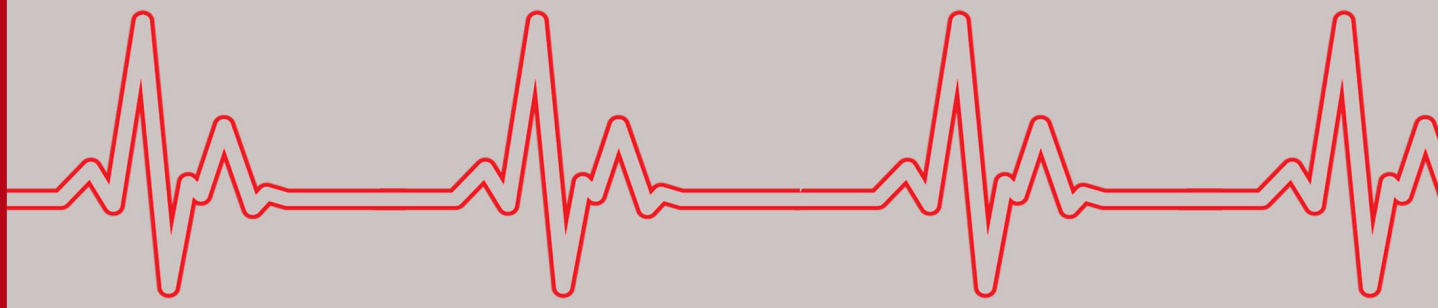
ECG



for Pediatric Critical Care

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❖ Preface:

ECG is one of the important diagnostic tool that is used almost daily in pediatric critical care to evaluate sick patients with cardiac or extracradic diseases. We commonly order ECG in patients with suspected or confirmed anatomical or functional cardiac issues, tachycardia, bradycardia, suspected conduction problems, pulmonary vascular diseases, baseline before starting certain medications and for patients with toxic ingestion.
Pediatric critical care fellowship program in McMaster university started to implement weekly ECG teaching for fellows and residents rotating in PICU (ECG of the week) that is usually led by fellows and enriched by intensivist to strengthen the skill of interpreting electrocardiogram.

This booklet is a scholar project in my pediatric critical care fellowship to be a part of teaching that can be used by learners in pediatric intensive care.
I started this booklet with very brief basic information followed by clinical scenarios with most common ECGs that is seen in PICU with brief interpretation.

I would like to thank PICU team in McMaster Children hospital particularly Dr. Cynthia Cupido and Dr. Naveen Sidhu for all encouragement, facilitation and support to make this booklet successful.

My acknowledgement to publishers of educational ECG websites, blogs and channels and ECG apps owner who gave me permission to use their ECGs for this booklet as a teaching material.
My acknowledgement to my wife (Dr. Aza Alsawafi) who designed the cover page and supported me in establishing this booklet.

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❖ Before you start:

- The content of this booklet is for educational purpose only and not for professional medical advice, diagnosis or treatment. I disclaim any responsibility for any diagnosis error that may result from trying to apply the content of this booklet for an individual case.
- For teaching purpose, I made my effort to choose the most representing ECG for each clinical scenario so each ECG shows only one diagnosis in order to not confuse the learner **but** still some ECGs may show additional findings.
- I avoided to put low quality ECGs or ECGs with artifact but in your clinical practice you may have such ECGs and you need to familiarize yourself.
- Remember that ECG is one tool that help you in diagnosis and in a lot of occasions you have to correlate the findings with other clinical data. You may see findings that are incidental or not clinically significant or normal variants.
- If you see any error on this work, please feel free to contact me/modify it as you can.
- This work was done solely for teaching purpose and it can be used for teaching and learning by anyone, anywhere, copied, printed, distributed and posted as far as it remains for the same purpose.

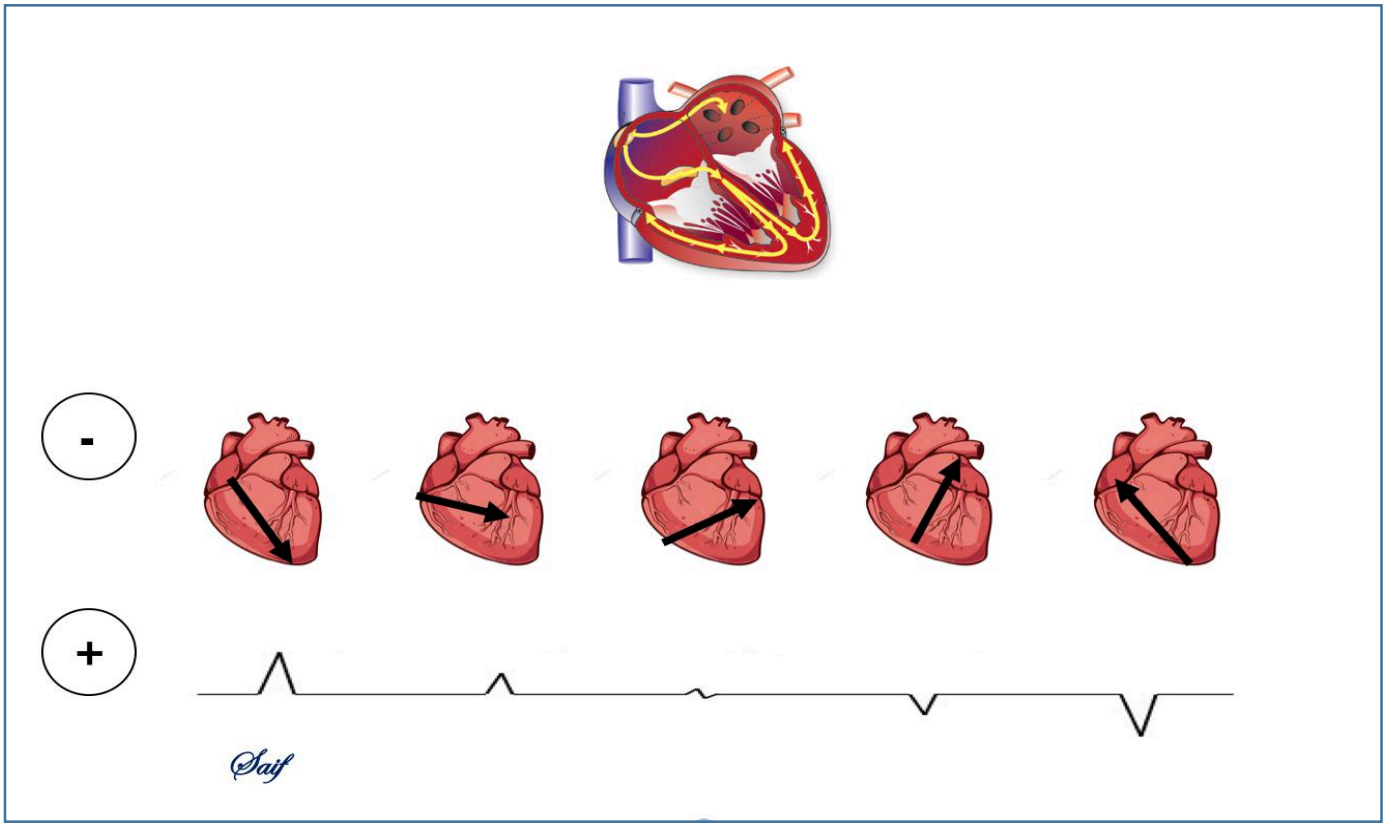
❖ Back to basics

The heart's electrical activity produces currents that radiate to the skin and sensed by electrodes attached to the patient. The electrical currents are transmitted to an ECG monitor and transformed into waveforms that represent the heart's depolarization and repolarization cycle.
An ECG shows the precise sequence of electrical events occurring in the cardiac cells throughout that process.[1]

12 Lead ECG that you order for your patient give you a picture of heart electrical activity from 12 different views.

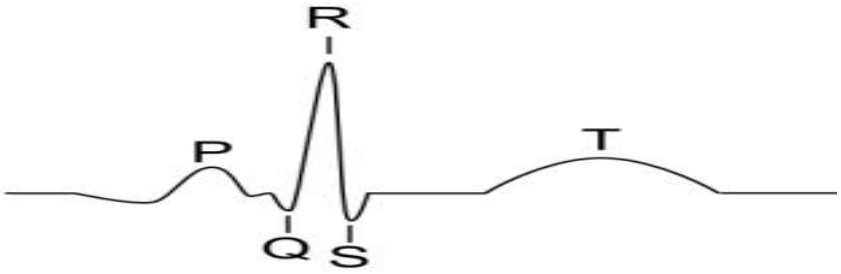
The electrical cardiac impulse arises from (SA) sinoatrial node which is the pacemaker of the heart and conducted through (AV) atrioventricular node to the ventricles down to bundle of His and Purkinje fibers.

