ECG in congenital Heart disease

Congenital Heart Disease (CHD)

- Occurs in 0.5-1% of all live births
- Simple way to classify is:
  - » L→R shunts
  - » Cyanotic CHD (R→L shunts)
  - » Obstructive lesions

Congenital Heart Disease

- Commonest group of life threatening anomalies
- 8/1000 live births
  - VSD 30-50%, PDA 10%, ASD 7%.
  - PS 7%
  - Coarctation 6%, AS 5%
  - Tetralogy 5%, TGA 5%
  - AV canal defects 3%

Despite the availability of advanced technologies,

a thorough history and physical examination is the core

of evaluating children with suspected heart disease

Symptoms of cardiac failure in the infant

- Poor feeding
- Failure to thrive
- Fatigue

Signs of cardiac failure in the infant

- Tachypnoea
- Tachycardia
- Hepatomegaly
- Sweating

Examination of CVS in the newborn

Look for cyanosis and dysmorphology

Physical exam

- Lungs
  - Respiratory rate and work of breathing
  - Oxygen saturations
- Abdominal exam
  - Liver size
- Extremities
  - Perfusion
  - Edema
  - Clubbing


Listen carefully


Do what is necessary to calm the baby down!

Feel the pulses
especially brachial and femoral

What is the difference between these two films?- both are infants with congenital heart disease.

ECG

- This may be real challenge in agitated infants or active children. To obtain an artifact-free ECG recording, distractors such as cartoons, movies, and stickers would be highly helpful

ECG

- Because of right ventricular (RV) dominance in infancy, some pediatric cardiologists prefer to obtain 15-lead ECG, including leads V3R, V4R, and V7.

During infancy, progressive decrease in pulmonary vascular resistance and closure of PDA shift physiological stress to the left side and the LV force become predominant by 6 months

The normal ECG values in pediatric are age- and heart rate-dependent. The most changes occur in first year of life. In the fetal life, circulatory system is primarily dependent on the RV. As a result, at birth the RV is larger and thicker than the left ventricle (LV). This produces ECG pattern reminiscent of RV hypertrophy (RVH) in adult

Age	<1 day	1–3 days	3–7 days	7–30 days	1–3 months	3–6 months	6–12 months	1–3 years	3–5 years	5–8 years	8–12 years	12–16 years	>16 years
Heart rate (beats per minute)	93–155 (122)	91–158 (124)	90–166 (128)	106–182 (148)	120–179 (149)	105–185 (142)	107–168 (132)	90–151 (119)	73–137 (108)	65–133 (100)	63–129 (92)	66–120 (86)	50 – 120
Electrical axis (degrees)	58–168 (>135)	65–171 (>134)	76–168 (>133)	65–159 (110)	31–115 (75)	7–105 (60)	7–98 (54)	8–100 (55)	7–104 (55)	10–140 (66)	9–115 (61)	11–133 (58)	-15 – 110
QRS duration	21–76	22–67	21–68	22–79	23–75	22–79	23–76	27–75	30–72	32–79	32–85	34–88	0.05 0.10
PR interval	79–160 (107)	81–139 (108)	75–137 (104)	73–138 (101)	73–130 (98)	74–145 (106)	73–156 (156)	82–148 (114)	85–161 (118)	90–164 (124)	87–171 (128)	92–175 (135)	0.12 0.20
Q-wave in III (mm)	0.1–5	0.1–5	0.1–5	0.1–5	0.1–5	<6.6	<6.3	<5.3	<4.2	<3.2	<2.7	<3.0	<3
R-wave in V1 (mm)	5–27 (14)	5–27 (15)	3–25 (13)	3–22 (11)	3–19 (10)	3–20 (10)	2–20 (9)	3–18 (9)	2–18 (8)	1–13 (7)	0.5–10 (6)	0.5–10 (5)	0.5 – 14
S-wave in V1 (mm)	0.5–23 (9)	0.5–21 (10)	0.5–17 (7)	0.5–12 (4)	0.5–13 (5)	0.5–17 (6)	0.5–18 (7)	1–21 (9)	2–22 (10)	3–24 (12)	3–26 (12)	3–22 (11)	0.5 – 23
R/S-ratio in V1	0.2–9.8 (2.3)	0.2–6.0 (2.0)	0.2–9.8 (2.8)	1.0–7.0 (2.9)	0.3–7.5 (2.3)	0.2–6.0 (2.4)	0.1–3.9 (1.8)	0.1–4.2 (1.4)	0–2.8 (0.9)	0–2.0 (0.8)	0–1.9 (0.6)	0–1.8 (0.5)	
R-wave in V6	0–12 (5)	0.1–12	0.5–12	3–17	5–22 (12)	6–23 (14)	6–23 (13)	6–23	9–25	9–27	10–26	7–23	4 – 2

Heart rate

Neonatal heart rate varies between 150 to 230 beats/min especially during crying. The heart rate reaches a peak between one and two months of life and then decreases gradually until six months

Normal resting heart rates

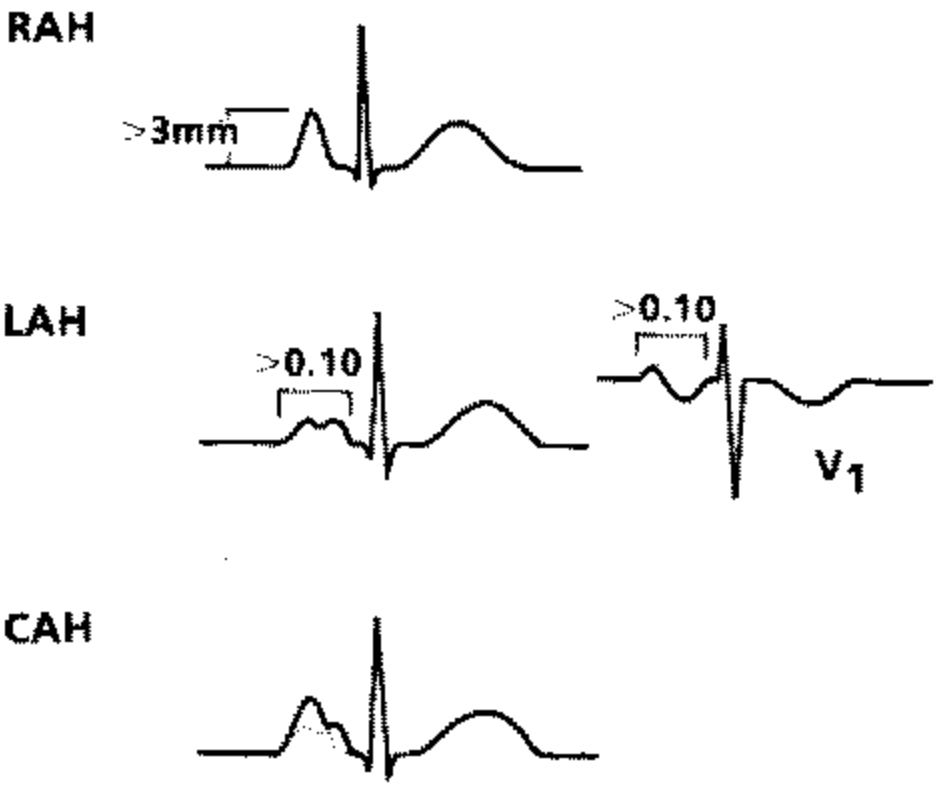
- Newborn: 110 - 150 bpm
- 2 years: 85 - 125 bpm
- 4 years: 75 - 115 bpm
- > 6 years: 60 - 100 bpm
- Adult: 50 - 100 bpm

Rhythm

For determination of heart rhythm, it is important to determine the exact origin of cardiac impulses and correlation of each P wave with next QRS complex

the P-wave axis would be between zero and +90 degrees and the P-wave morphology would be positive in leads I, II, and aVF and biphasic in lead V1

Atrial enlargement

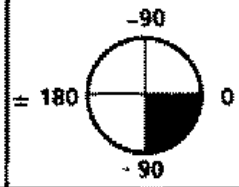
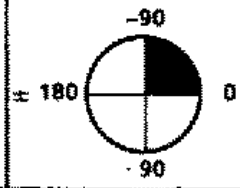
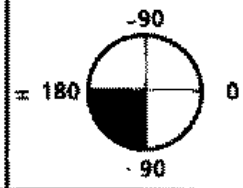
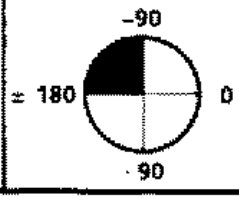


PR interval

Normal PR interval duration is shorter in children and changes with age and heart rate.

The neonatal PR interval may vary between 70 ms and 140 ms with mean of 100 ms

Quadrant determination

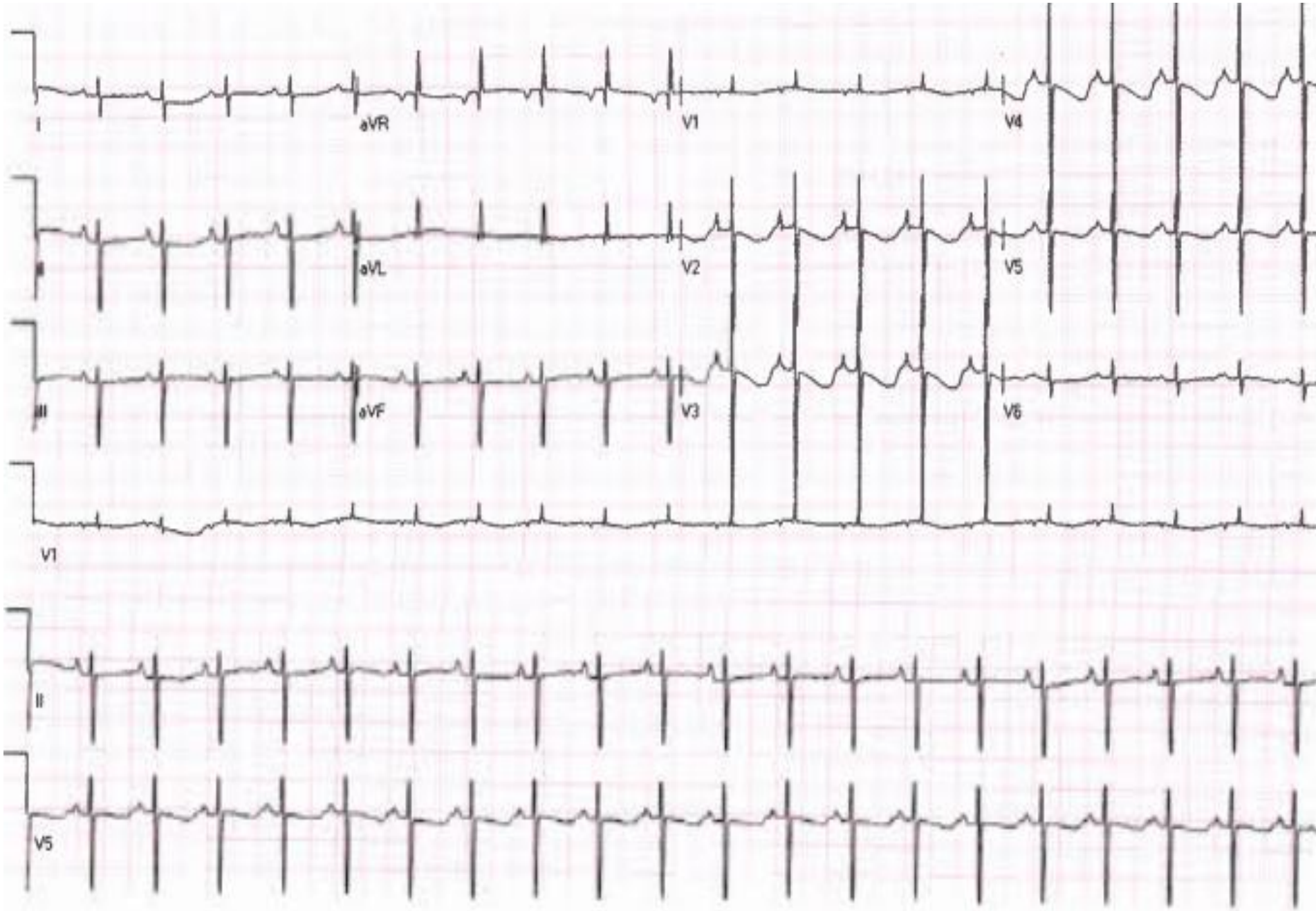
	Lead I	Lead aVF	
0° – +90			
0° – -90°			
+90° – ±180°			
-90° – ±180°			

Normal axis

Left axis
"Boston"

Right axis

Extreme R/L axis
"Seattle"


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

Newborn with
a complete AV septal (canal) defect. Note typical abnormally superior axis (northwest axis) along with right atrial enlargement.
V

QRS complex

Measurement of R-wave amplitude and QRS duration especially in precordial leads reflect ventricular depolarization status. Because of lower ventricular mass, the QRS duration is usually shorter in children than in adult: under 4 years of age, it is less than 0.09 sec, less than 0.10 sec up to 16 years of age, and less than 0.11 sec by late adolescence

Initial Forces

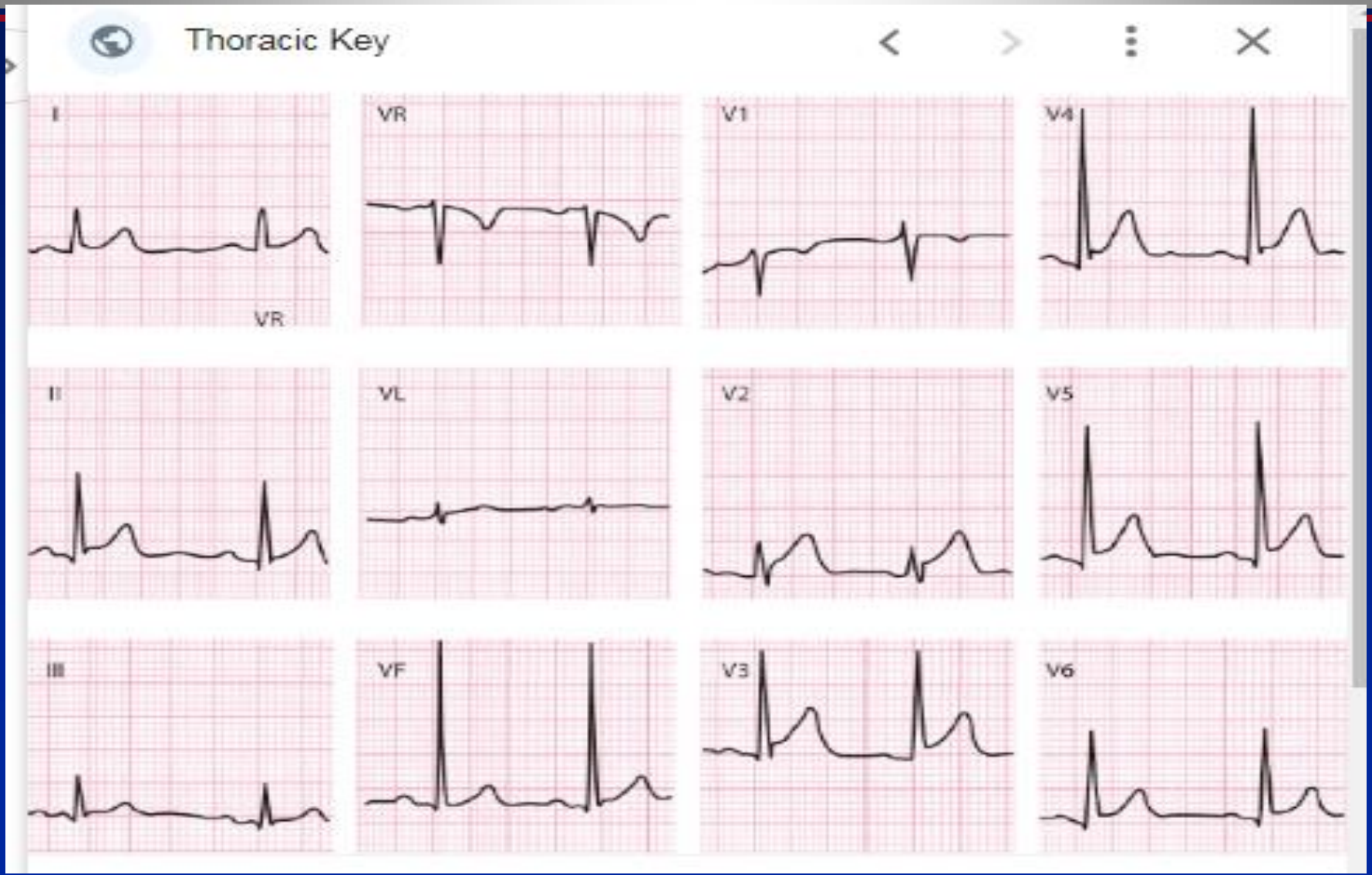
The Q wave occurs at the beginning of the QRS complex. One

normally finds a small (<4 mm) Q wave in leads V5 and V6,

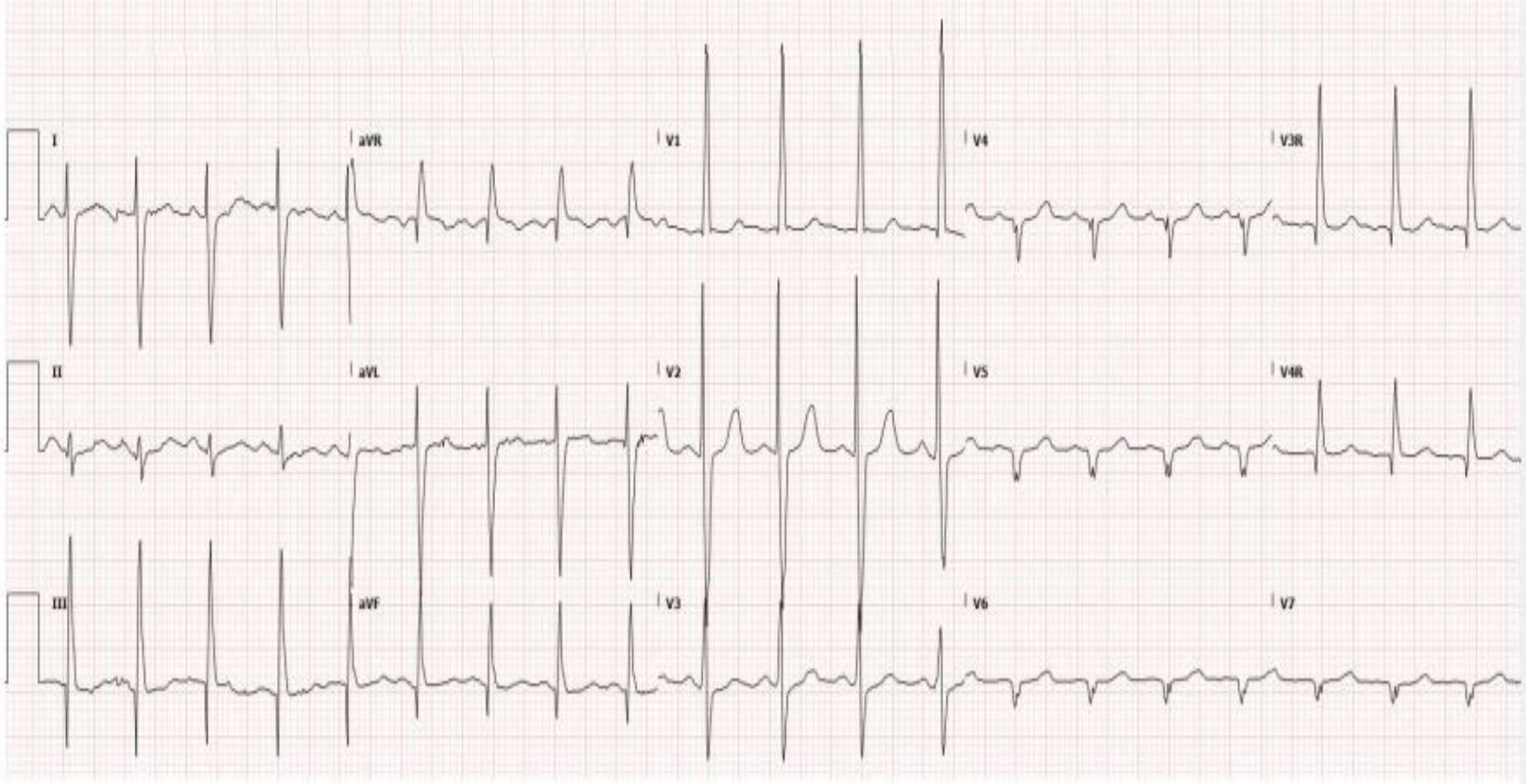
and aVl This is because normal initial depolarization, made

up of several different areas of endocardial activation including the septum, is rightward,

