule (near 95% of cases in partial forms and in 100% of complete one)**
5. **CCW rotation activation in FP is an hallmark**
6. **Right Bundle Branch Block pattern is characteristic: the usual patterns in right precordial leads is an rSR`or rsR´ consequence of RVOT hypertrophy**
7. **Biventricular hypertrophy criteria are frequently present**
8. **The P loop is direct to the left and inferiorly with normal or increased magnitude With significant mitral regurgitation the left atrium dilated and produces increased posterior and inferior forces.**
9. **The QRS loop in FP is superiorly oriented and is inscribed in a CCW fashion**
10. **The QRS loop in HP has Type A, B or C RVH patter with high, middle or lown pulmonary artery pressure respectively.**

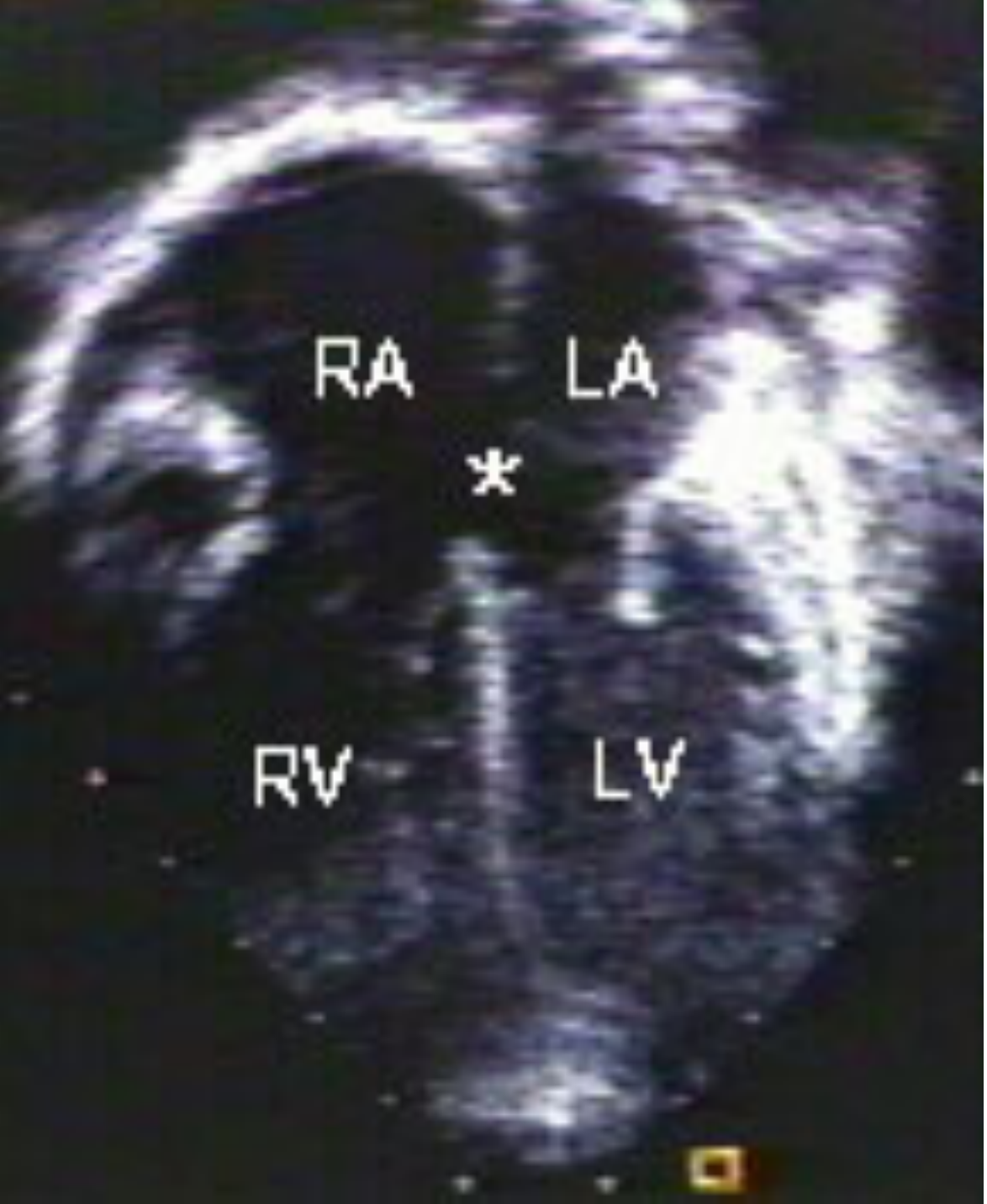
Echocardiography

Echocardiography confirms the diagnosis of a primum ASD or partial atrioventricular (AV) canal defect. Anatomy is delineated by 2-dimensional imaging, and shunt flow and AV valve regurgitation are assessed by color and pulsed Doppler.