The upward and downward deflections of the waveform in ECG represent the direction of the cardiac electrical activity in relation to the leads.



❖ ECG and pediatric age group

ECG complex consist of 5 waveforms that represent cardiac electrical activity in one cycle. They are labeled with letters PQRST.



The basic principles of interpreting ECGs in children are identical to those in adults, but the progressive changes in anatomy and physiology which take place between birth and adolescence result in some features which differ significantly from the normal adult pattern and vary according to the age of the child.[2]

It is extremely important to know normal ECG pattern and have the knowledge of the age difference to be able to interpret ECG correctly in different pediatric age groups.

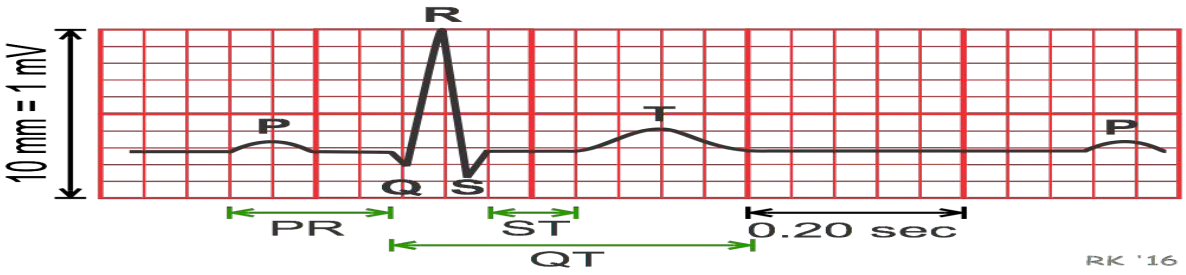
There are tables or centile charts that show normal values in relation to patient age. Most of the textbook and studies use tables from tow common papers:

1) Normal ECG standards for infants and children by Davignon A, et al Pediatr Cardiol 1979
2) New normal limits for the paediatric electrocardiogram by Rijnbeek PR, et al. Eur Heart J 2001; 22:702–11.

At the end of this booklet I put for you some important tables of normal values of ECG component according to age group from Rijnbeek paper but please make your effort to check also other tables and use it when you interpret pediatric ECG in your daily practice.

❖ What does PQRST represent and mean?

Each component of ECG represent important cardiac event.



David Dickinson,2016 [3]

P: Represents atrial depolarization (conduction of an electrical impulse through the atria). It is normally rounded and upright in lead I, II, aVF and lead V2-V6 but negative in aVR.
Abnormal morphology or deflection may represent abnormal origin and high amplitude represents increased atrial size.

PR Interval:

Tracks the atrial impulse from the atria through the AV node, bundle of His, and right and left bundle branches.[1]
It is calculated from the beginning of P wave to the beginning of QRS complex and varies according to age.
Short PR interval usually indicate that the impulse is originating from a focus other than SA node and prolonged PR interval indicate a conduction delay.

QRS:

Represents depolarization of the ventricles. Normally it must follow P wave.
The duration is calculated from the beginning of Q wave to the end of S wave.
The amplitude varies according to age and leads.
QRS is positive in leads I, II, III, aVL, aVF, and V4 to V6 and typically negative in leads aVR and V1 to V3.

QRS relation to P wave, morphology, duration, size and deflection give you a lot of information about the origin of the rhythm (supraventricular or ventricular), different types of blocks, ventricular hypertrophies and axis.

ST segment:

Represents the end of ventricular conduction or depolarization and the beginning of ventricular recovery or repolarization. It is calculated from the beginning of S wave to the beginning of T wave. It is normally neither positive or negative.ST segment elevation or depression indicate myocardial injury and ST elevation indicate pericardial inflammation.

T:

Represents ventricular recovery or repolarization. It is usually rounded and smooth and normally positive in all leads except aVR. It is variable in lead V1 according to age. It is important to remember that T wave is upright in lead V1 from birth till one week of age. It will be inverted after one week till adolescent age. In adult is variable but mostly upright.

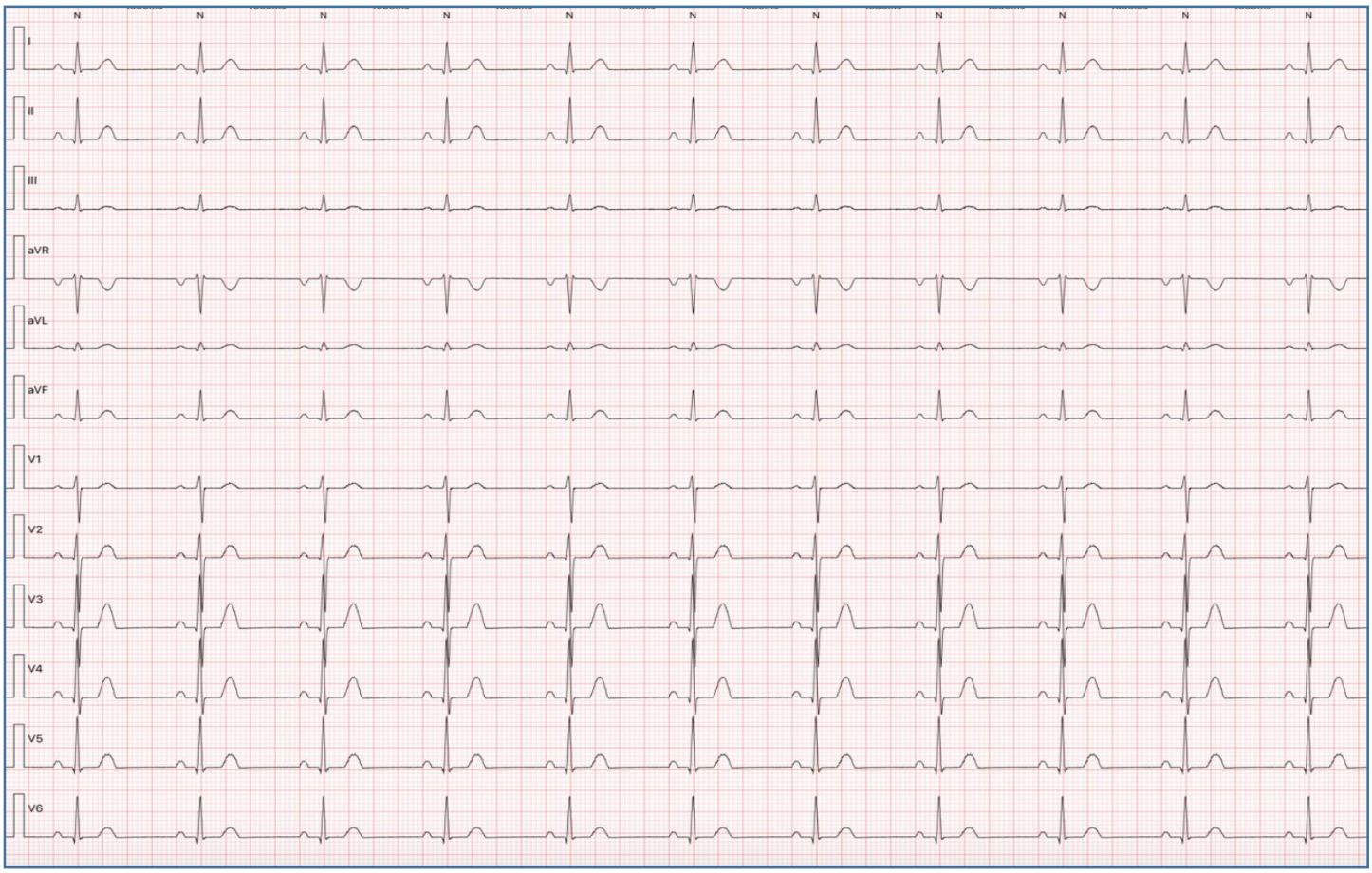
❖ What is sinus rhythm?