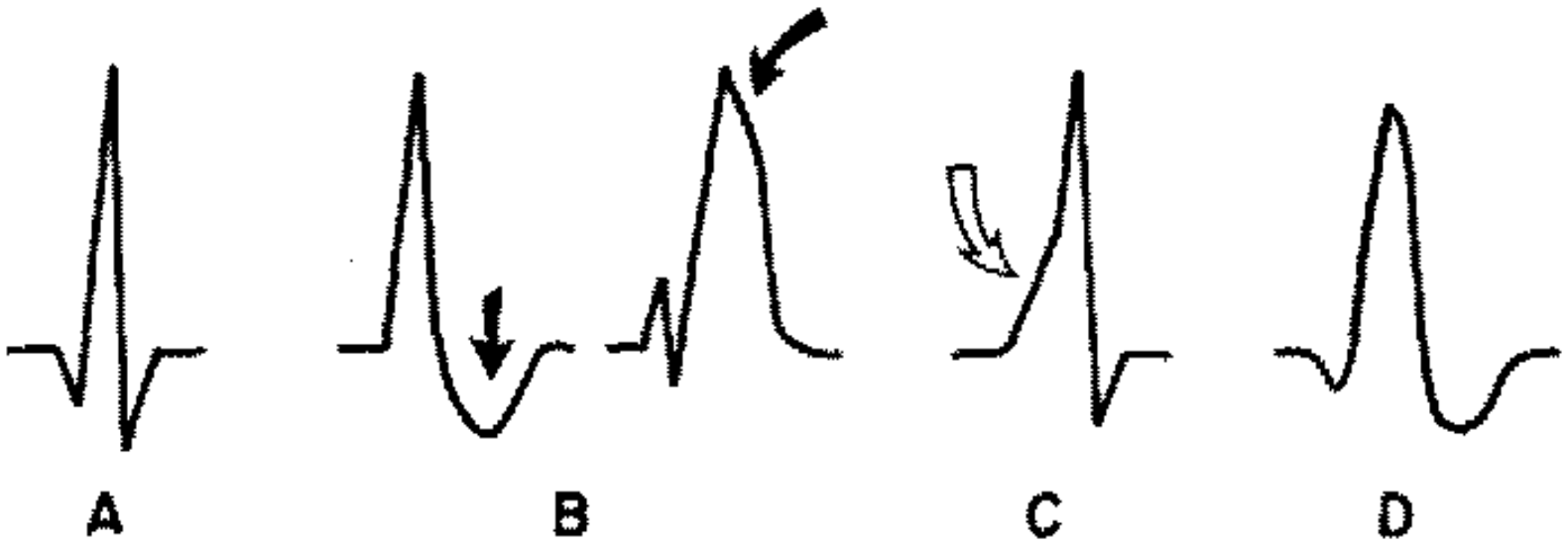
Normal-Initial Forces



Abnormal initial force



QRS morphologies



Normal

RBBB

Preexcitation ("delta wave")

IV block

T wave

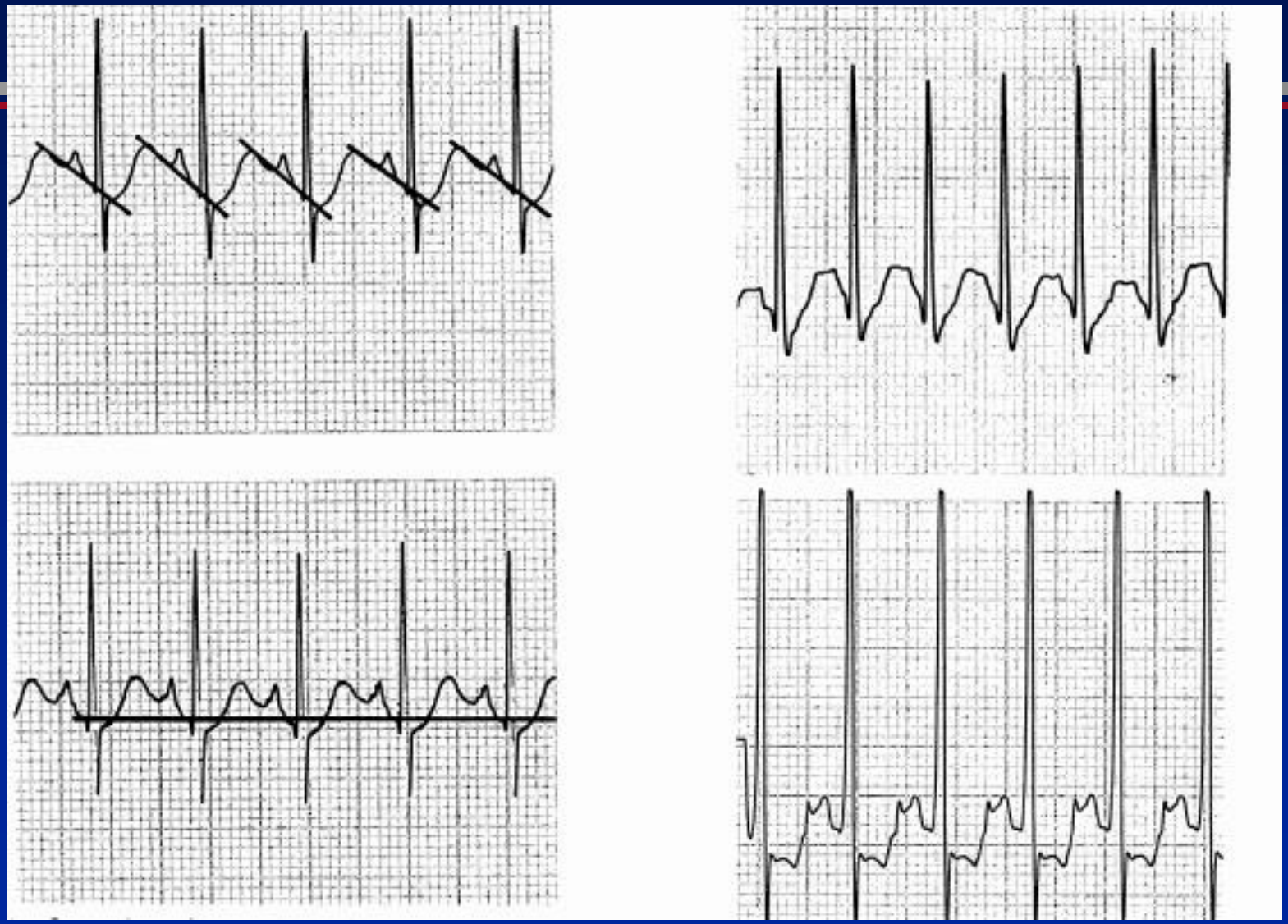
In first week of life, T-wave is upright in leads V1 and V3R. Then, it becomes inverted until 8 years and even may be continued to adolescence. In first 3-5 years of life, 50% of children have inverted T-wave in lead V2 but this value decreases to 5-10% in 8-12 years

T wave

Persistent positive T-wave after first week may represent RVH

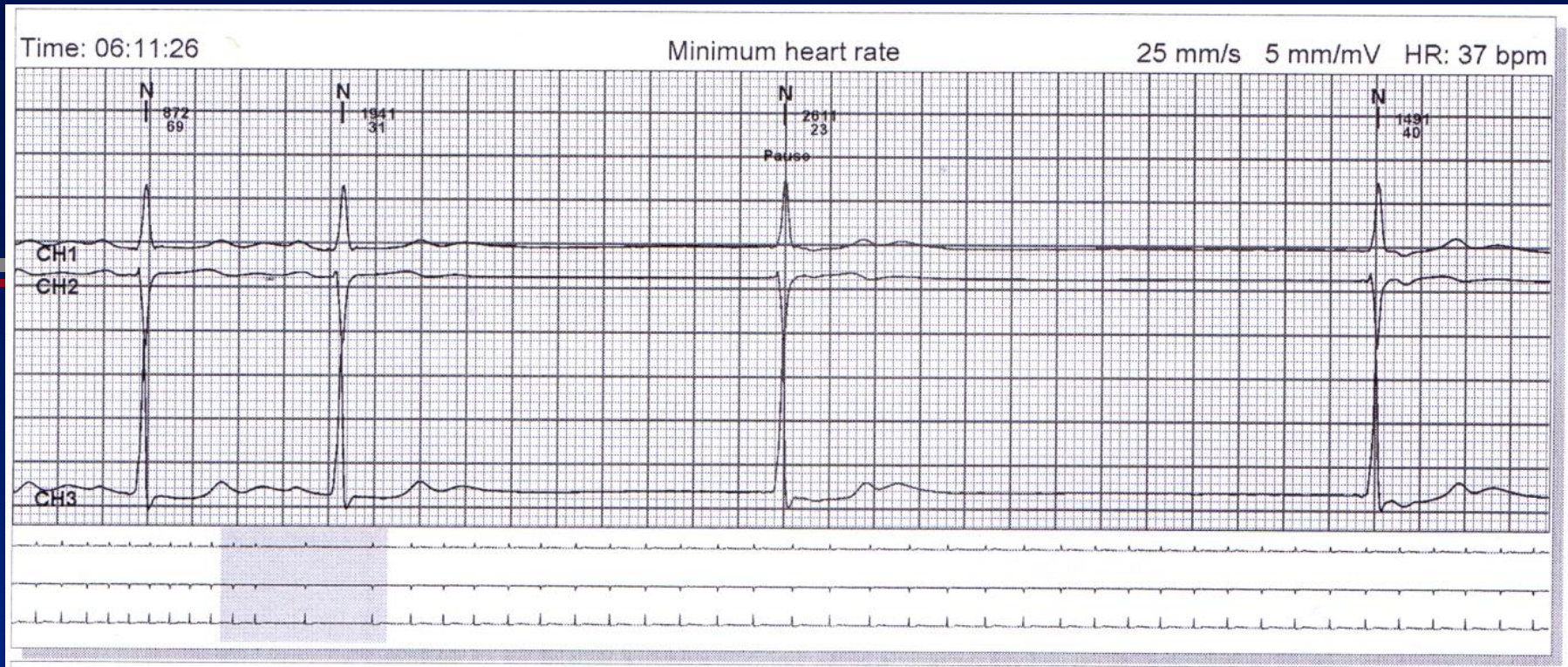
ST segment

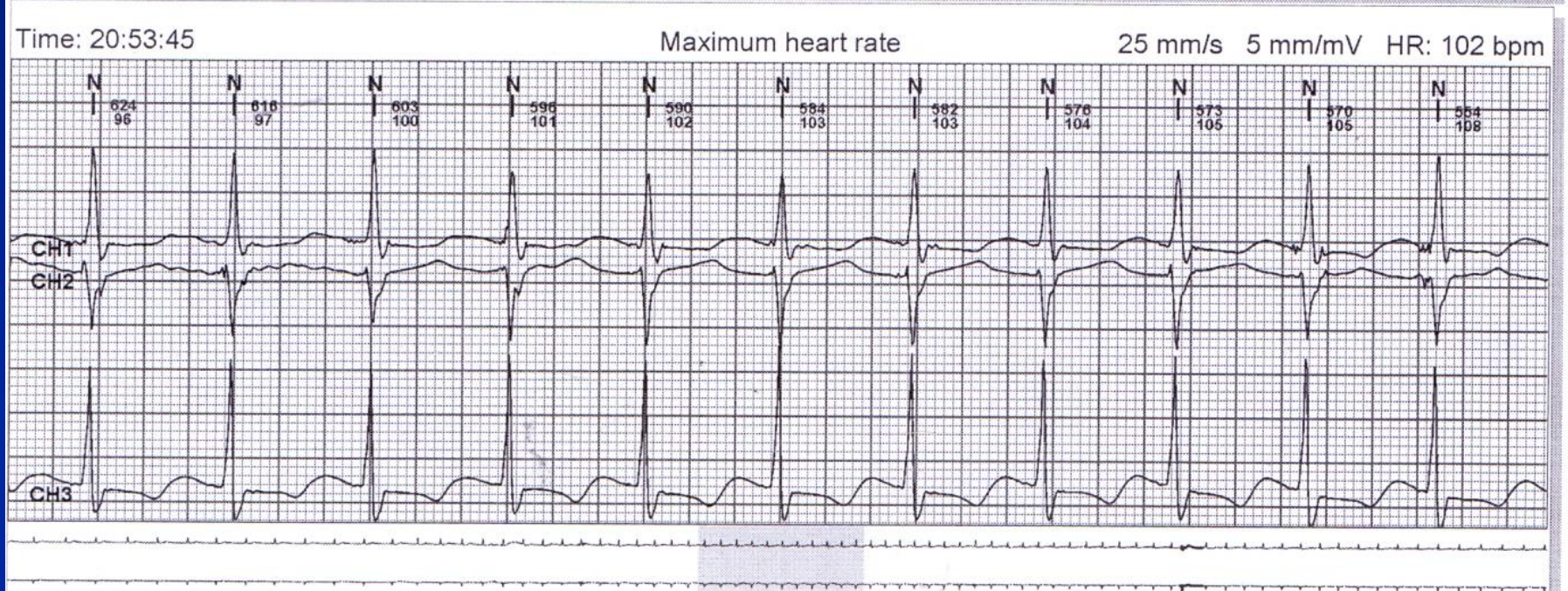
measured from end of the QRS complex to onset of the T-wave. J-point is the beginning of ST segment. It represents termination of depolarization with onset of ventricular repolarization. It is elevated when it is at least 1 mm above the isoelectric line and depressed when it is 0.5 mm below the isoelectric line



Conduction abnormalities

AV block can occur in children as well as in adult. Underlying causes may be congenital or acquired. The acquired causes including: Surgical repair of congenital heart disease, cardiac catheterism, infectious and inflammatory cardiac disease.


Time: 06:11:26
Minimum heart rate
25 mm/s 5 mm/mV HR: 37 bpm
N 872 69
N 1941 31
N 2611 23
Pause
N 1491 40
CH1
CH2
CH3


Time: 20:53:45
Maximum heart rate
25 mm/s 5 mm/mV HR: 102 bpm
N 624 96
N 616 97
N 603 100
N 596 101
N 590 102
N 584 103
N 582 103
N 576 104
N 573 105
N 570 105
N 564 108
CH1
CH2
CH3

L→R Shunts ("Acyanotic" CHD)

- Defects
  1. VSD
  2. PDA
  3. ASD
  4. AVSD (or complete atrioventricular canal)
- May not be apparent in neonate due to high PVR (ie- bidirectional shunt)

Ventricular Hypertrophy

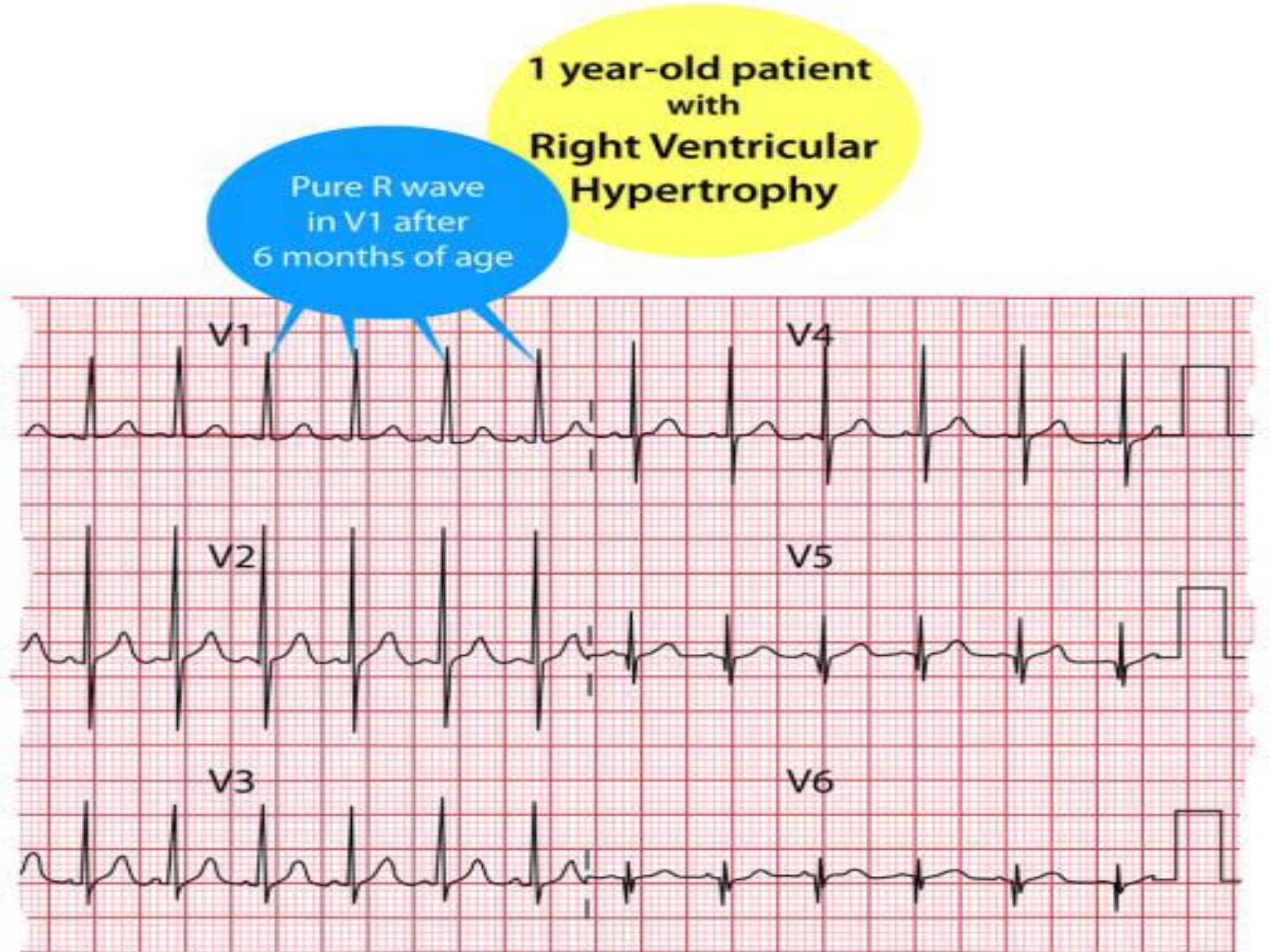
- RVH and LVH can be markers of significant disease states
  - Congenital Heart disease
  - Shunts
  - Pulmonary HTN
- Hypertrophy produces abnormalities on EKG
  - QRS axis
  - QRS voltages
  - R/S ratio
  - T axis