Two-dimensional imaging The apical 4-chamber view and subcostal imaging planes readily demonstrate a OP-ASD, showing an area of "drop-out" in the inferior atrial septum. Care must be taken to differentiate this from the drop-out noted in the region of the coronary sinus. This may be particularly difficult when the coronary sinus is dilated from drainage of a left superior vena cava. Two-dimensional echocardiographic examination of the atrial septum utilizing the subcostal approach is the preferred method for the confident, noninvasive diagnosis and categorization of atrial septal defects. Two-dimensional echocardiographic contrast and Doppler examinations complement the technique and enhance diagnostic accuracy.

In the apical imaging plane in a normal heart, the tricuspid valve is more apically positioned than the mitral valve. In AV canal defects, both valves are visualized at the same horizontal level, and the crux of the heart is absent. In a partial canal defect, distinct left and right AV valves are identified. The leaflets are attached to the crest of the interventricular septum and no defect of the interventricular septum is visualized. A tricuspid valve cleft or other abnormalities of the valve leaflets also may be noted. When present, a cleft is visualized in the anterior mitral valve leaflet pointing toward the interventricular septum. This is best seen in a parasternal or subcostal short-axis view. A double orifice mitral valve or single papillary muscle may be noted. Since the aortic root is not wedged between the mitral and tricuspid annuli, the aortic valve is anteriorly positioned, resulting in a long, narrow, left ventricular outflow tract with a so-called "gooseneck" appearance. LVOT obstruction may occur from mitral valve tissue crossing the subaortic area.

1. **Shub C, Dimopoulos IN, Seward JB, et al. Sensitivity of two-dimensional echocardiography in the direct visualization of atrial septal defect utilizing the subcostal approach: experience with 154 patients. J Am Coll Cardiol. 1983 Jul;2:127-135.**



Two-dimensional, apical, 4-chamber echocardiogram of a partial atrioventricular (AV) canal defect. The asterisk (*) delineates an area of dropout in the inferior atrial septum at the site of the OP-ASD. The AV valves are separate but aligned at the same horizontal level, consistent with a 2-orifice common AV valve. In systole, the medial leaflets of the right- and left-sided AV valves demonstrate attachments to the crest of the interventricular septum, allowing no ventricular level shunting.

RA = Right Atrium
LA = Left Atrium
RV = Right Ventricle
LV = Left Ventricle.

Color Doppler: The direction of atrial level shunting is readily detected by color Doppler and is best seen from the long-axis subcostal imaging plane. AV valve regurgitation is quantifiable by color Doppler, particularly well seen in the apical 4-chamber view but best evaluated in multiple planes. Tricuspid regurgitation typically is mild in the absence of pulmonary hypertension, whereas mitral regurgitation may range from trivial to severe. A LV to RA shunt should be interrogated, and lack of interventricular shunting should be confirmed. Differentiation of a primum ASD from a dilated coronary sinus is also aided by color and spectral Doppler.

Pulsed or continuous wave Doppler: The presence and degree of LVOT obstruction as well as relative pulmonary stenosis from increased flow across the pulmonary valve may be detected. The peak velocity (v) of the tricuspid regurgitant jet can be used to estimate right ventricular pressure. In the absence of RVOTO, the pulmonary artery systolic pressure will approximate (4 X v X v) + RA pressure. Pulmonary artery systolic pressure higher than 25 mm Hg indicates the presence of pulmonary hypertension. Estimation of the pulmonary artery pressure by continuous wave Doppler technique is not reliable in patients with left ventricle to right atrial shunting; this high velocity jet may be misinterpreted for the tricuspid regurgitant jet, resulting in an overestimation of the pulmonary artery pressure.

Three-dimensional echocardiography: Although rarely used, 3-dimensional echocardiography may offer a more accurate reconstruction of the AV valve(s) and the atrial septum, providing a more complete preoperative picture for the surgeon.

TransEsophageal Echocardiography (TEE): TEE generally is reserved for anatomical definition in older patients with poor acoustic windows and for intraoperative assessment during surgical repair. Postoperative assessment is particularly helpful while weaning from cardiopulmonary bypass. Mitral stenosis, residual AV valve regurgitation, LVOT obstruction and residual atrial level shunting may be identified. Pulmonary artery pressure may be estimated by the peak velocity of the tricuspid regurgitation jet. Optimally, residual problems can be identified and corrected before leaving the operating room.