When you read any ECG and with above explanation about PQRST, the most initial and basic thing is to decide if the rhythm is sinus or not?
To not miss anything and to make it easy, always check all component of PQRST in systematic way and check multiple leads.
Sinus rhythm is characterized by:

1) Normal Rate for age
2) P wave shape and size are normal and it is upright in lead I, II and aVF
3) PR interval is normal and constant in all beats
4) Each P wave followed up by QRS complex
5) Regular P-P and R-R interval (atrial and ventricular rhythm)
6) Normal QRS duration, no ectopic or aberrant beat.
7) Normal QT interval
8) Upright T wave in lead II

ECG index	
1	Normal Sinus rhythm
2	Sinus Tachycardia
3	Sinus Bradycardia
4	Sinus arrhythmia
5	Newborn ECG < 7 days old
6	Neonate ECG > 7 days old
7	Right atrial enlargement
8	Left atrial enlargement
9	Left Ventricular Hypertrophy
10	Right Ventricular Hypertrophy
11	Supraventricular Tachycardia (SVT)
12	First degree AV block
13	Second degree AV block Type 1
14	Second degree AV block Type 2
15	Third degree AV block
16	Ventricular Tachycardia
17	Ventricular Fibrillation
18	Asystole
19	Long QT syndrome
20	Premature Atrial Contractions (PAC)
21	Premature Ventricular Contractions (PVC)
22	Right Bundle branch Block
23	Left Bundle Branch Block
24	Hyperkalemia
25	Biventricular Hypertrophy
26	Wolff-Parkinson-White Syndrome
27	Pulmonary Hypertension
28	Ventricular Pacing
29	Pericarditis
30	Myocarditis

1 17-year-old boy admitted to PICU post scoliosis repair.

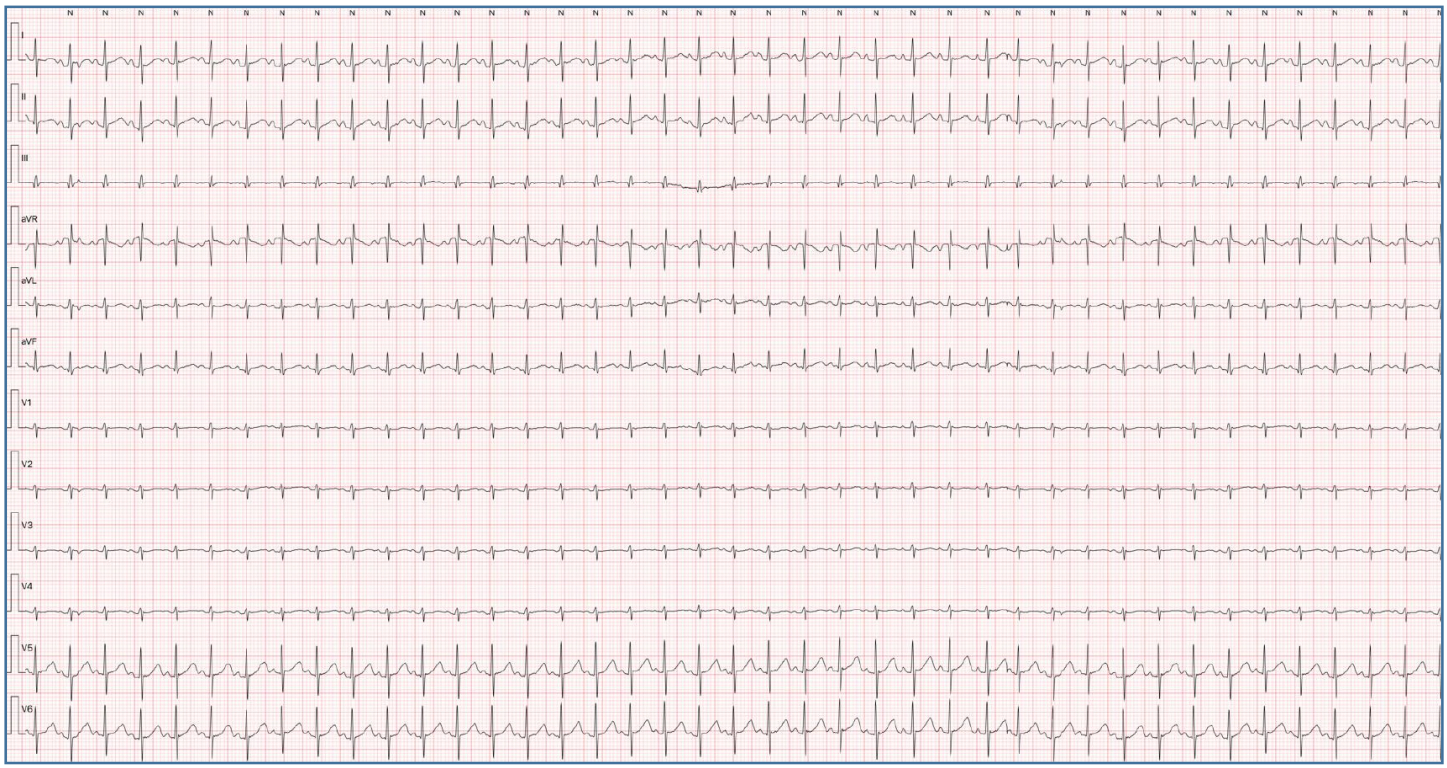


(4)

Interpretation:

- Normal Sinus Rhythm with heart rate of 60 BPM
- P wave is normal in shape and size and upright in lead I, II and aVF
- PR interval is constant in all beast and each P wave followed up by QRS
- Regular P-P and R-R interval.
- QRS is normal in shape and duration
- T wave is upright in all leads except aVR
- QTc is normal

2 3-year-old girl admitted with viral pneumonia. She has high grade fever and tachycardia.