Age	<1 day	1–3 days	3–7 days	7–30 days	1–3 months	3–6 months	6–12 months	1–3 years	3–5 years	5–8 years	8–12 years	12–16 years	>16 years
Q-wave in III (mm)	0.1–5	0.1–5	0.1–5	0.1–5	0.1–5	<6.6	<6.3	<5.3	<4.2	<3.2	<2.7	<3.0	<3
R-wave in V1 (mm)	5–27 (14)	5–27 (15)	3–25 (13)	3–22 (11)	3–19 (10)	3–20 (10)	2–20 (9)	3–18 (9)	2–18 (8)	1–13 (7)	0.5–10 (6)	0.5–10 (5)	0.5 – 14
S-wave in V1 (mm)	0.5–23 (9)	0.5–21 (10)	0.5–17 (7)	0.5–12 (4)	0.5–13 (5)	0.5–17 (6)	0.5–18 (7)	1–21 (9)	2–22 (10)	3–24 (12)	3–26 (12)	3–22 (11)	0.5 – 23
R/S-ratio in V1	0.2–9.8 (2.3)	0.2–6.0 (2.0)	0.2–9.8 (2.8)	1.0–7.0 (2.9)	0.3–7.5 (2.3)	0.2–6.0 (2.4)	0.1–3.9 (1.8)	0.1–4.2 (1.4)	0–2.8 (0.9)	0–2.0 (0.8)	0–1.9 (0.6)	0–1.8 (0.5)	
R-wave in V6 (mm)	0–12 (5)	0.1–12 (5)	0.5–12 (5)	3–17 (8)	5–22 (12)	6–23 (14)	6–23 (13)	6–23 (14)	9–25 (15)	9–27 (17)	10–26 (17)	7–23 (15)	4 – 21
S-wave in V6 (mm)	0.2–10 (4)	0.2–10 (3)	0.4–10 (4)	0.2–10 (3)	0.3–7 (3)	0.2–10 (3)	0.2–8 (2)	0.1–7 (2)	0.1–6 (2)	0.1–4 (1)	0.0–4 (1)	0–4 (1)	0 – 4
R/S-ratio in V6	0.5–9 (2.5)	0.5–11 (3)	0.5–10 (2.5)	0.5–12 (4)	0.5–12 (4.5)	0.5–18 (6.5)	0.5–22 (8)	0.5–28 (9.5)	0.8–30 (11)	1–30 (12)	2–33 (14)	2–39 (15)	

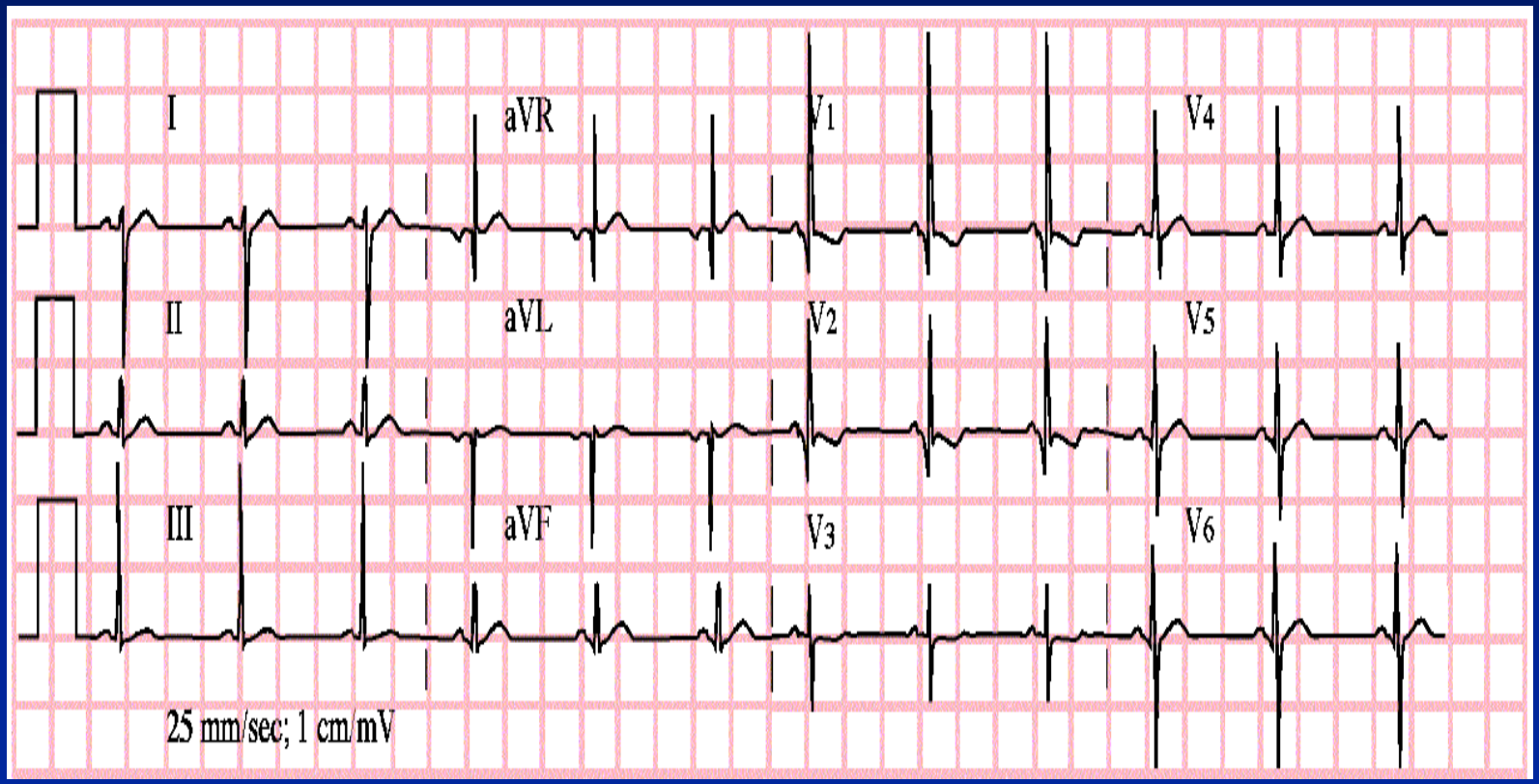
RVH in children mostly results from congenital heart diseases with pressure- and volume-overload mechanisms. Other causes include cardiomyopathy, hereditary myocardial disease, pulmonary vascular disease, and respiratory disease

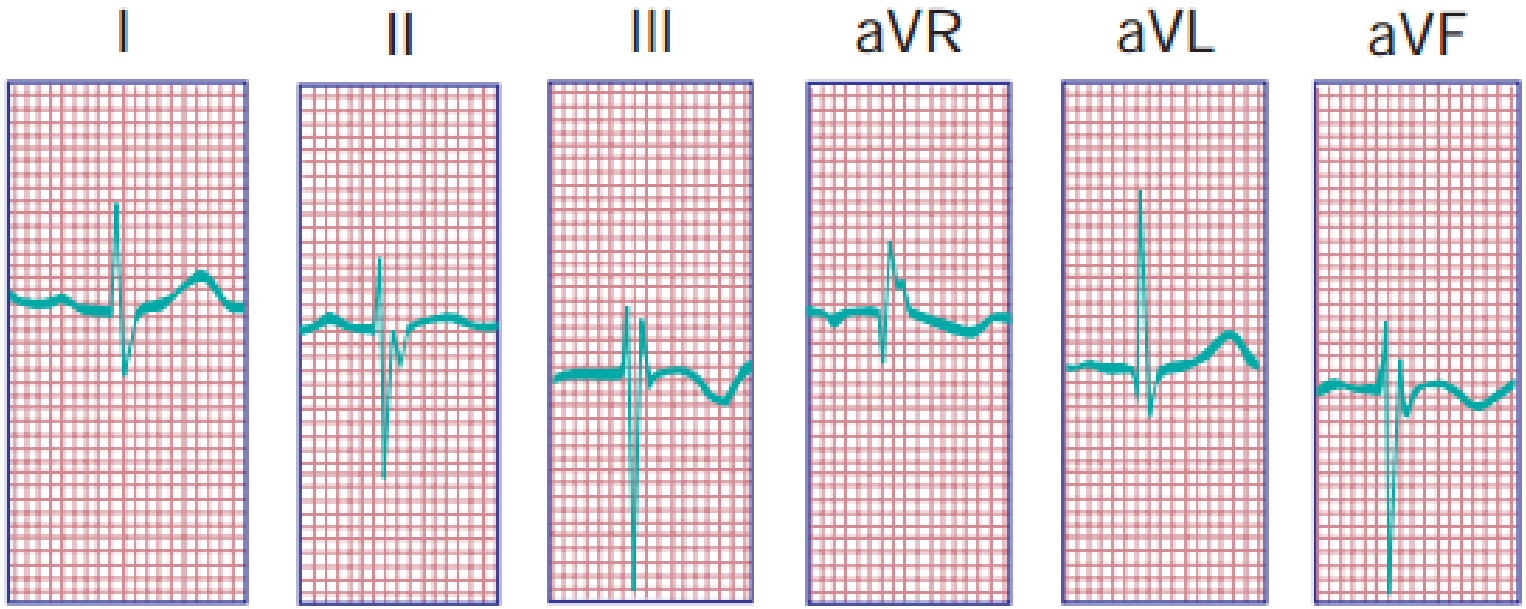
Systolic RVH

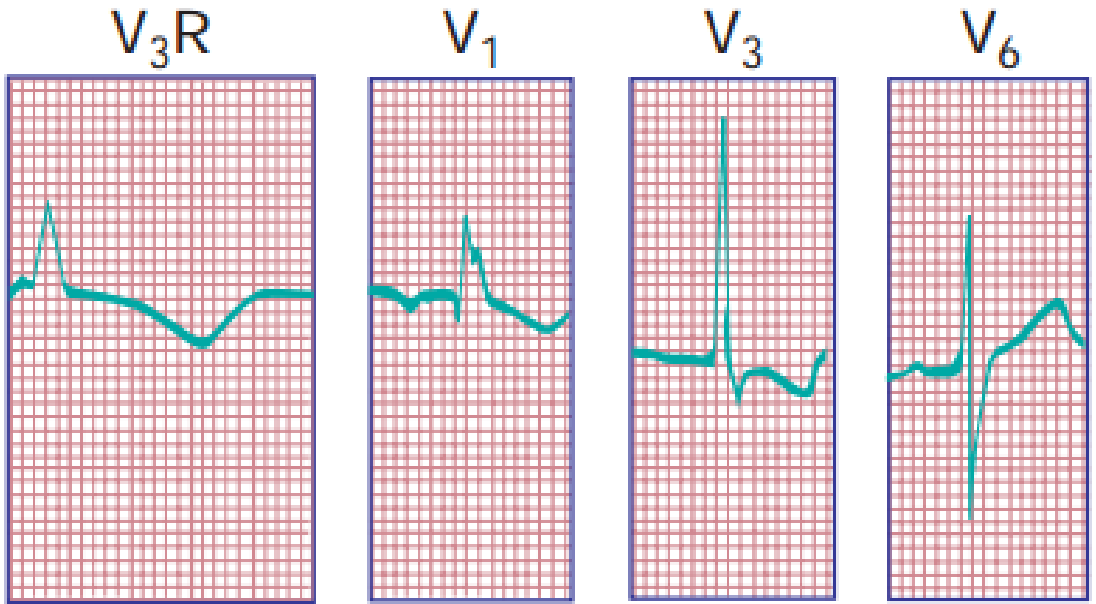
- Severe
  - Marked RAD
  - qR pattern V3R or V1
  - Tall pure R wave > 15 mm (any age) in right chest
  - Upright T wave > 3-5 days of age
  - Very tall R wave with ST depression and T wave inversion in V1 (“strain”)
  - Deep S wave V6


1 year-old patient
with
Right Ventricular
Hypertrophy
Pure R wave
in V1 after
6 months of age
V1
V4
V2
V5
V3
V6

Diastolic RVH




I
II
III
aVR
aVL
aVF


V3R
V1
V3
V6

Atrial septal defect

Atrial septal defect (ASD) is a congenital heart disease with left to right shunt. The ECG pattern mainly results from volume overload that related to ASD size: in small ASD, ECG is usually normal, however, in the larger ASD, there is rsR’ pattern in right precordial leads including V4R and V1 due to volume overload and RV conduction delay

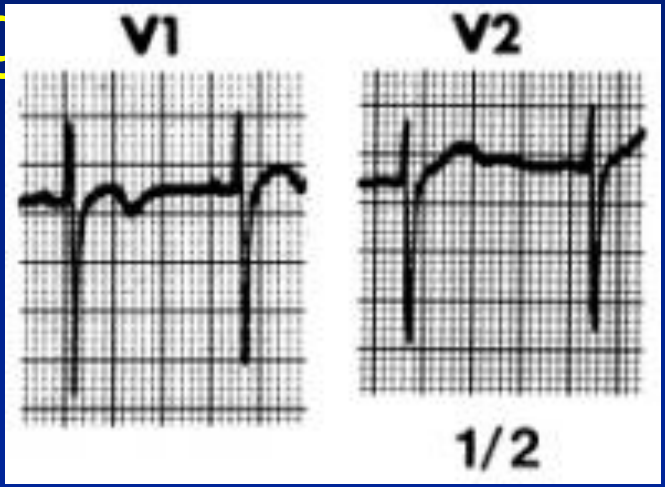

aVR
V1
V4
V3R
I
aVL
V2
V5
V4R
III
aVF
V3
V6
V7

CRITERIA FOR LVH

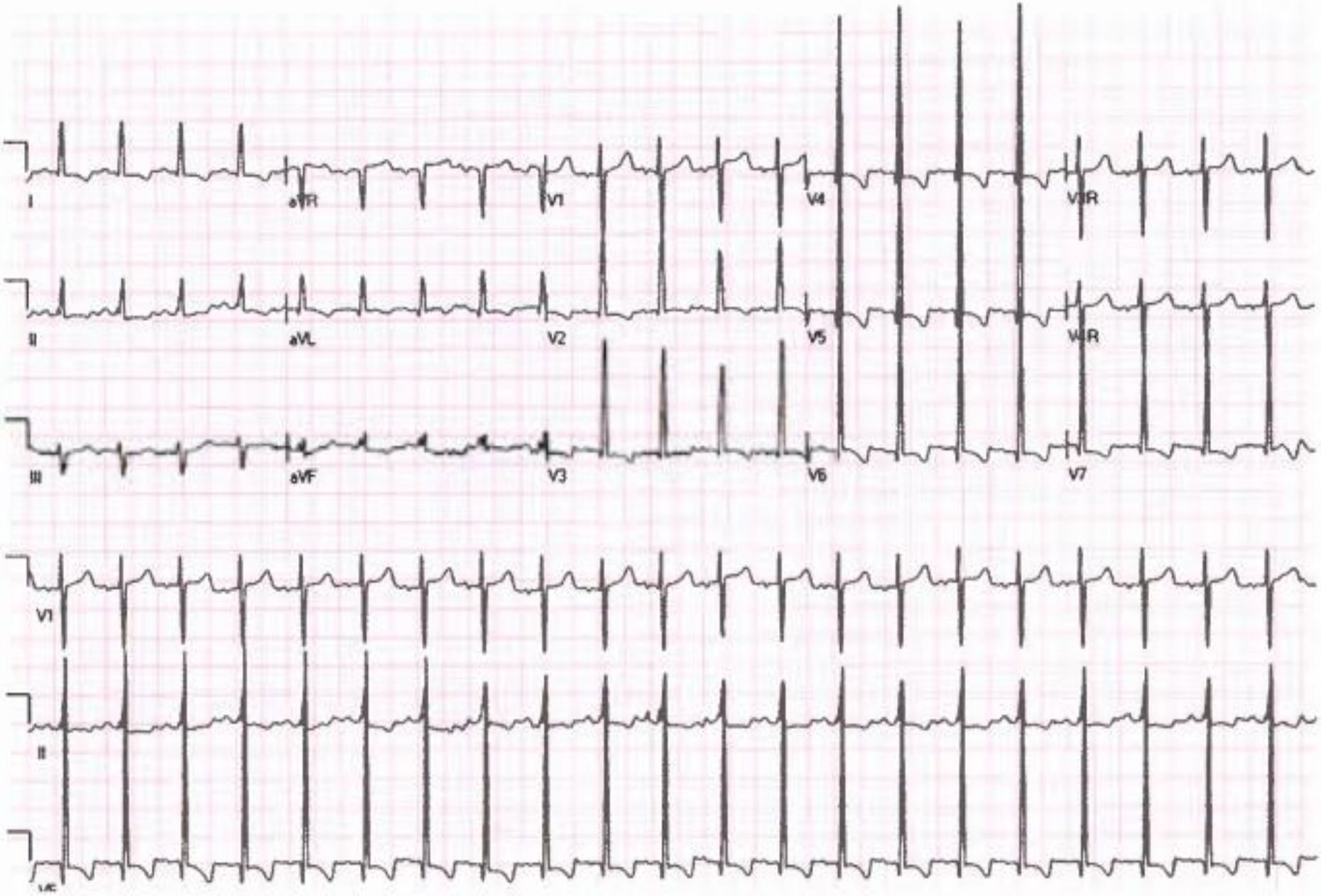
1) LAD for the patient's age
2) QRS voltages in favor of the LV
   a) R in I, II, III, aVL, aVF, V5, or V6 greater than the upper limits of normal for age
   b) S in V1 or V2 greater than the upper limits of normal for age
3) Abnormal R/S ratio in favor of the LV
   » R/S ratio in V1 and V2 less than the lower limits of normal for the patient's