Piatkowski R, Budaj-Fidecka A, Scislo P, **Transesophageal real time three-dimensional echocardiography in assessment of partial atrioventricular septal defect** Echocardiography. 2009 Oct;26:1092-4.

Fetal Echocardiography

In a retrospective multicenter study of 30 cases of confirmed partial OP-ASD.. The echocardiographic features deemed indicative of OP-ASD were:

1) Loss of the normal offset appearance of the AV valves.
2) 18 of the 30 (60%) cases were diagnosed before 24 weeks of gestation and 12 were diagnosed later.
3) Suspicion of CHD and known aneuploidy (trisomy 21) accounted for 60% of the referral indications.
4) The two anatomical landmarks deemed indicative of OP-ASD were detected in all cases at echocardiography. 20 cases were isolated (one with increased nuchal transluceny at the 12-week scan, one with polyhydramnios, one with fetal growth restriction) including four that were detected on routine ultrasound examination by the authors.
5) Additional cardiac anomalies were present in 5 (17%) cases, 4 of which involved aortic coarctation. There were associated chromosomal anomalies in 13 (43%); however, excluding the 6 cases referred because of known Down syndrome, the adjusted association rate with aneuploidy was 29.2%
6) Extracardiac anomalies, including non-chromosomal syndromes, were present in 10 cases (33.3%). Regarding fetoneonatal outcome, there were 13 terminations of pregnancy, one early neonatal death and 16 survivors, including four with mild to severe neurodevelopmental delay due to associated syndromic conditions.
7) OP-ASD seems to be associated with a high rate of chromosomal/non-chromosomal syndromic conditions, including skeletal dysplasias. Inutero, aortic coarctation represents the most frequently associated cardiac lesion (13.3%).

1. Paladini D, Volpe P, Sglavo G, et al. **Partial atrioventricular septal defect in the fetus: diagnostic features and associations in a multicenter series of 30 cases.** Ultrasound Obstet Gynecol. 2009 Sep;34:268-73.

Colleagues commentaries

Lactante con disnea de esfuerzo, insuficiencia cardiaca de alto gasto cardiaco, cardiomegalia severa y soplo de insuficiencia mitral mas soplo de hiperflujo pulmonar. El flujo tricuspideo esta aumentado.
ECG con PR largo para la edad (BAV primer grado) mas hemibloqueo anterior izquierdo.
No menciona los pulsos femorales.
El frémito en punta es en verdad poco frecuente en pediatria, pero con esas salvedades debo estimar que hay una mitral displásica, cleft?, quizas hasta canal AV parcial, cortocircuito I-D auricular, y quizas tambien interventricular. Podria acompañarse de displasia tricuspidea (enf polivalvular?)
Si bien no veo isquemia manifiesta, algunas veces el implante anomalo de coronaria izquierda puede producir mucho de lo descripto en este paciente y no tener isquemia ECG.
De todas formas, en un consultório pediátrico antes de terminar de escribir el mail ya la hicimos el eco.
Las malformaciones cardiacas pediátricas se corresponden con la embriologia mucho mas que con los semiologos. (aceptese el comentario jocoso).

Diego Esandi

El caso es compatible con canal AV completo. BCRD HBAI Sobrecarga Bi ventricular.
Las neumonia se explican por la hipertension venocapilar pulmonar. la sudoresis y fatiga facil por el mismo motivo, la sudoresis suele ser nocturna y en perlas en la cabeza.
El impulso de VD es por el shunt de I a derecha con agrandamiento de VD. IM presente en canal AV fremito de CIV Primer ruido debil por IM. (mala coaptacion valvular) Segundo ruido fijo por BCRD. Soplo tricuspideo de IT .
El ECG: Bloqueo completo de rama derecha con sobrecarga derecha. El eje es -100° aproximadamente por hemibloqueo mas SVD. Hemibloqueo anterio izquierdo.
SVI por Q D1 aVL V5 V6. Sobrecarga auricular izquierda (M mitral) PR largo BAV de primer grado para la edad?
Emilio Marigliano