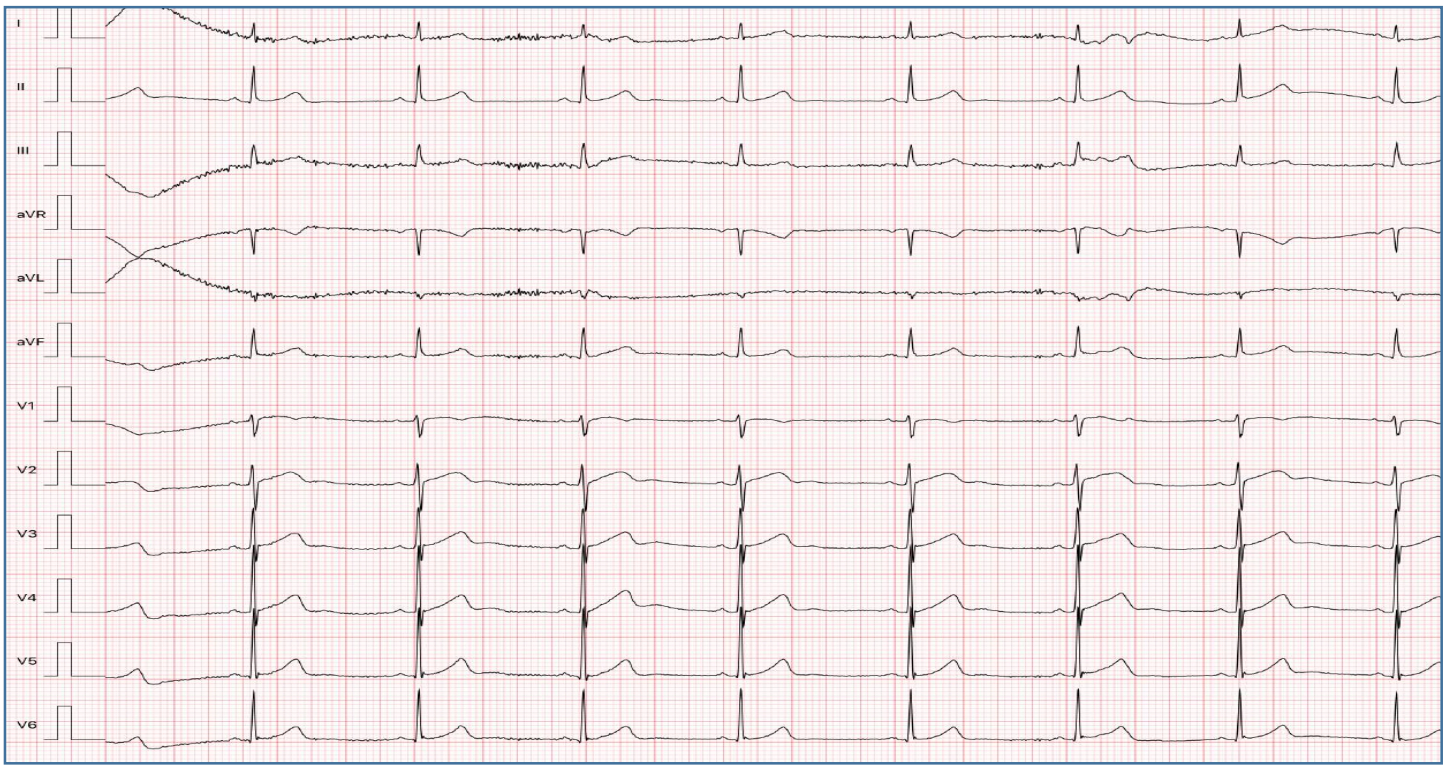


(4)

Interpretation:

- Sinus tachycardia with heart rate of 160 BPM
- This ECG has all features of sinus rhythm except heart rate is high for age.

3 2-year-old boy with respiratory failure ventilated and sedated with dexmedetomidine.

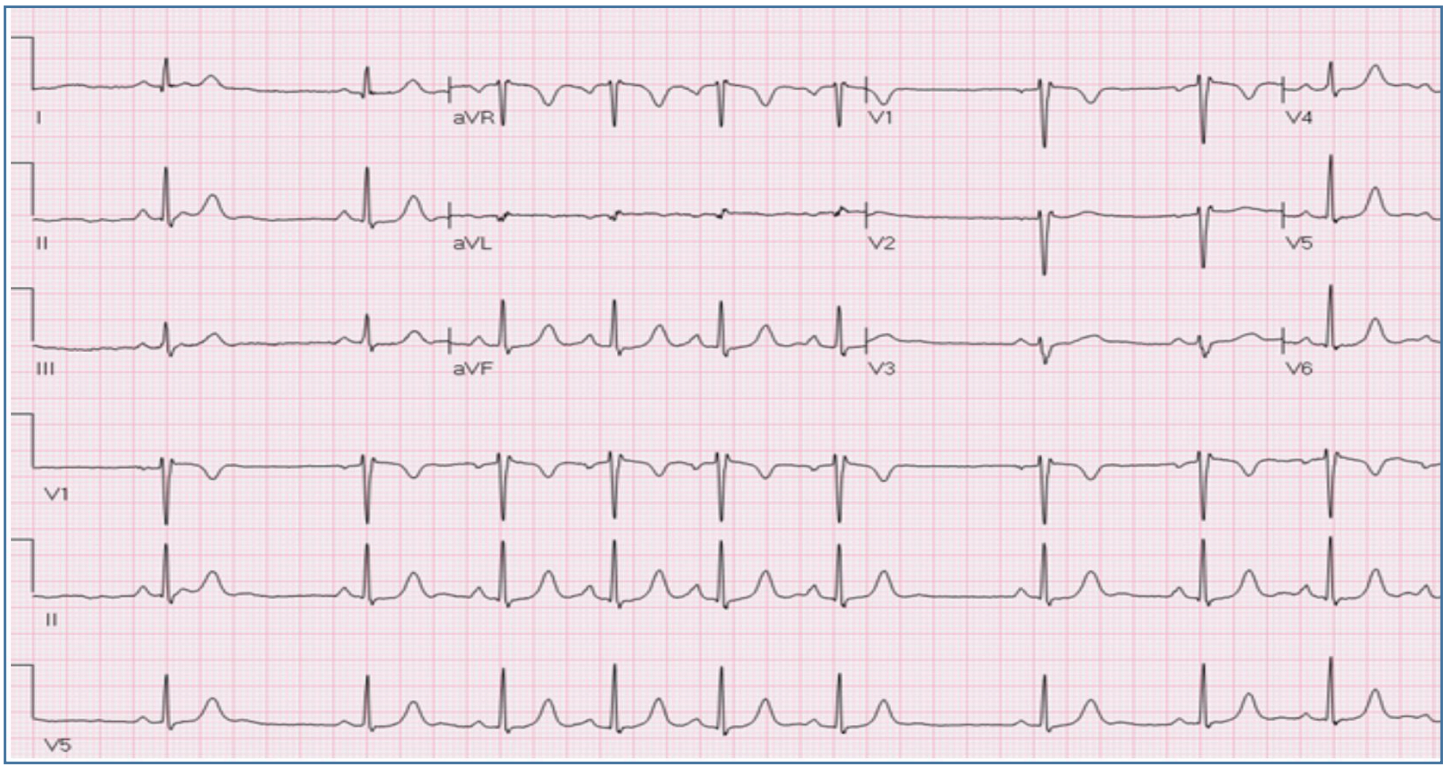


(4)

Interpretation:

- Sinus bradycardia with heart rate of 60 BPM
- This ECG has all features of sinus rhythm apart from low heart rate for age

4 6-year-old girl with DKA.It was noticed that her heart rate was irregular.