3) Abnormal R/S ratio in favor of the LV

- R/S ratio in V1 and V2 less than the lower limits of normal for the patient's ag



*Note that lead V2 is in ½ normal standardization

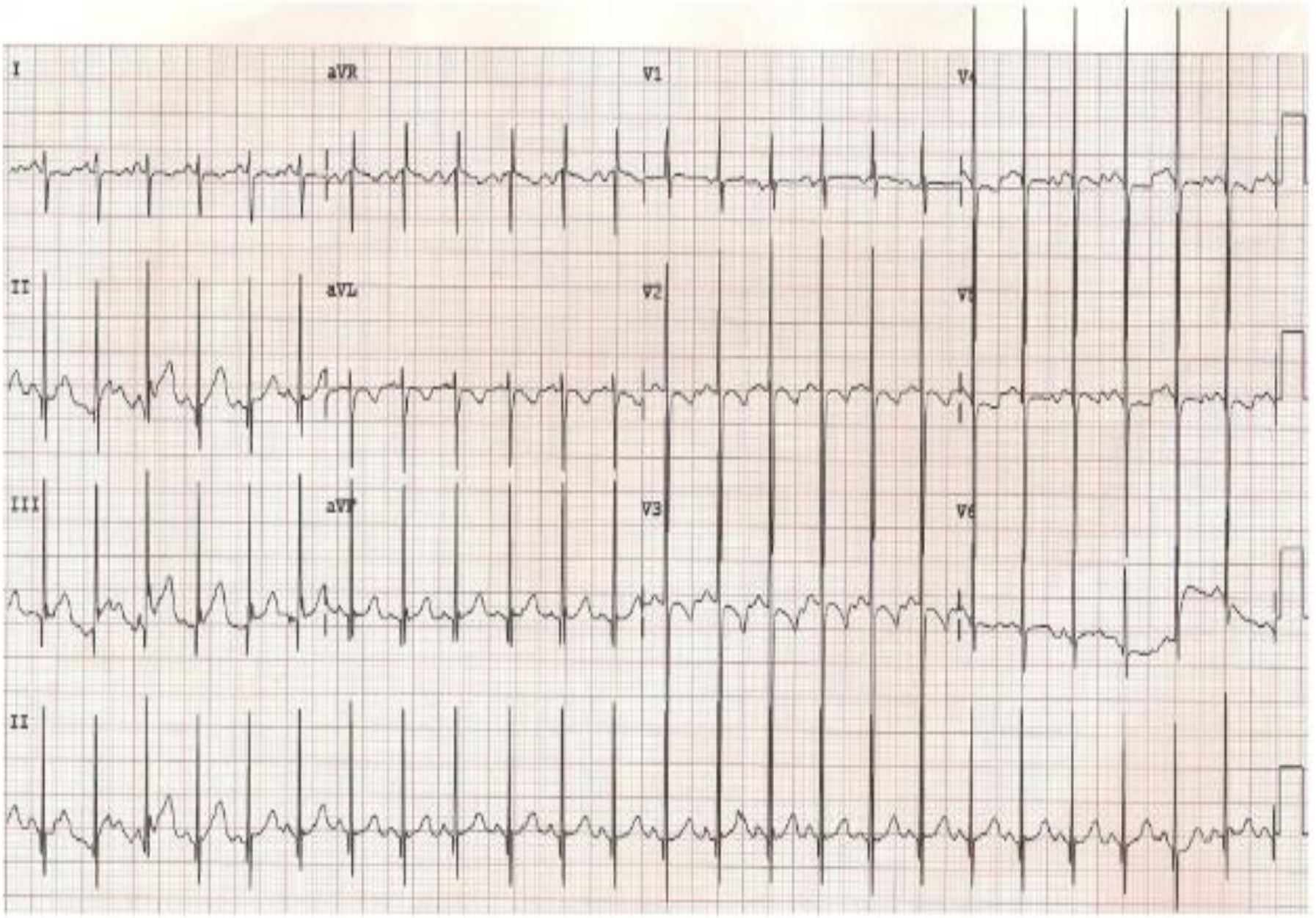

I
aVR
V1
V4
V8R
II
aVL
V2
V5
V9R
III
aVF
V3
V6
V7
V1
II

An 8-month-old
male with left ventricular hyper trophy. Note that the ECG is half-standard, and there is a T wave abnormality.

Combined ventricular hypertrophy

- Criteria
  - » Positive voltage criteria for LVH *and* RVH
    - – In absence of BBB, preexcitation
  - » Positive voltage criteria for LVH *or* RVH with relatively large voltages for the other ventricle
  - » Large equiphasic QRS complexes in ≥ 2 limb leads and midprecordial (V2 - V5) leads

    - "Katz-Wachtel" phenomenon


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

L→R Shunts – General Points

PDA & VSD

- Presents in infancy w/ heart failure, murmur, and poor growth
- Left heart enlargement (LHE)
- Transmits flow and pressure

ASD

- Presents in childhood w/ murmur or exercise intolerance (AVSD or 1^{o} ASD presents earlier)
- Right heart enlargement (RHE)
- Transmits flow only

AVSD can present as either depending on size of ASD & VSD component

VSD-PDA

In moderate and large size VSD, left to right shunt degree is significant. Volume overload cause dilation and hypertrophy of LA and LV

A characteristic finding of large VSD is sign of RVH on ECG.

Screening criteria for RVH

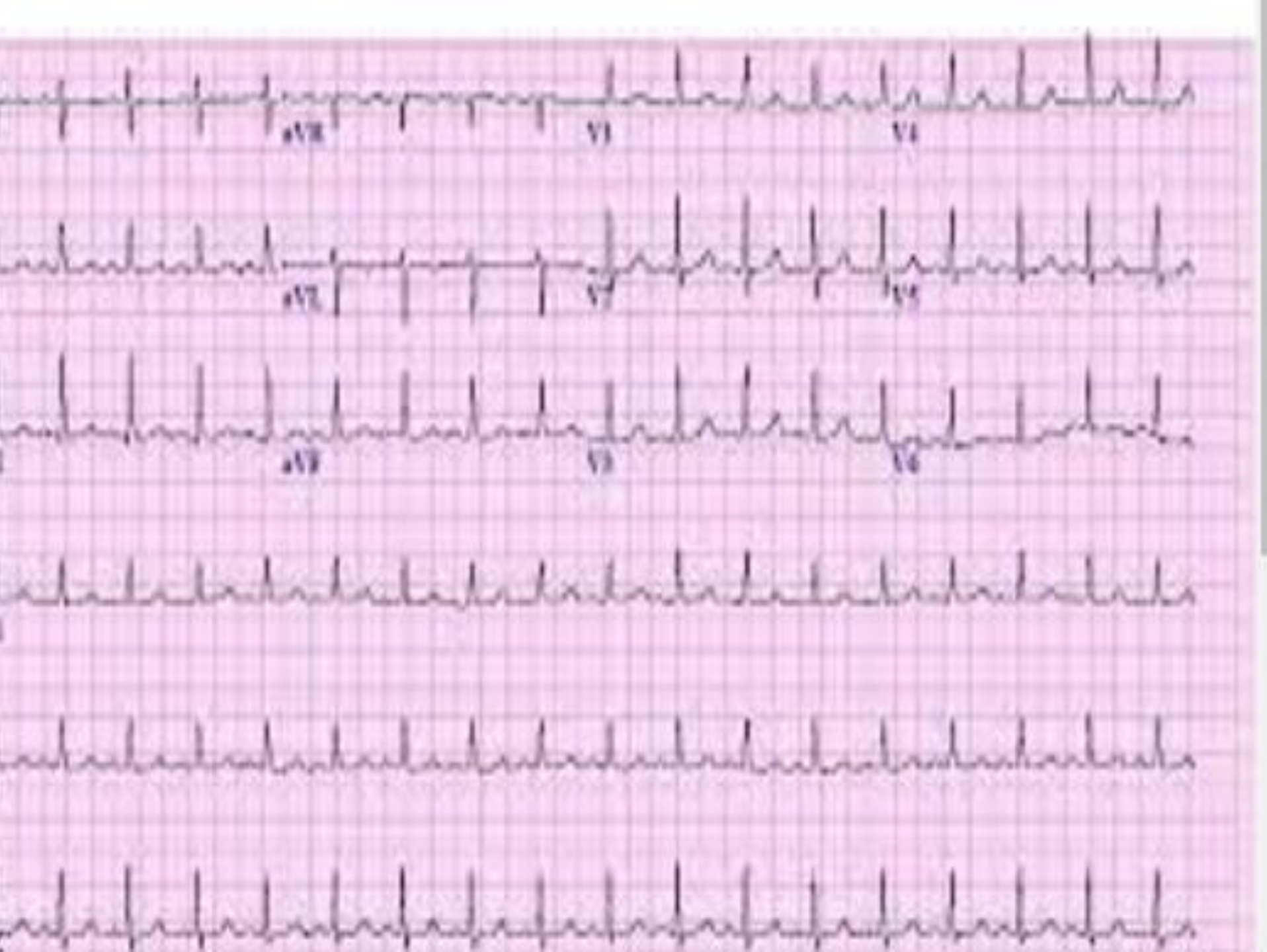
1) RAD greater than +120° in any child over 1 month is highly suggestive of RVH
2) Upright T in V1
   - In patients > 3 days and < 6yr old
   - Provided that the T is upright in the left precordial leads (V5, V6)
3) Q wave in V1 always suggests RVH
4) S wave > R wave in Lead V6

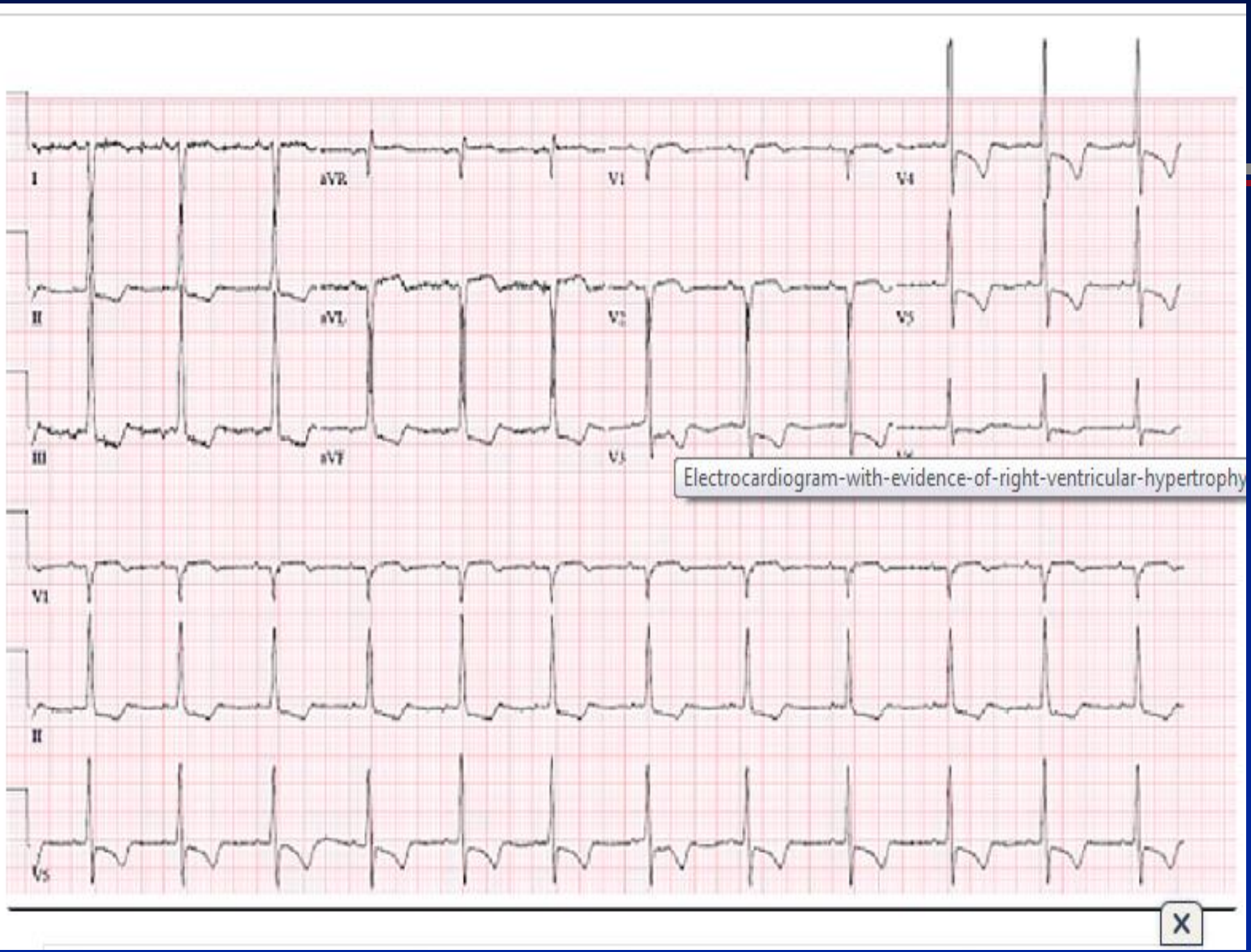
CRITERIA FOR RVH

1) RAD for the patient's age
2) Increased rightward and anterior QRS voltages
   a) R in V1, V2, or aVR greater than the upper limits of normal for the patient's age
   b) S in I and V6 greater than the upper limits of normal for the patient's age

   *Note: Assumes QRS is not widened for age indicating abnormal conduction delay
3) Abnormal R/S ratio in favor of the RV
   a) R/S ratio in V1 and V2 greater than the upper limits of normal for age
   b) R/S ratio in V6 less than 1 after one month of age

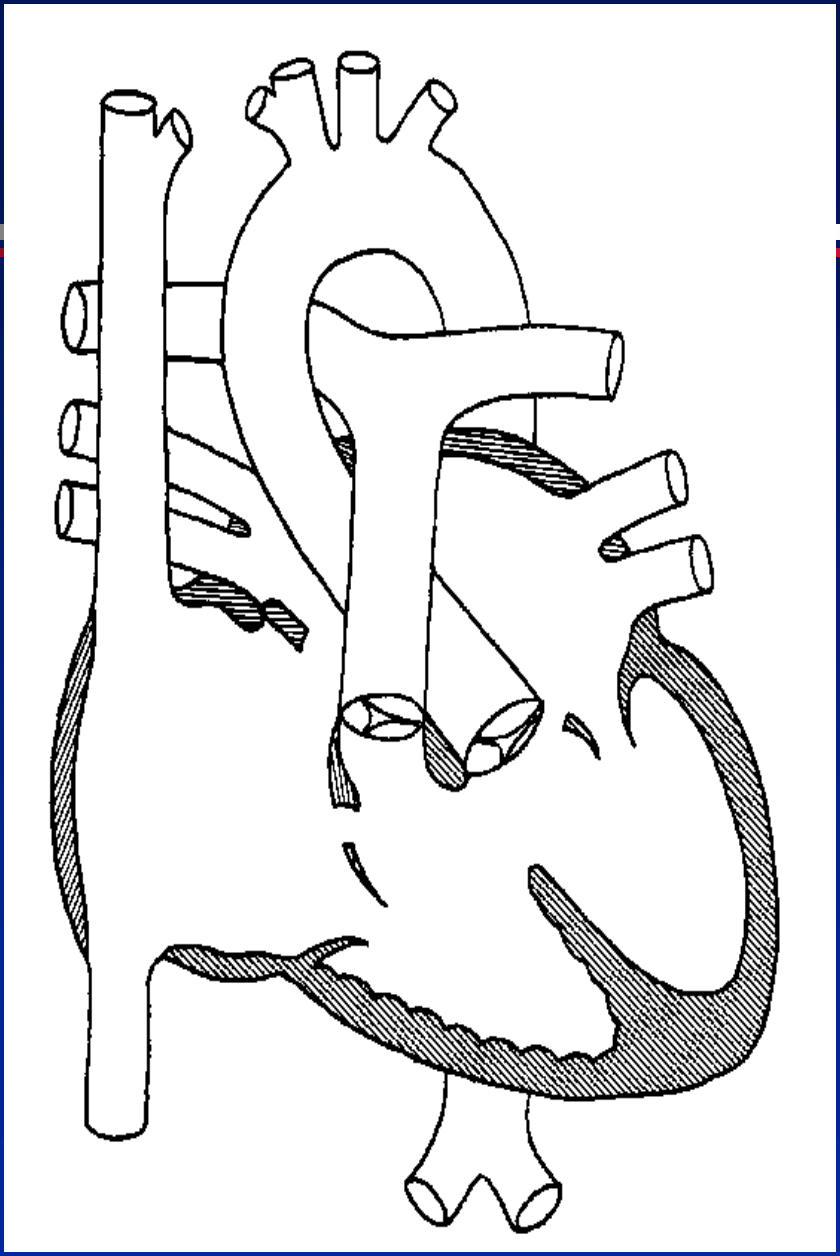
A missed VSD



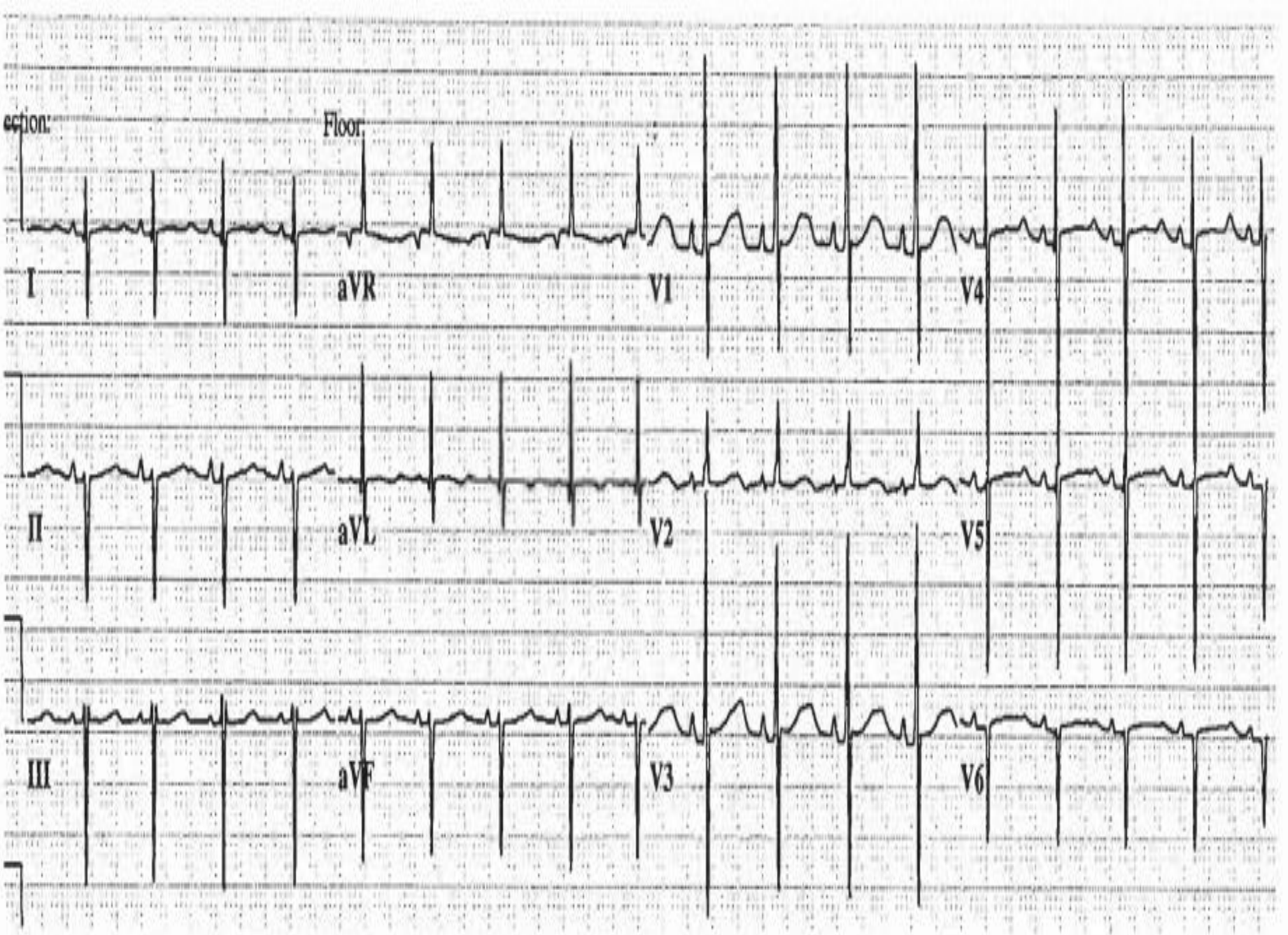

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
Electrocardiogram-with-evidence-of-right-ventricular-hypertrophy
V1
II
V5