Diagnóstico ECG: Ritmo Sinusal con BAV de 1er grado. Criterios de cremiento auricular izquierdo y biventricular: en el PF voltajes de HVI y en el PH criterios definidos de HVD rSR' Y criterio de voltaje y repolarizacion. Parece corresponder a una HVD tipo A con rotacion inicialmente anti-horaria pero rapidamente se torna horária con desarrollo predominante anterior y a la derecha, del asa QRS. Desde el punto de vista de los trastornos de conducción intraventricular tiene un Hemibloqueo Anterior Izquierdo, y si bien tiene leves retardos en la porción media del QRS, lo cual descarta el BRD (la porcion final tiene velocidad normal en ambos planos). El primer vector tiene dirección y sentido conservado lo cual descarta trastorno de Rama Izquierda. Entonces estos retardos medios, con duración practicamente normal del QRS aun considerando la edad, representan los trastornos secundarios a la hipertrofia de los ventriculos y Down Regulation de las Conexinas , como ha mencionado repetidas veces Samuel.
Desde el punto de vista de los datos semiológicos se corresponde con una CIA con importante Qp/Qs. Jose Luis Suarez lsuarez@INTRAMED.NET

Muy interesante ECG Dr Perez Riera, aparte de los datos aportados del examen físico, seria improtante saber si presenta signos de cianosis peribucal o en manos.
Ritmo sinusal 122 x min. Eje desviado a la extrema izquierda. BAV de primer grado, signos de CAI predominantes, BCRD con signos de crecimento VD.Por lo referido en el examen fisico y los hallazgos en el ECG me inclino por una CIA tipo ostium primun y el cierre precoz del R2 aortico por IM severa asociada, lo que tambien me explica el R1 disminuido de intensidad. La insuficiencia mitral severa podria corresponder por prolapso de valvula mitral que puede acompañar a las CIA, o como en este paciente impresiona presentar dilatacion severa del VI por sobrecarga volumétrica (RX ICT mayor 0,65), lo que produce la IM por la dilatacion del anillo mitral y la falta de adecuada coaptación de las valvas mitrales como se observa en las miocardiopatias dilatadas. El segundo ruido pulmonar desdoblado amplio por aumento de las presiones ventriculares derechas asociadas a la CIA, al igual que el rolido tricuspideo por el aumento volumétrico dado por el tamaño de la CIA no por estenosis tricuspidea asociada.
Martin Ibarrola

Estimados colegas del foro, este paciente tiene, (no es un sindrome Down no?) por los datos de la historia clínica (cuadros respiratorios a repetición, hiperflujo pulmonar, sobrecarga de cavidades derechas, incompetencia de válvula mitral, rolido tricuspídeo), del analisis del ECG (ritmo sinusal, bloqueo AV de primer grado, hemibloqueo anterior izquierdo, bloqueo de la rama derecha del haz de His e HVD) y de la RxTx (que no se muestra informando solo un aumento del indice cardiotorácico, falta saber que pasa con la arteria pulmonar, el flujo pulmonar y que cavidades se estiman dilatadas) una cardiopatía congénita dada por una CIA amplia tipo ostium primum asociada a alteracion de valvula mitral: cleft?.
Saludos
Pedro Chiesa

Querido Amigazo Prof Andrés: este ECG del niño de 11meses muestra una hipertrofia biventricular. Ondas R de gran voltage en V1 en presencia de desvio del eje a la izquierda y profundas ondas S en II, III y aVF. La desviación del eje frontal a la izquierda con ondas S profundas señala hipertrofia basal del ventrículo izquierda importante. La desviación del eje a la izquierda , segun mi experiencia acompaña frecuentemente las hipertrofias basales. Este patrón solo es muy frecuente en atresias tricuspídeas, pero la hipertrofia septal esta expresada en la R dominante en V1

Mi diagnóstico es: ostium primum severo. por lo que indicaria corrección quirúrgica lo antes posible.

Una posibilidad lejana puede ser CIV, pero esta nunca se manifiesta tan precozmente, "but never say never".

Un afectuoso saludo a nuestro compañero de la casta privilegiada de informadores de ECG

Samuel Sclarovsky

T o my dear friend, Professor Andrés

The ECG from the 11 month baby shows a biventricular hypertrophy (left axis deviation with deep S waves in II, III ,aVF , and high R in V. The left axis deviation with deep S waves in II, III, aVF indicate basal left ventricular hypertrophy. The frontal left axis deviation is a frequent finding accompany the pattern of basal hypertrophy. The hypertrophy basal area depresses the conduction velocity , allowing the posterior wall , to depolarized the posterior wall a few milisecons earlier that the anterior wall

This isolated pattern in the presence of cyanosis is compatible with tricuspid atresia , but the baby is not cyanotic ,with high R V1 in expressing by the septal hypertrophy. My final diagnosis is ostium primum, I recommend corrected surgery as soon as is possible.

This pattern is very seldom in babies with VSD "but never say never"

M y friendly regard

Samuel Sclarovsky