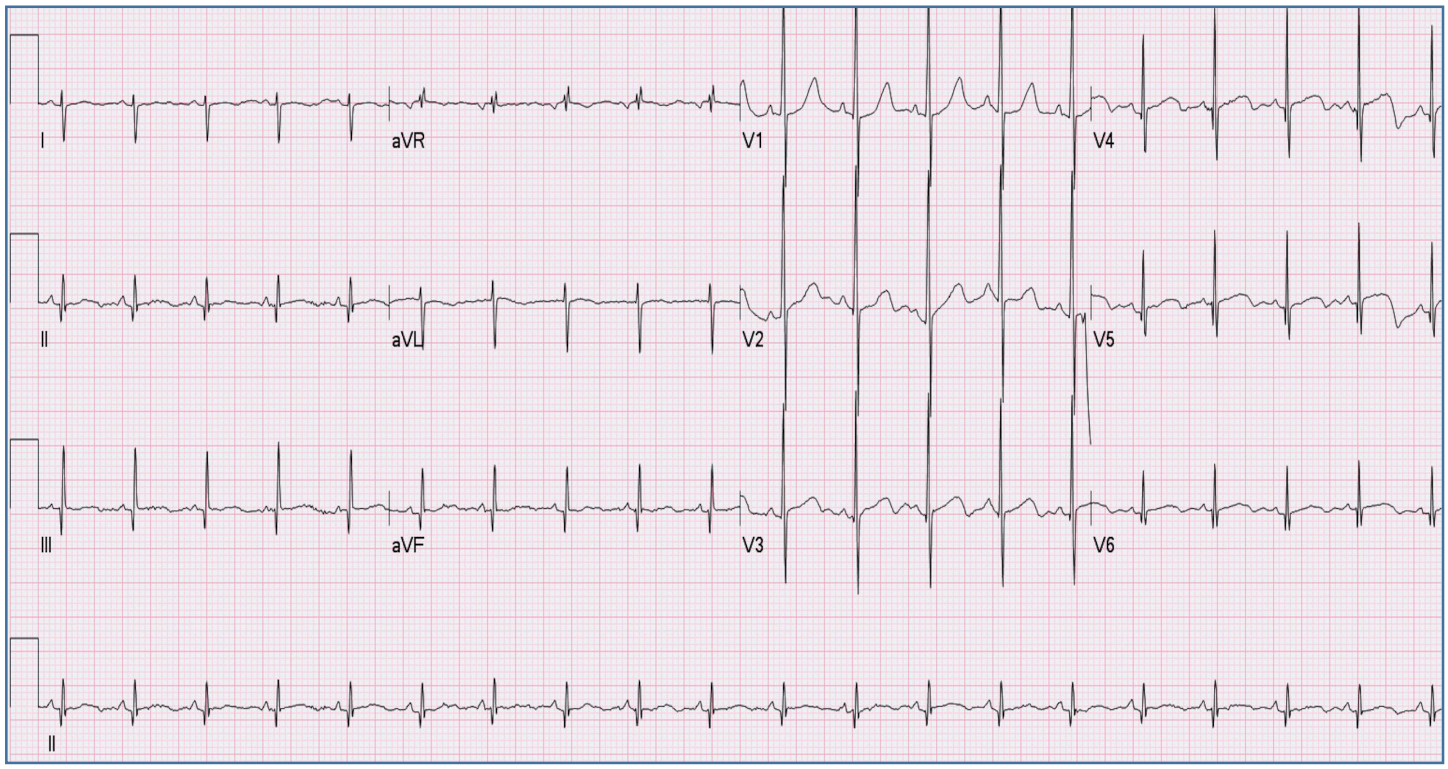


(8)

Interpretation:

- Sinus arrhythmia with variable heart rate between 50 - 100
- This ECG has all features of sinus rhythm apart from variability in P-P and R-R interval.
- Sinus arrhythmia refers to changing sinus node rate with respiratory cycle. It is common in young and healthy individual and does not have clinical significance. The rate increases with inspiration and decreases with expiration.

5 4-day old baby admitted with transient tachypnea of newborn for CPAP support.

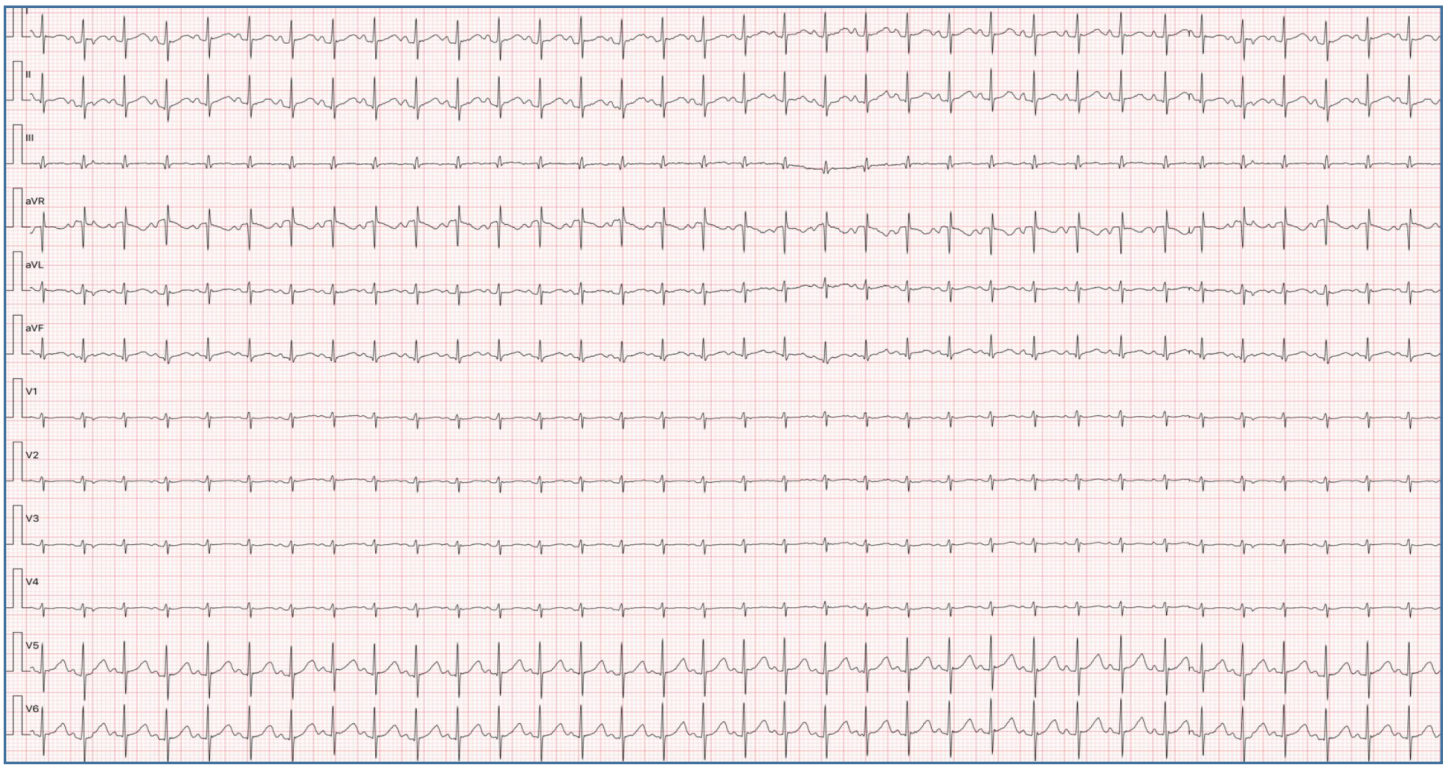


(17)

Interpretation:

- Normal neonatal (less than 7-day old) ECG with sinus rhythm
- Notice that T wave is upright in lead V1 which is due to right ventricular dominance and Right axis deviation secondary to higher pulmonary vascular resistance that will normally drop after birth.