Atrioventricular Septal Defect

Complete AV canal defect



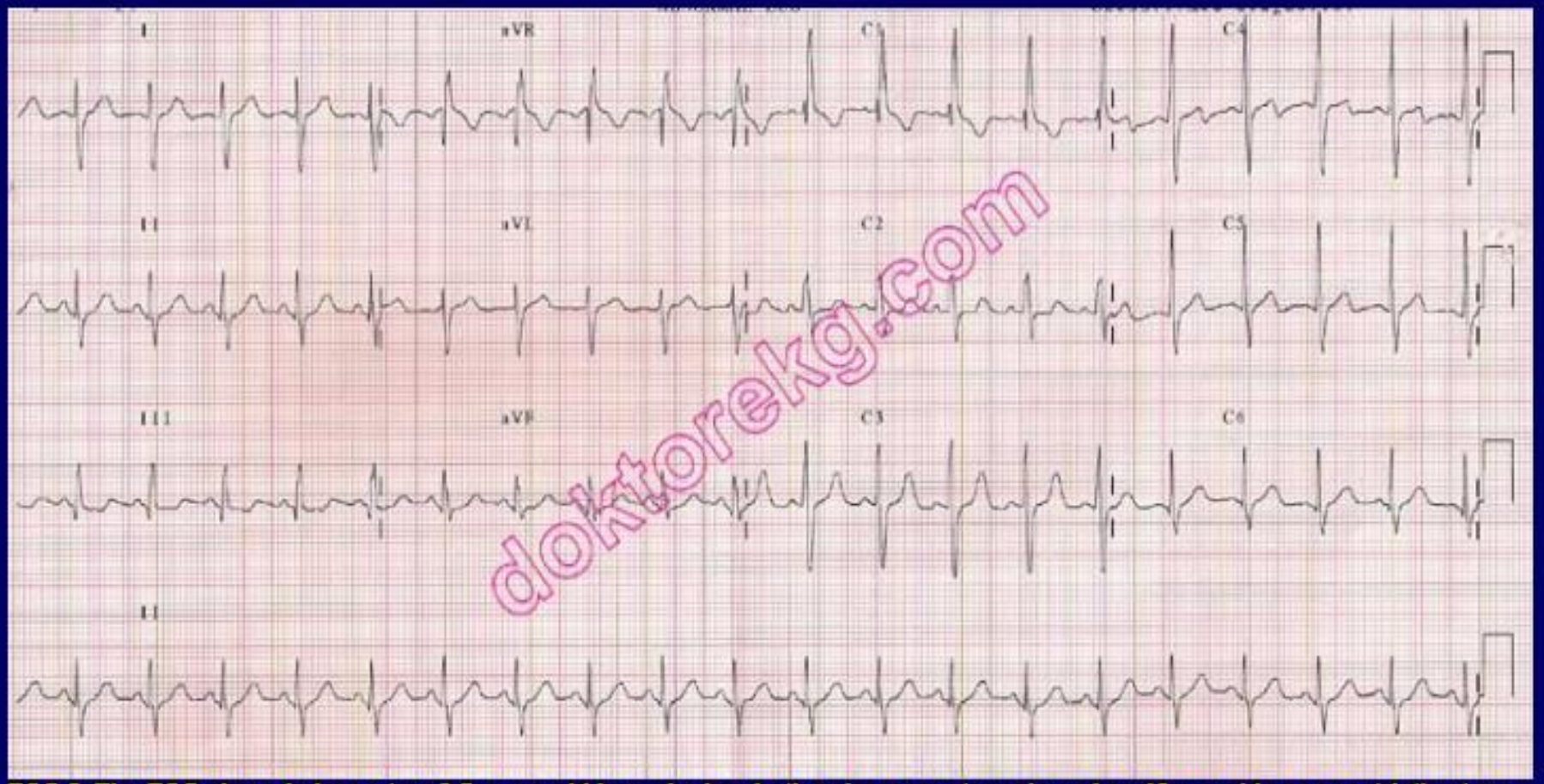
- Big L-R shunt when the PVR falls


ection:
Floor:
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

Diagnosis?

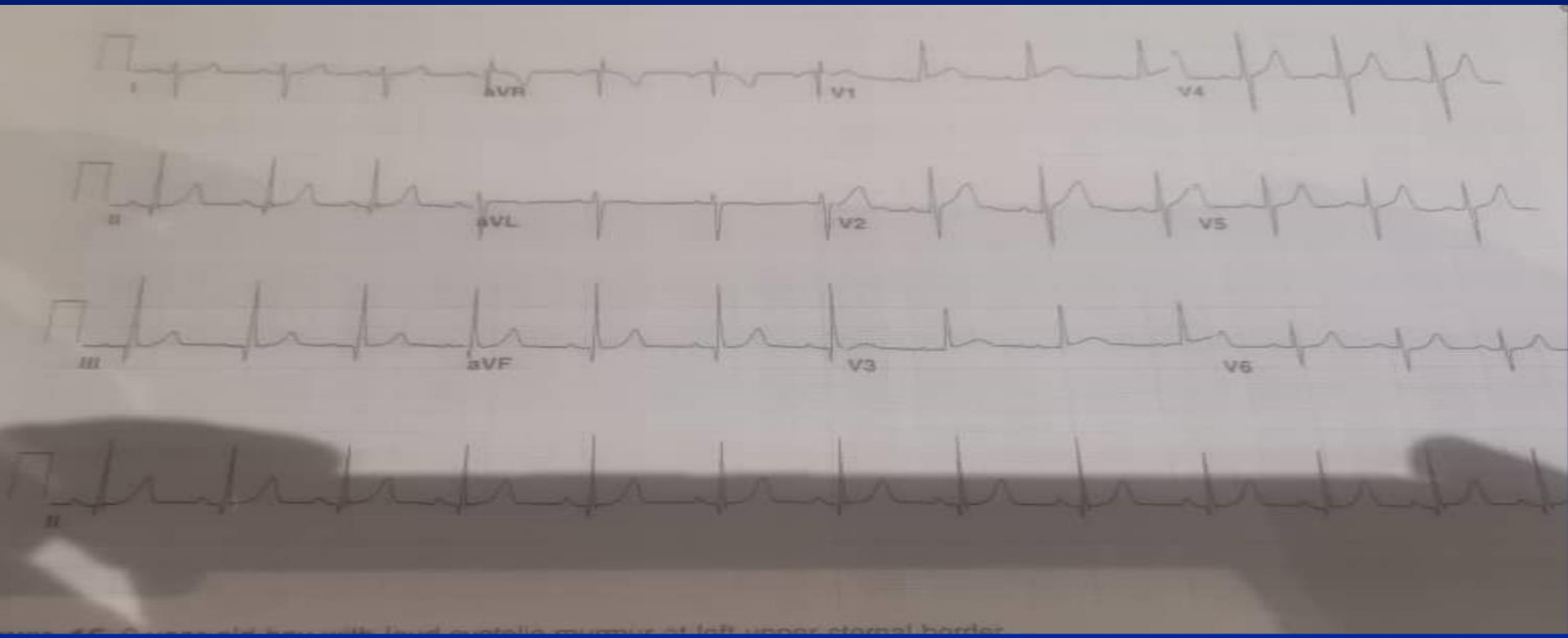
Obstructive lesions

Pulmonary stenosis



ECG 2. The ECG above belongs to a 3.5 years-old boy who has both pulmonary stenosis and an 18mm wide non-restrictive type

9-year-old boy with loud systolic murmur at left upper sternal border



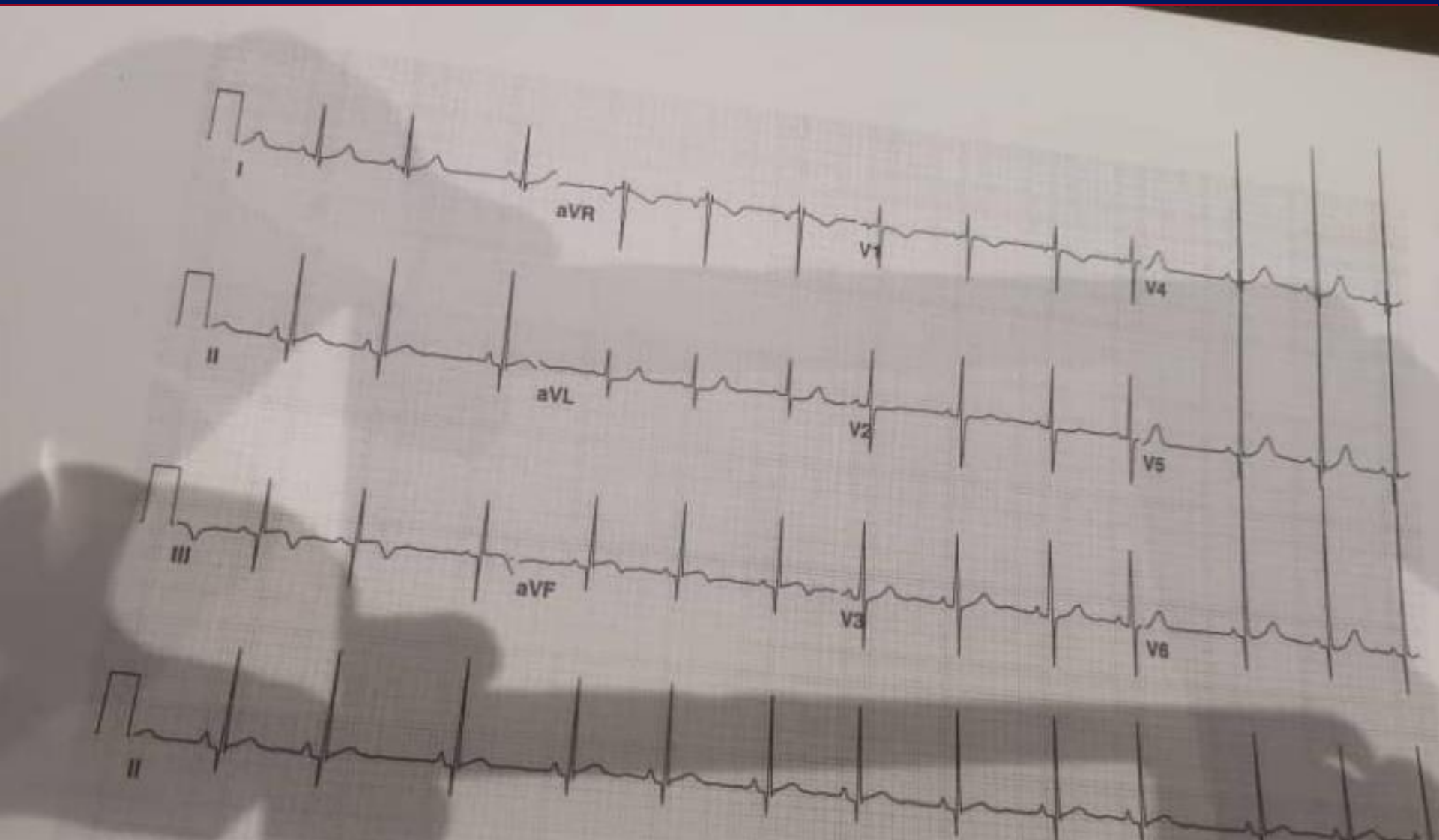
Aortic valve stenosis

aortic valve stenosis presents with pressure overload and LVH. Both voltage and repolarization criteria in ECG are useful for identifying the LVH

Aortic valve stenosis

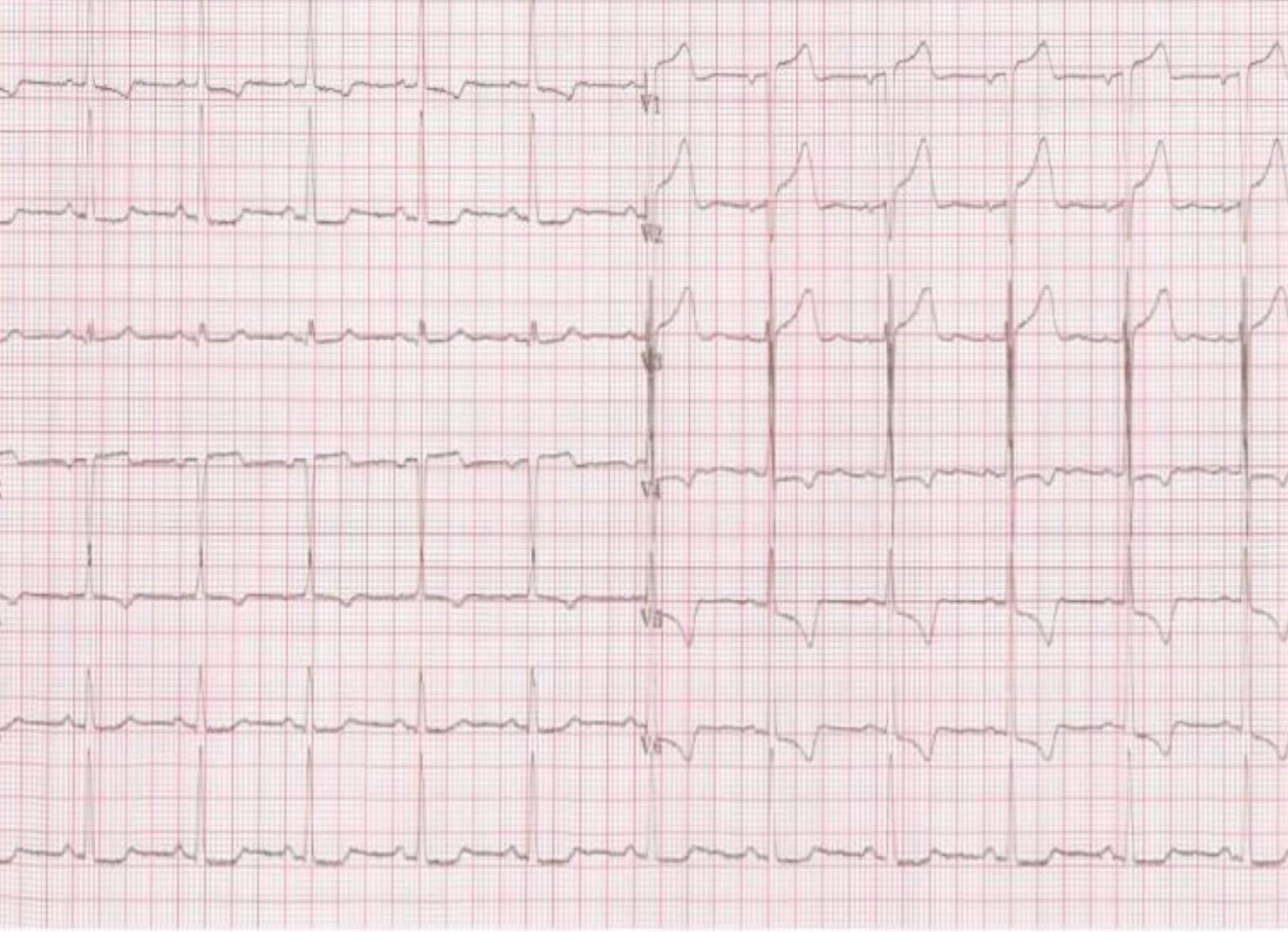
With progression to severe stenosis, sign of subendocardial ischemia and strain pattern as inverted T-wave and ST-segment depression in left precordial leads appear