6 22-day old baby with upper airway obstruction required BIPAP support



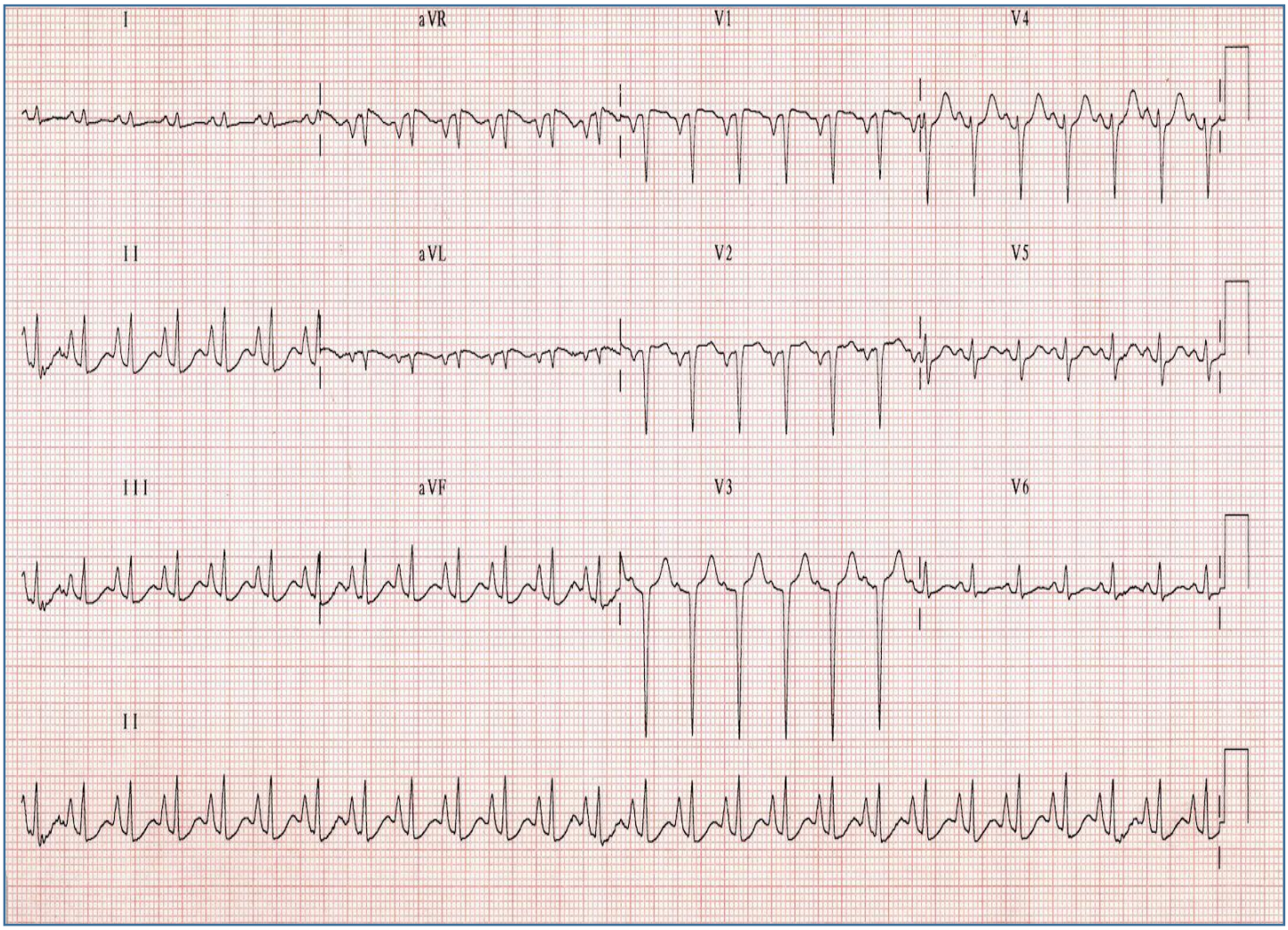
(4)

Interpretation:

- Normal neonatal (more than 7-day old) ECG with sinus rhythm
- Notice that T wave has changed normally to be negative in lead V1
- T wave must be always negative in lead aVR in all ages
- Persistent positive T wave beyond neonatal period indicate right ventricular hypertrophy.
- Negative T wave may last till late teens then it can be variable but mostly positive

7

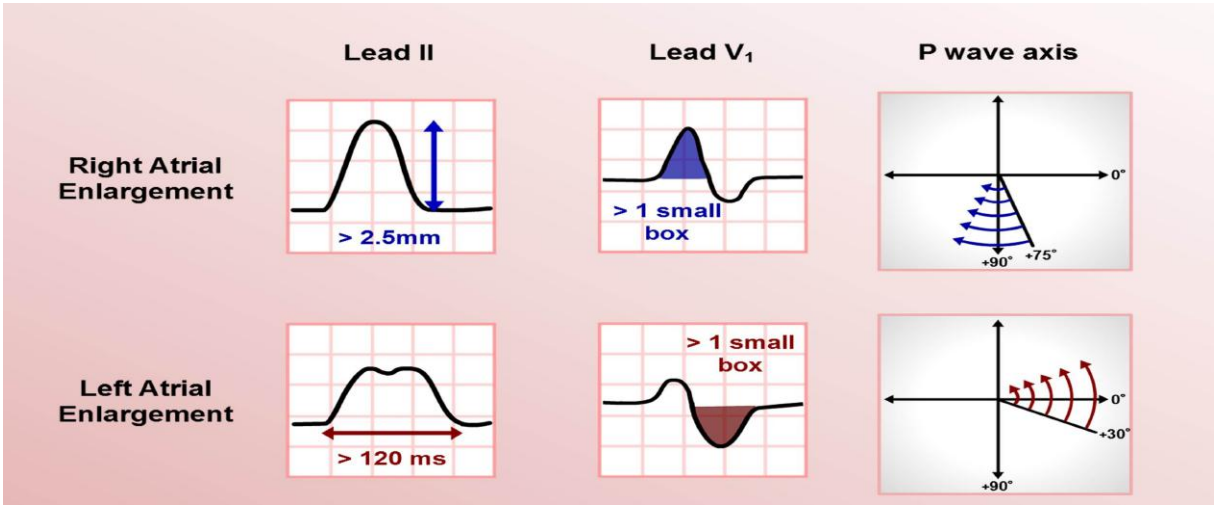
5-year-old with chronic lung disease and recurrent pneumonia with loud P2 on CVS exam.



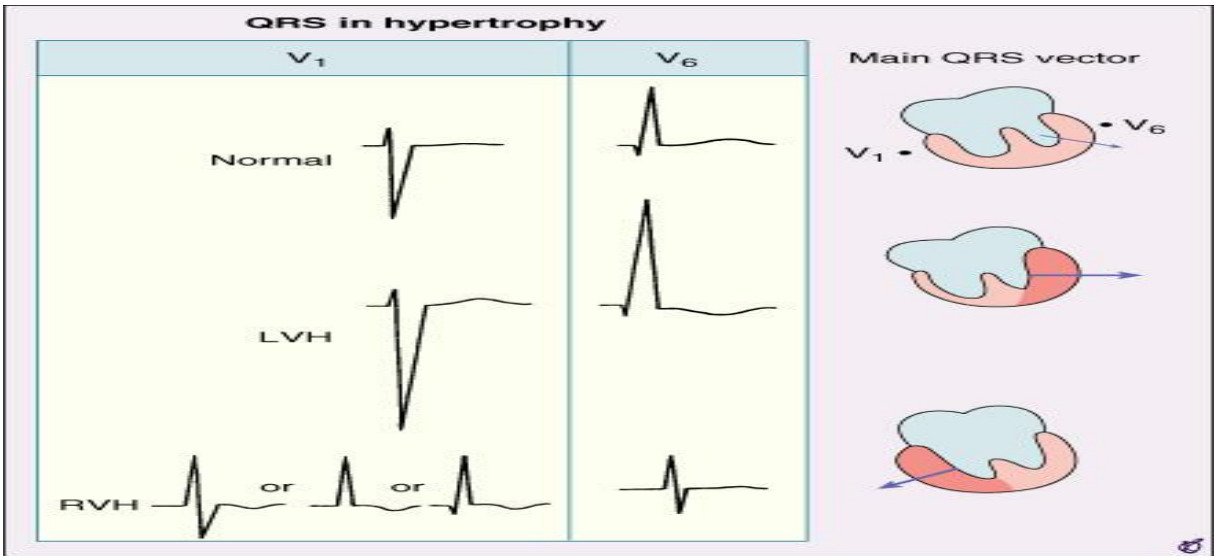
(8)

Interpretation:

- Peaked P wave that indicates right atrial enlargement
- This patient has pulmonary hypertension secondary to chronic lung disease.
- Right atrial enlargement produces a peaked P wave (*P pulmonale*) with amplitude:
  - > 2.5 mm in the inferior leads (II, III and AVF)
  - > 1.5 mm in V1 and V2
  - Remember:
    - P wave normal amplitude varies according to age so refer to normal values table.
    - Atrial abnormalities are most easily seen in the inferior leads (II, III, aVF) and lead V1, as the P waves are most prominent in these leads. (8)

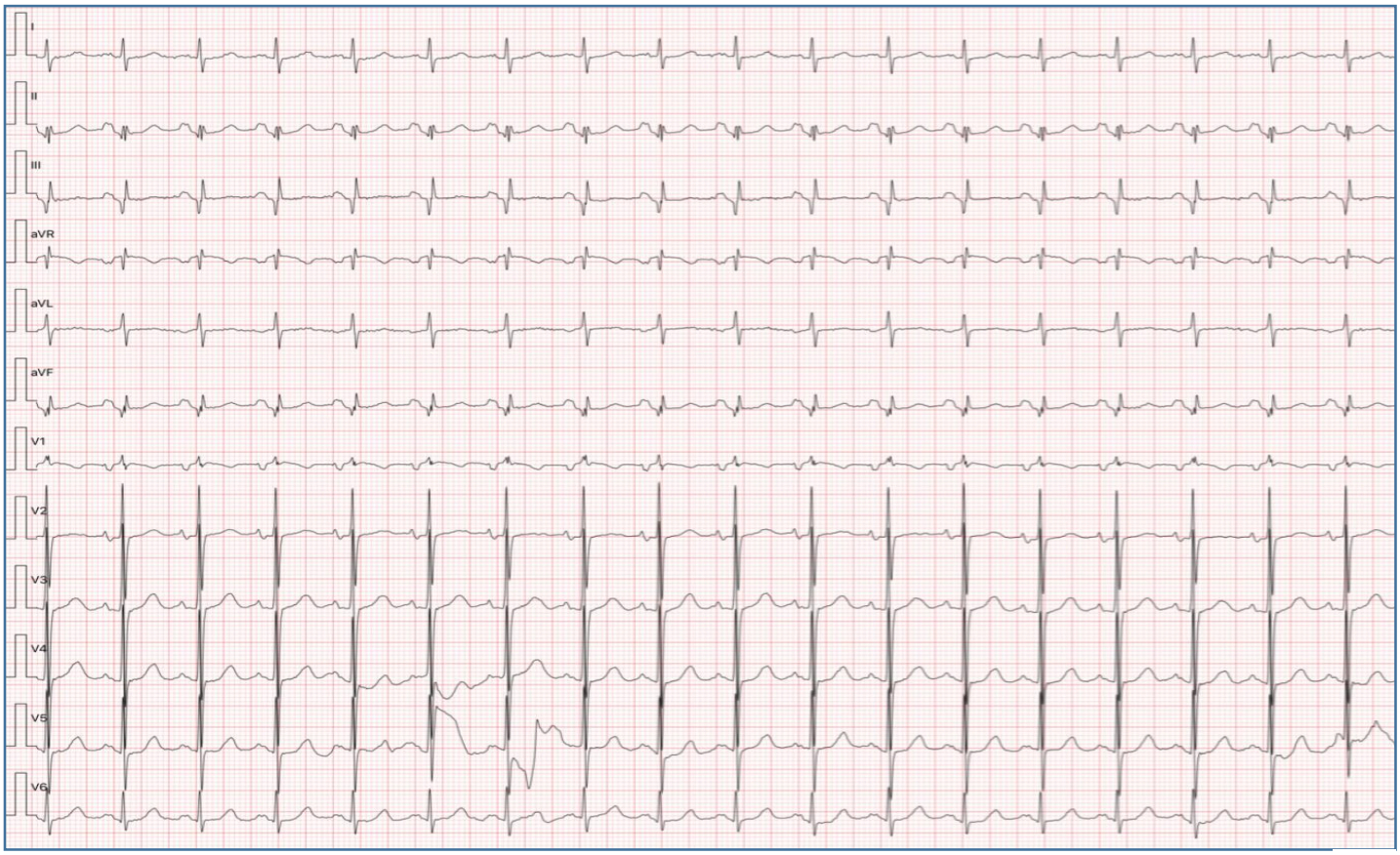

Lead II
Lead V1
P wave axis
Right Atrial Enlargement
> 2.5mm
> 1 small box
0°
+90°
+75°
Left Atrial Enlargement
> 120 ms
> 1 small box
0°
+30°
+90°

(9)


QRS in hypertrophy
V1
V6
Normal
LVH
RVH
or
or
Main QRS vector
V1
V6

(10)

8 11-year-old boy with heart failure. He is known to have severe mitral stenosis

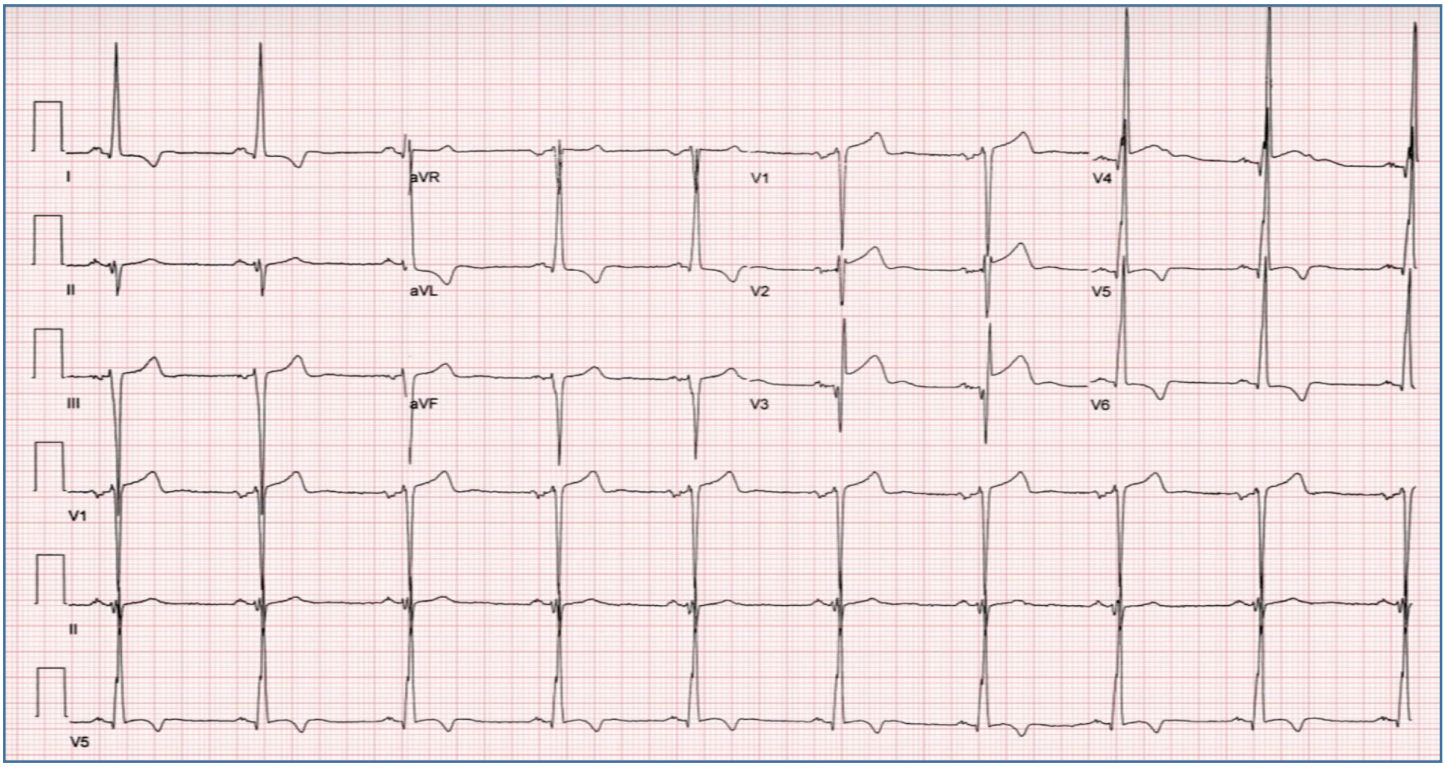


(4)