5-year-old girl with systolic murmur at right upper sternal border

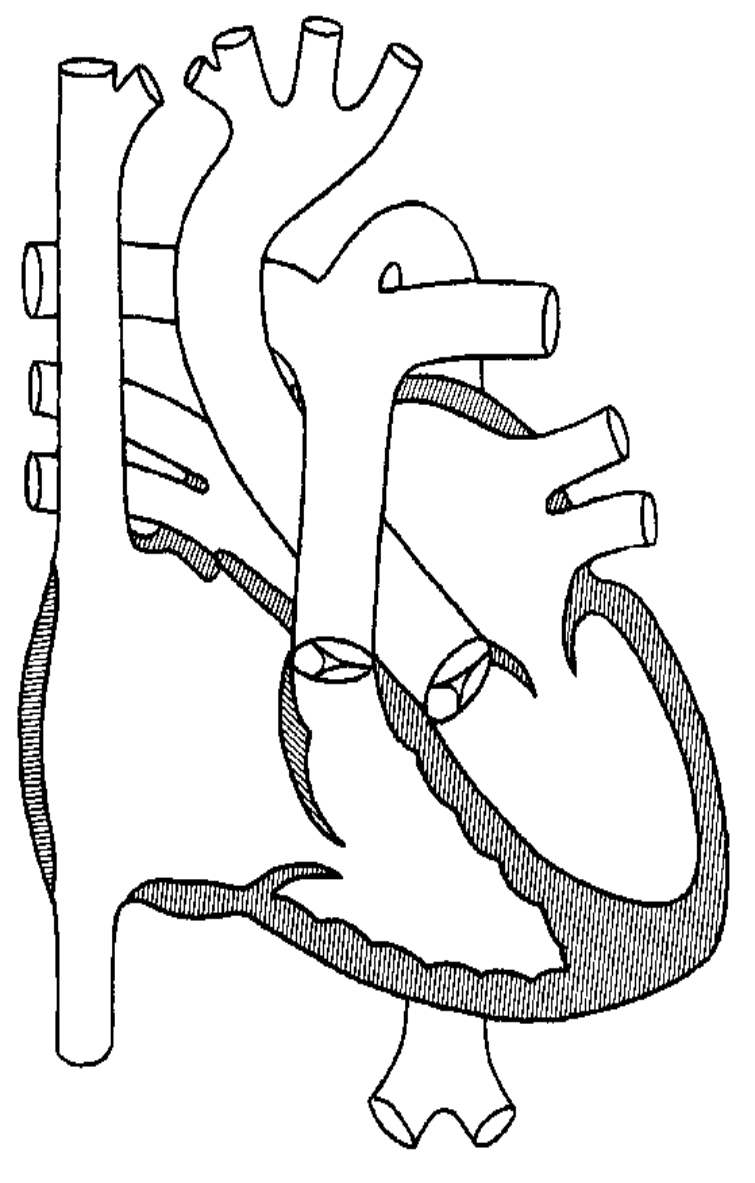


Left ventricular hypertrophy: 5 years old

- R wave in V6 >25 mm
- Amplitude of R wave in V5 or V6 plus S wave in V1 >47 mm
- S wave in V1 ≥25 mm
- Deep Q waves in lead III (≥4 mm) or V6 (≥5 mm)



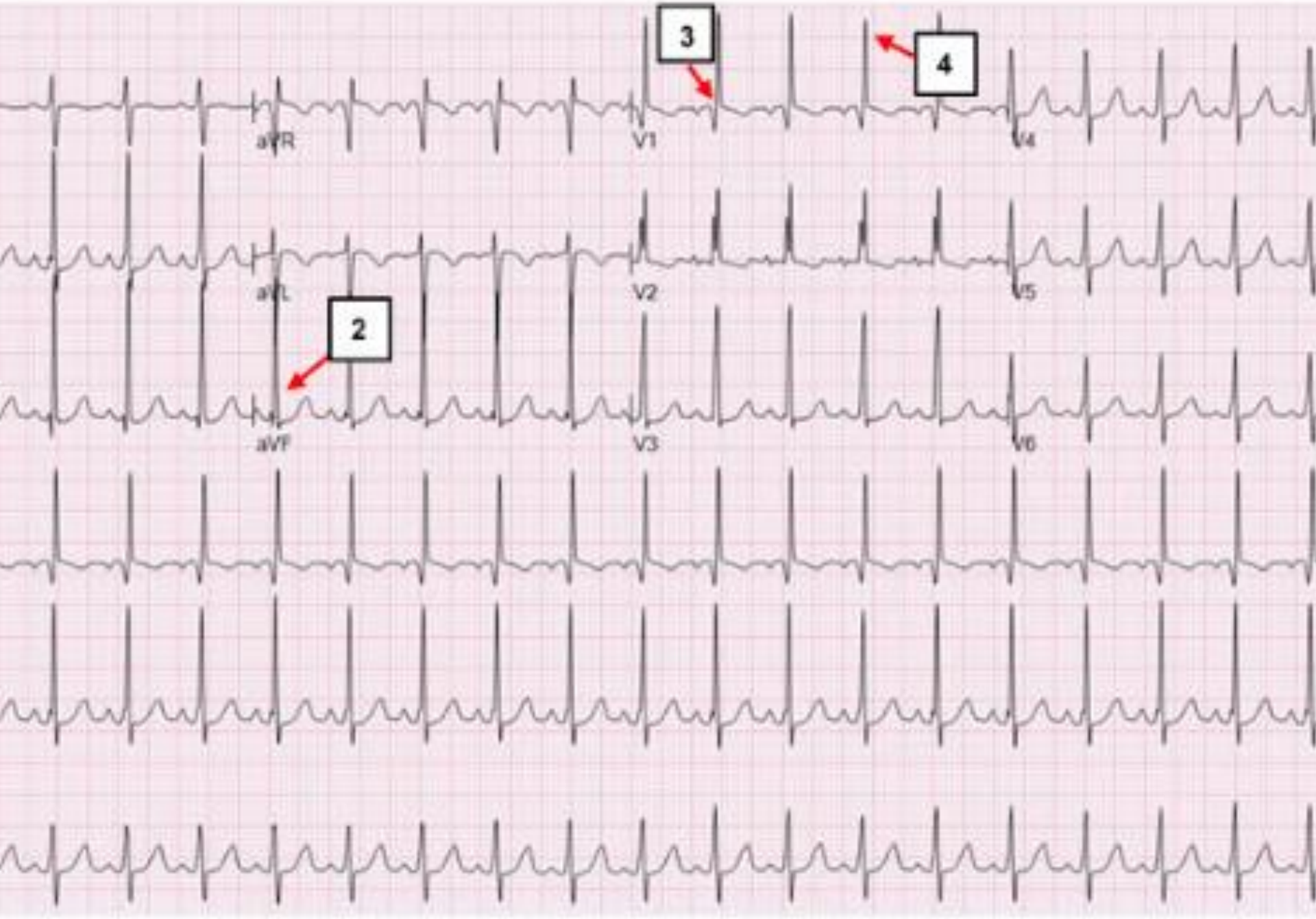
Interrupted aortic arch/coarctation

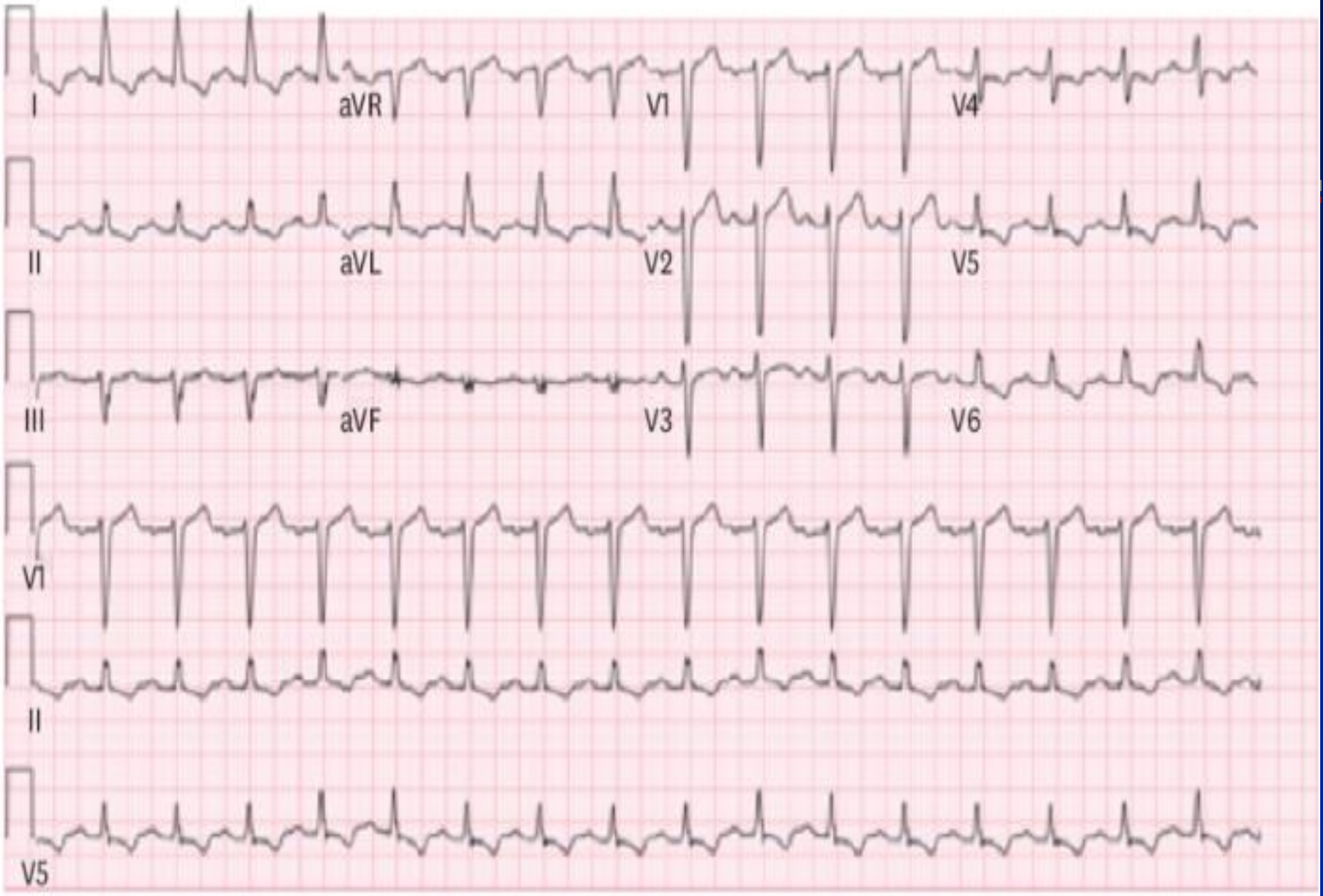


- Heart failure/collapse

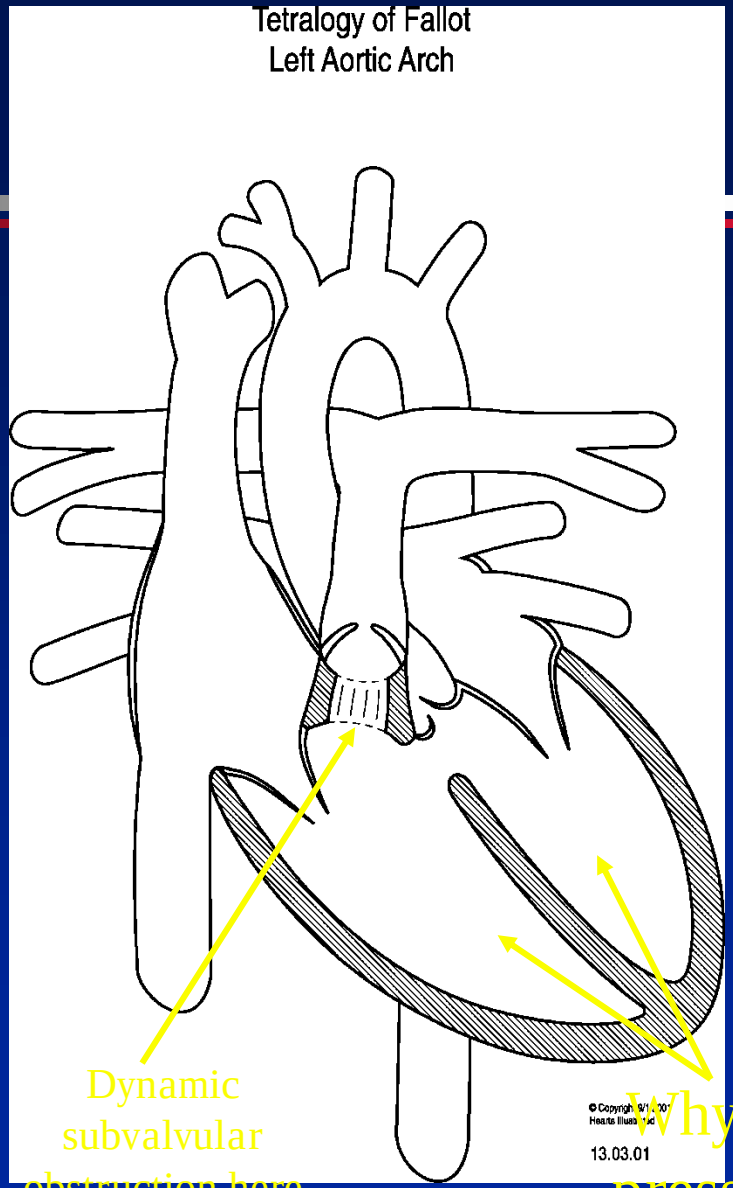
Coarctation of aorta

In neonate and infancy, the COA is asymptomatic and ECG is usually normal. It is important to note that presence of LVH in this period necessitate role out of other left-sided obstructive disease including aortic valve stenosis.


3
4
aVR
V1
V4
aVL
V2
V5
2
aVF
V3
V6


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

R→L Shunts

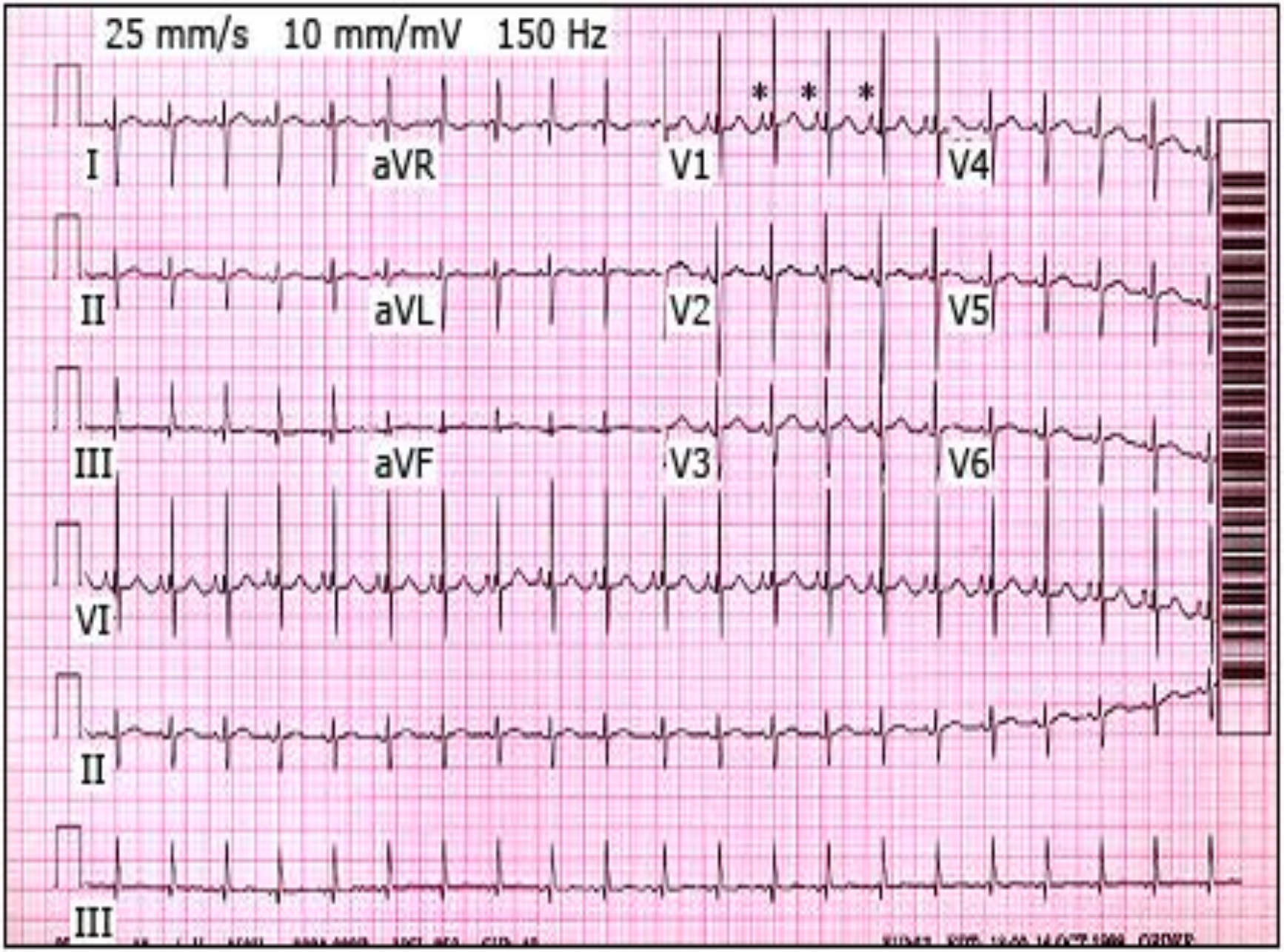


Dynamic subvalvular obstruction here *causes "Tet spells"*

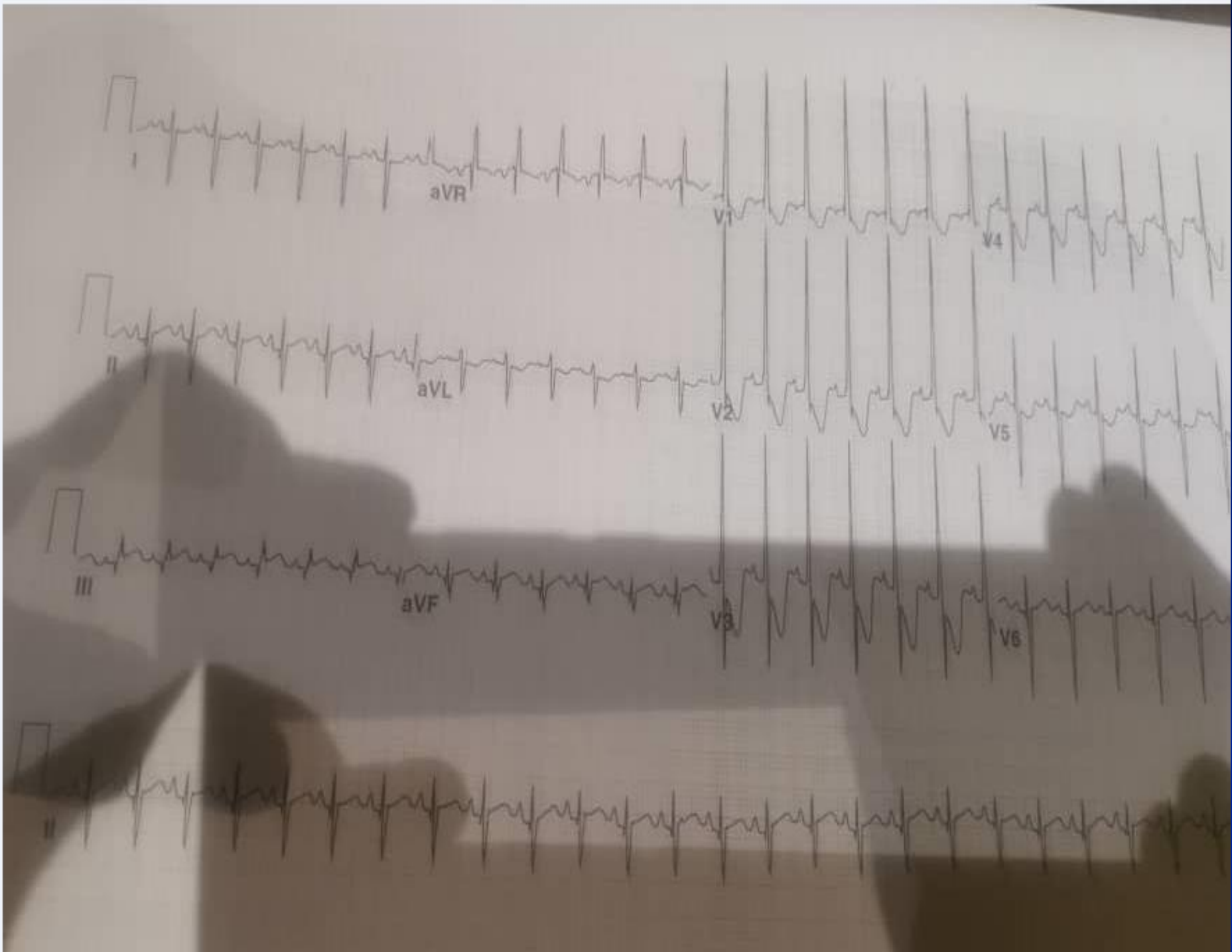
Why are pressures equal?

↓ PBF

- Presents more often with cyanosis
- See oligemic lung fields
- Closure of PDA may worsen cyanosis

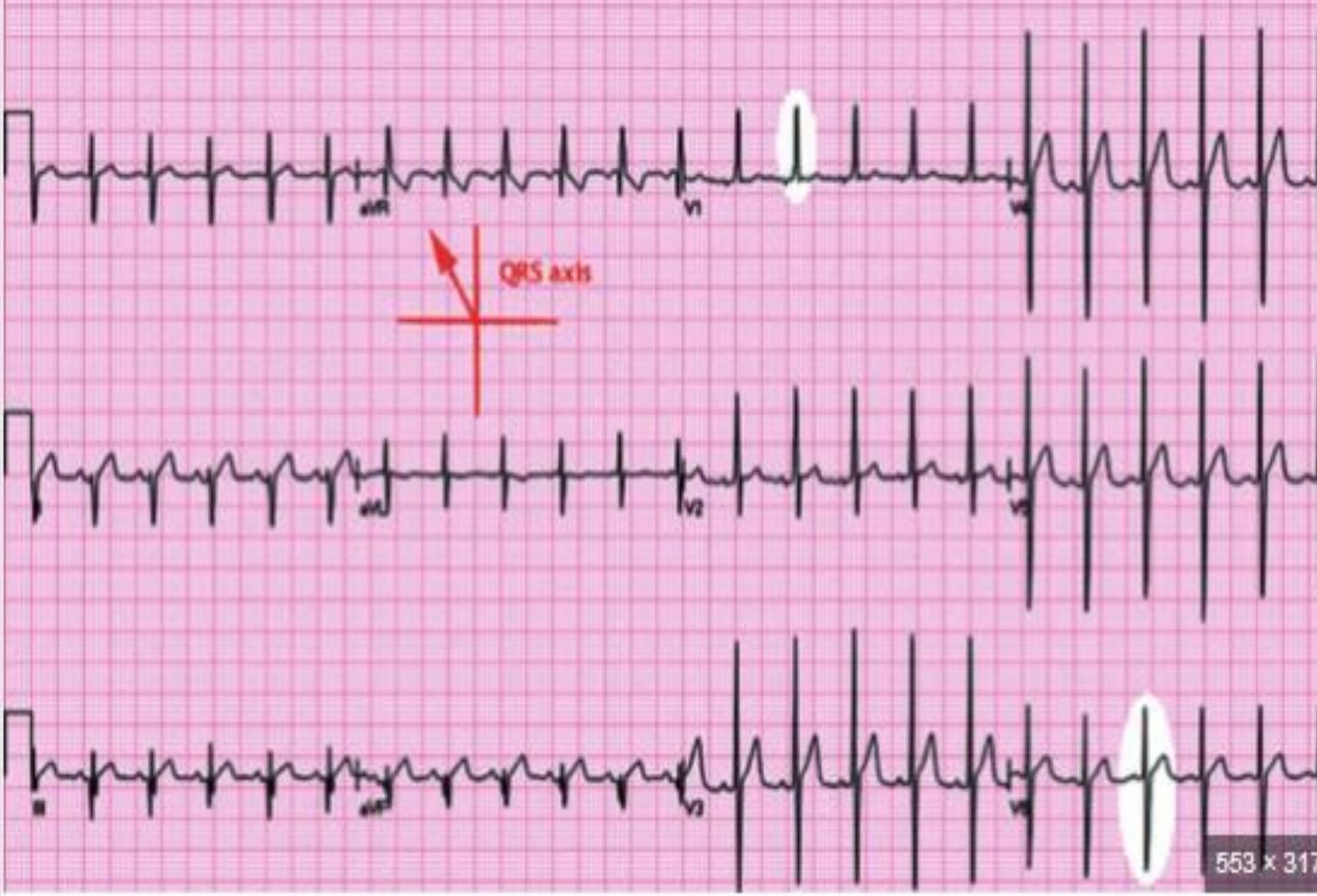

25 mm/s 10 mm/mV 150 Hz
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
VI
II
III

1-week-oldinfant with harsh systolic murmur


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

Tetralogy of Fallot

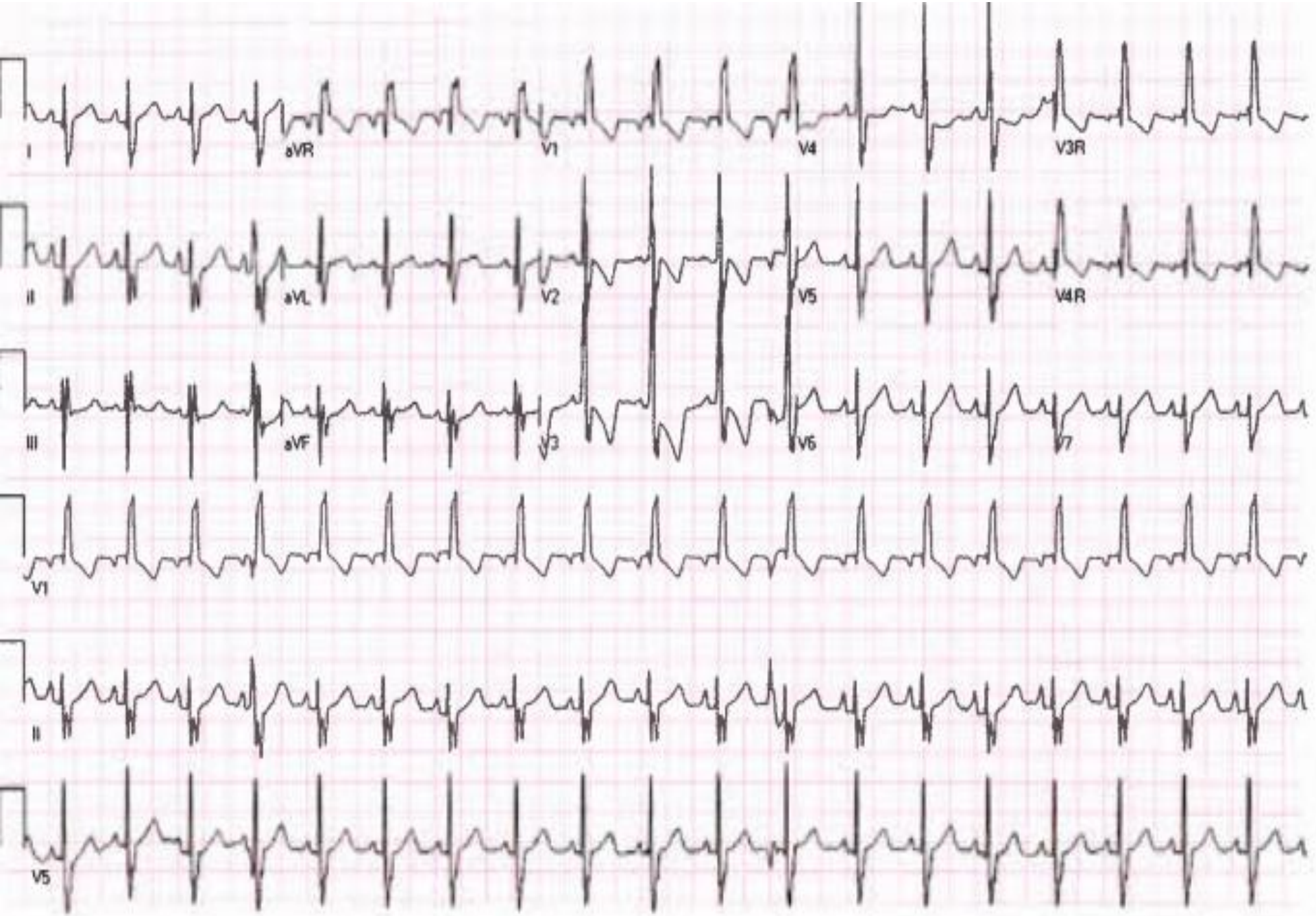
This anomaly includes pulmonary stenosis and VSD that results in right axis deviation and RVH in ECG. The SA node and AV node is intact but cases of complete AV block were seen.

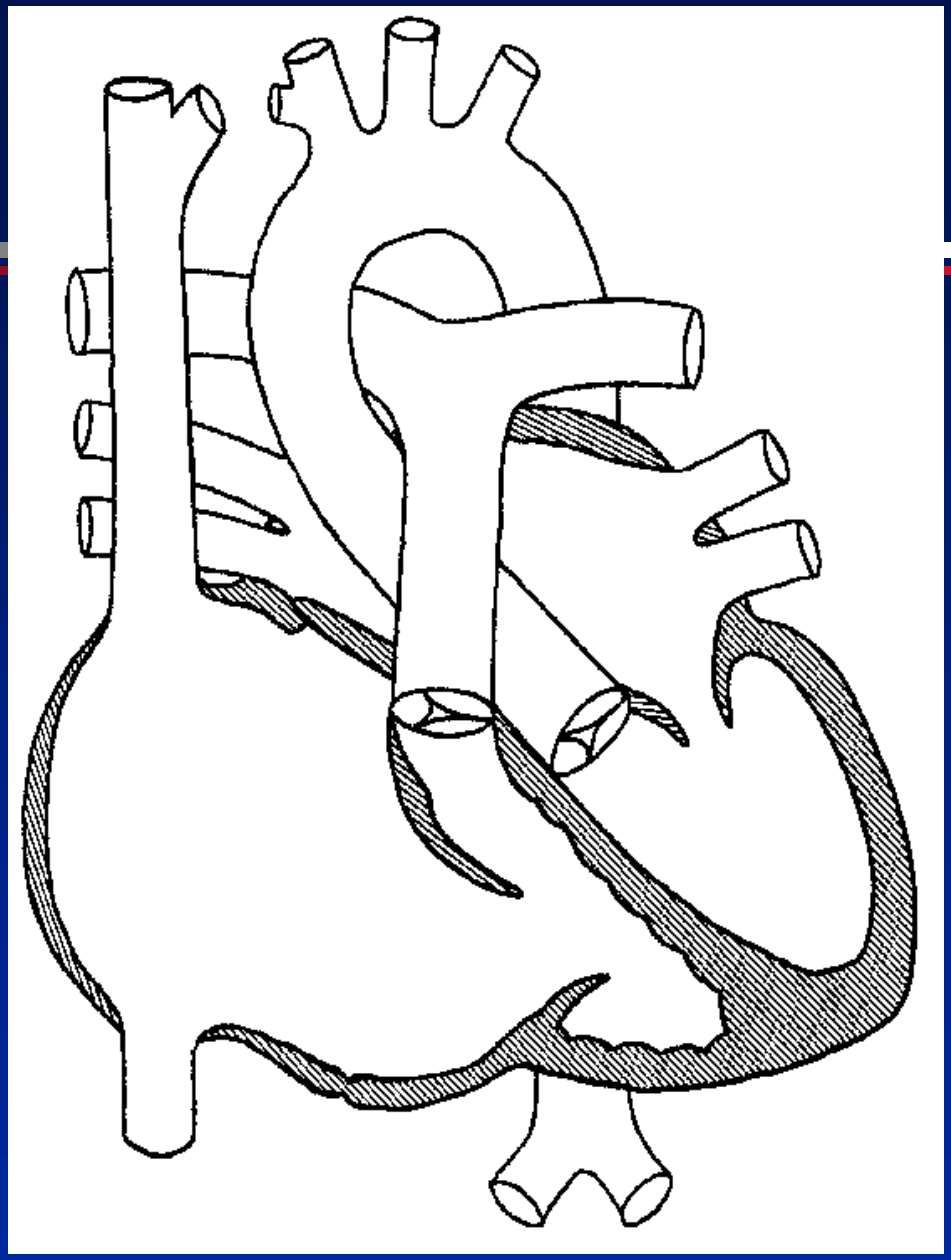


Tetralogy of Fallot | SpringerLink

Visit

Right bundle
branch block with left anterior
hemiblock following complete
repair in an L'l-rnonth-old with
tetralogy of Fallot and AV sep
tal (canal) defect. Note lack of
initial Q waves in leads II, III,
and aVF


I
aVR
V1
V4
V3R
II
aVL
V2
V5
V4R
III
aVF
V3
V6
V7
V1
II
V5



Ebstein's anomaly

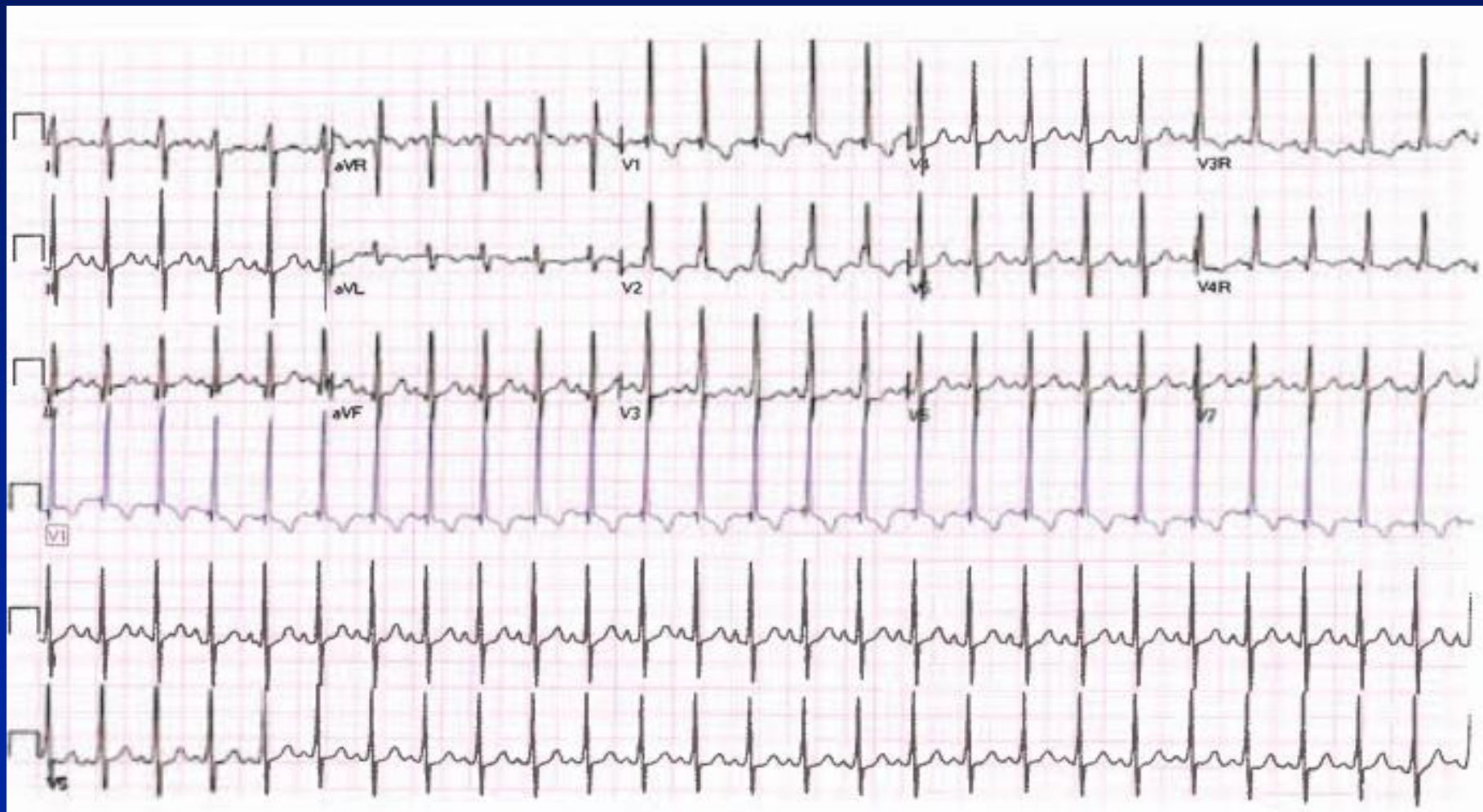
- The tricuspid valve is abnormal and inserts well down into the RV. There is often severe trisuspid regurgitation, which can lead to death in the fetus or infant. Usually also with ASD so right-to-left flow results in cyanosis.

Ebstein anomaly

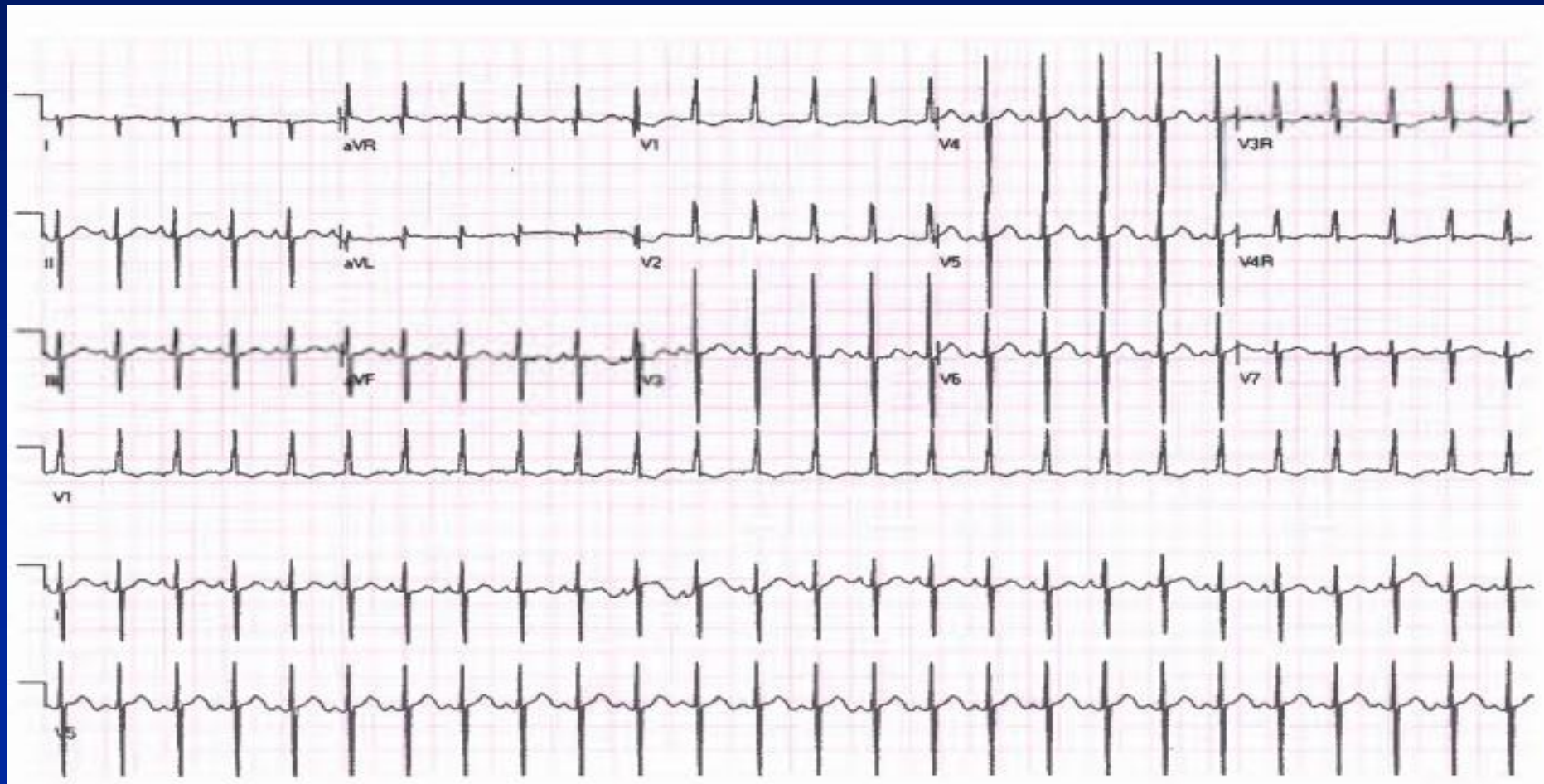
. The RA enlargement and tricuspid valve regurgitation results in tall peaked P wave in ECG especially lead II and increase in duration of P-wave. Other ECG findings include RBBB and Q-wave in right precordial leads


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

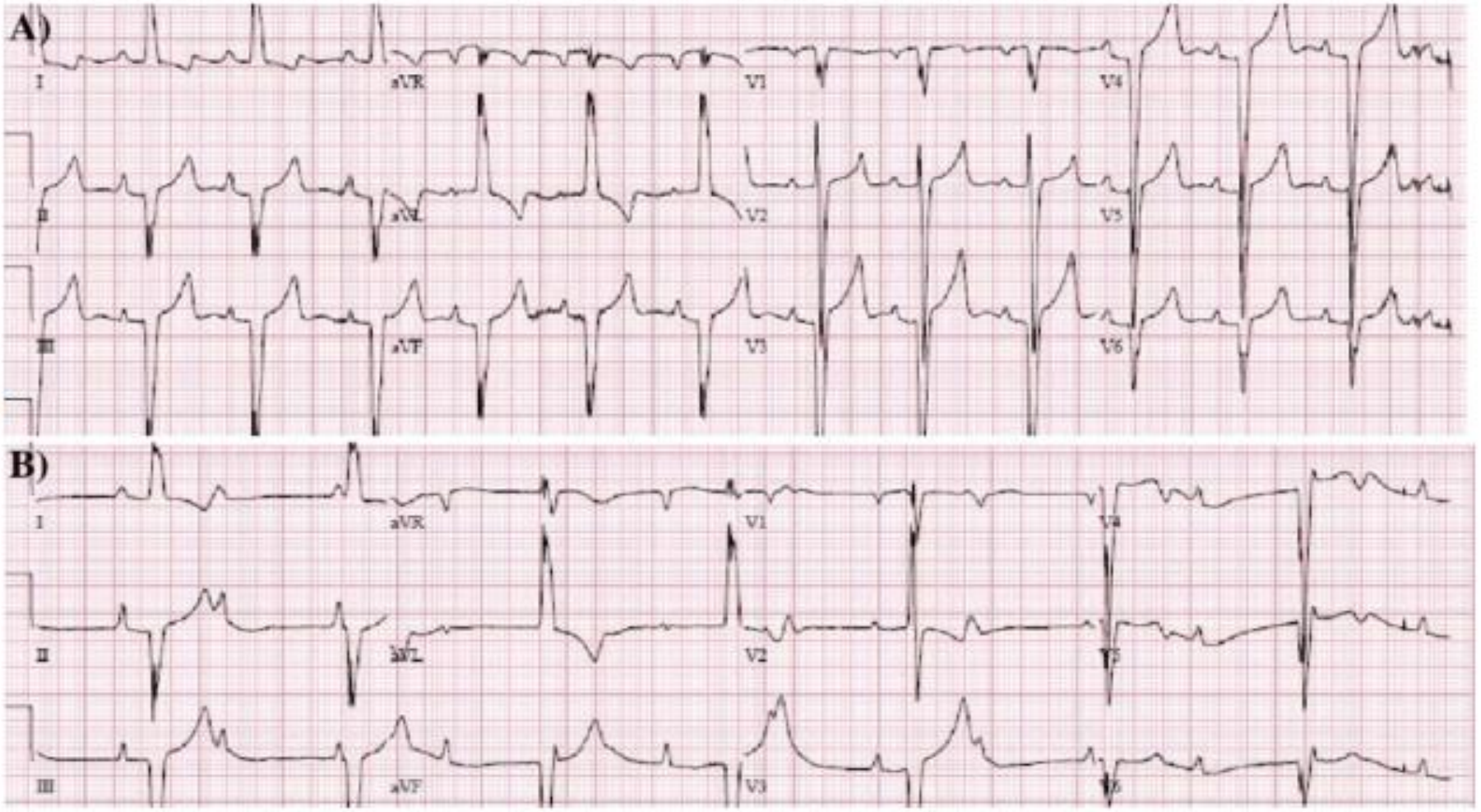
HLHS



D-TGA



CCTGA

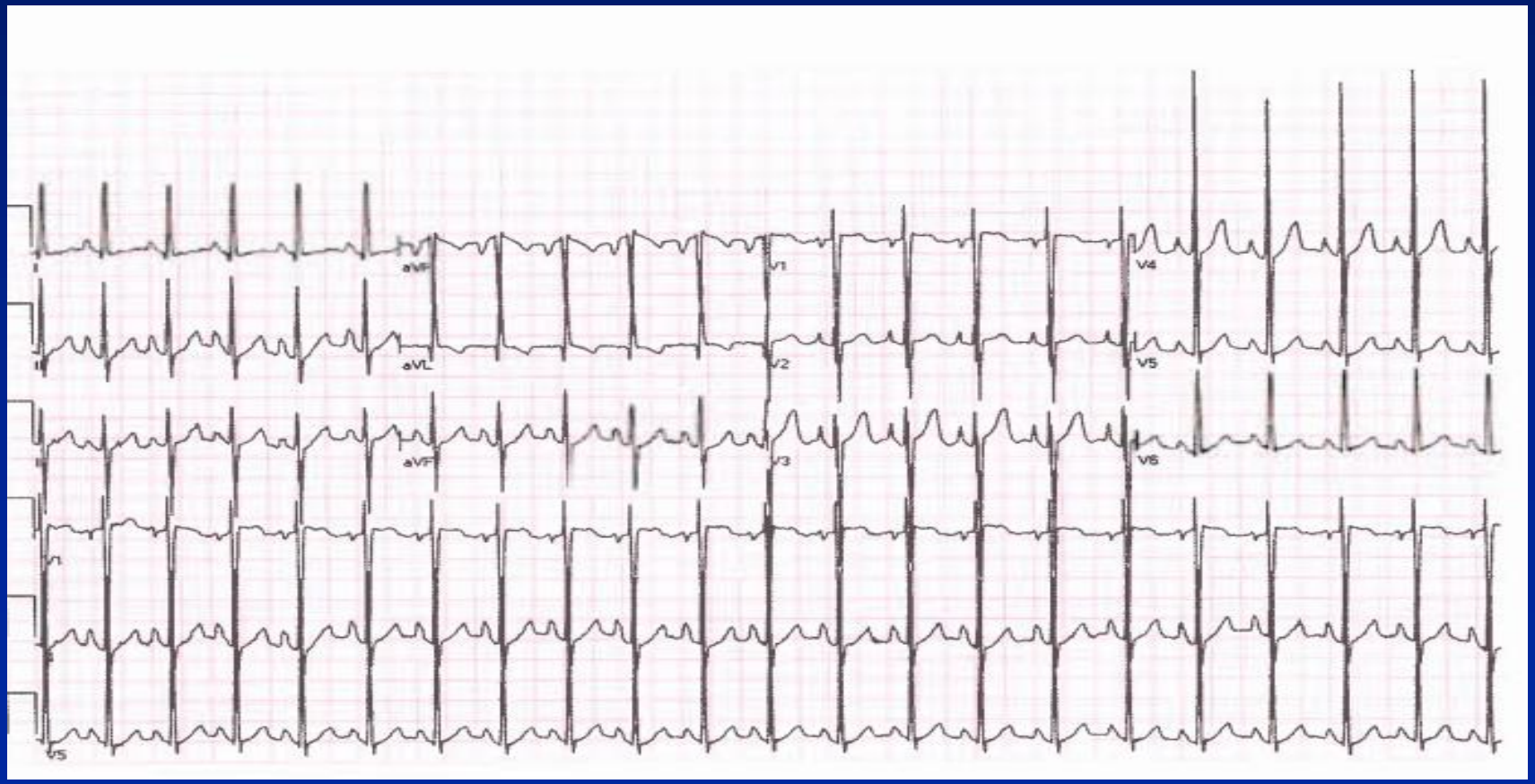

A)
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
B)
I
aVR
V1
II
aVL
V2
III
aVF
V3

development of AV block in a girl with congenitally
corrected transposition


V4


V1

Tricuspid atresia

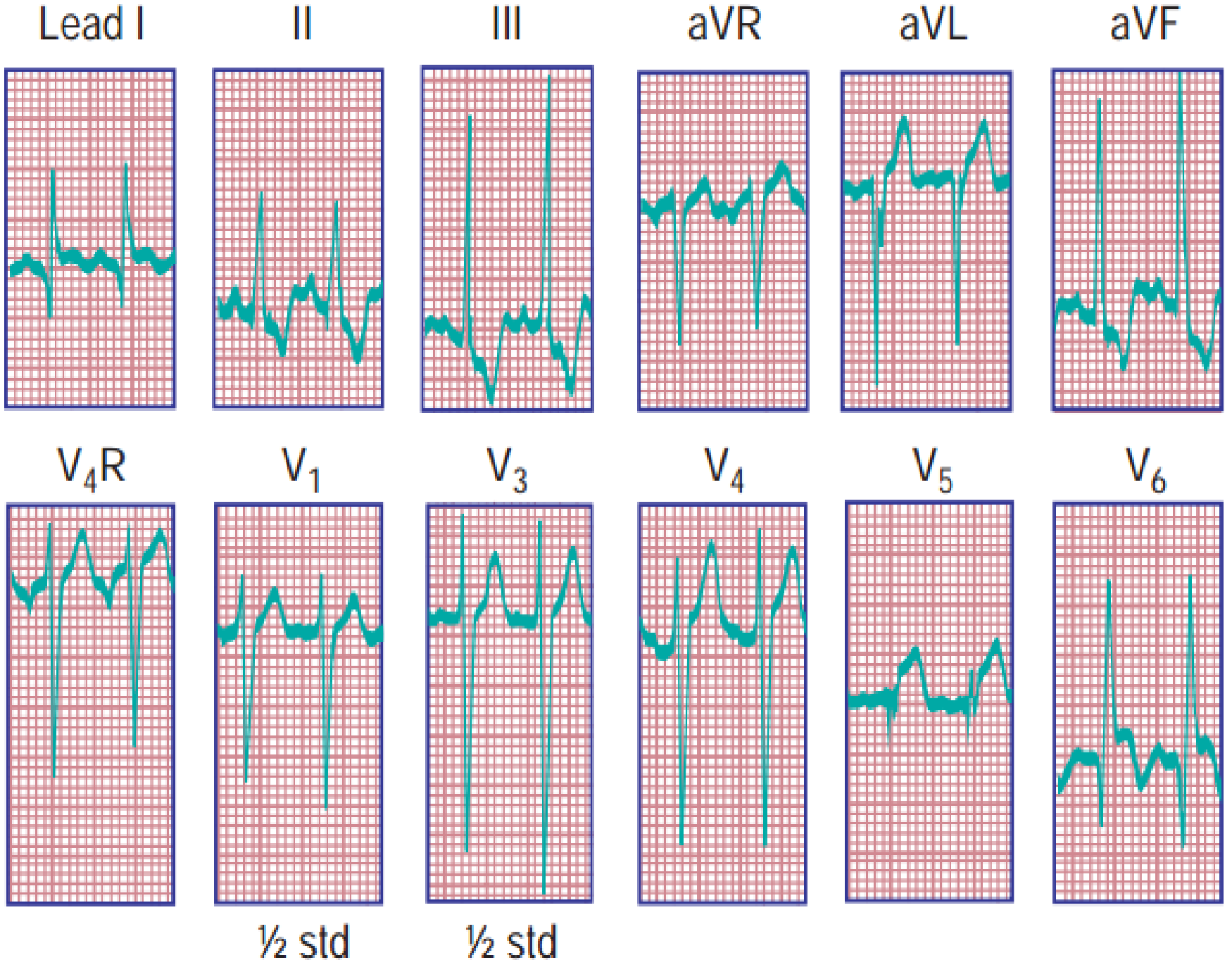


6-month-old with tricuspid atresia and normally related great vessels. The ECG shows right atrial enlargement and left axis deviation


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

ALCAPA

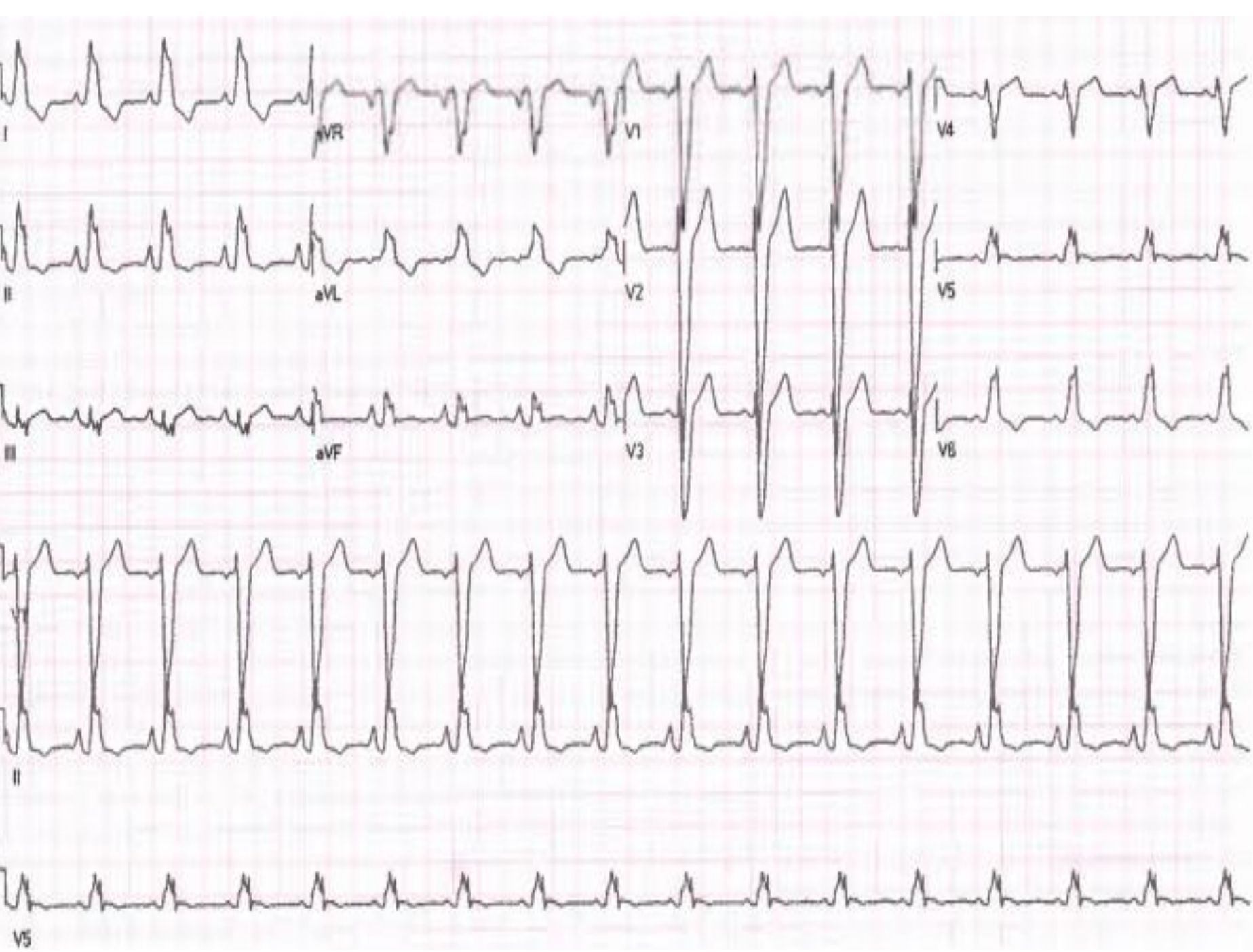
Abnormal left coronary origin from PA


Lead I
II
III
aVR
aVL
aVF
V4R
V1
V3
V4
V5
V6
½ std
½ std

After conventional surgical repair, one of the well-known ECG pattern is RBBB


I
aVR
V4
II
aVL
V5
III
aVF
V6
V1
II
V5

3-year-old following repair of tetralogy of Fallot. Note Q waves in inferior leads, documenting normal left anterior fascicular conduction


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
V5

LBBB after sub AO web resection

THE END