Interpretation:

- Bifid P wave mostly seen in lead II that indicate left atrial enlargement
- Left atrial enlargement produces broad bifid P wave in lead II (P mitrale) and enlarges the terminal negative portion of P wave in lead V, obvious in this ECG
- Classically seen in mitral stenosis and any other diseases that cause left atrial enlargement. (8)

9 16-year-old with Chronic Kidney disease and Chronic hypertension admitted to PICU with hypertension emergency

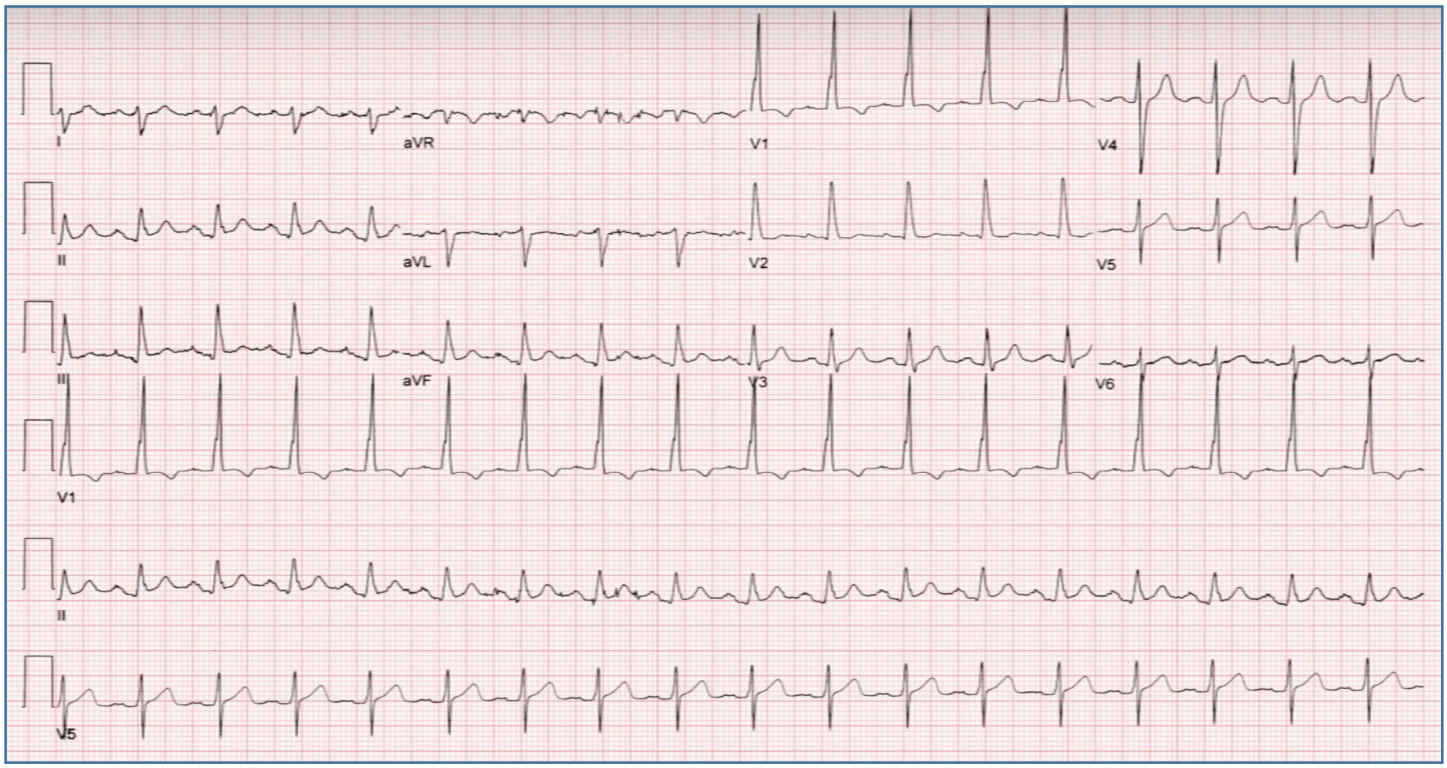


(9)

Interpretation:

- Left Ventricular Hypertrophy with left axis deviation
  - Tall R wave in Lead I, aVL, V5 and V6
  - Secondary repolarization abnormalities
  - Deep S wave in V1
  - For axis Notice deflection of QRS in lead I and aVF
- To decide about abnormal R wave and S wave amplitude in different leads you need normal values tables. Attached at the end of this booklet.

10 15-year-old with pulmonary hypertension



(9)

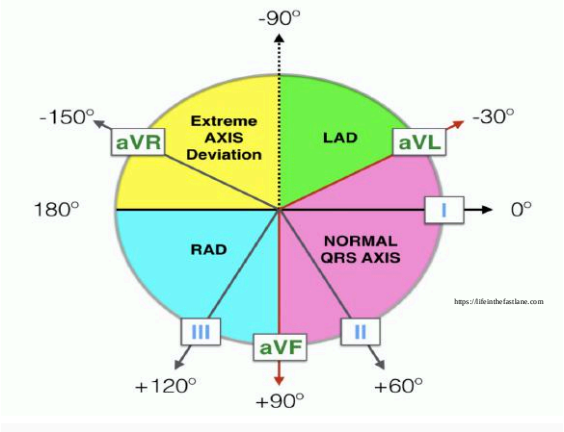
Interpretation:

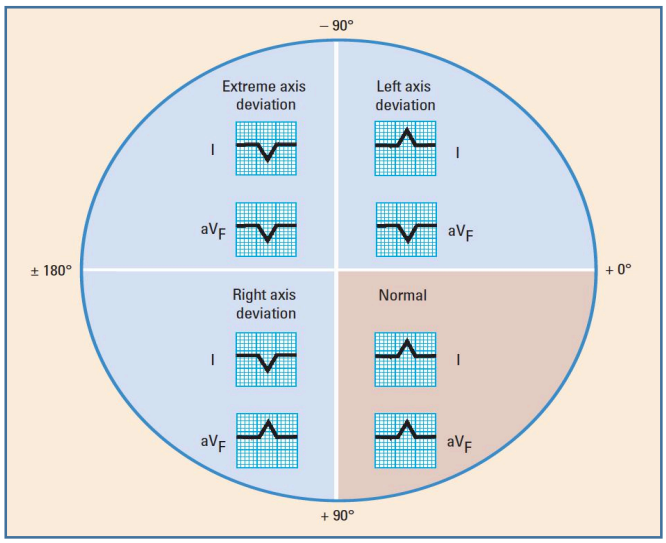
- Right Ventricular Hypertrophy with Right axis deviation
  - Tall R wave in V1 and V2
  - Secondary repolarization abnormalities
  - Deep S wave in Lead I and aVL, V5 and V6
  - For axis, notice QRS deflection in lead I and aVF

❖ Normal QRS axis varies with age: [8]

- 1 week – 1 month: + 110° (range +30° to +180°)
- 1 month – 3 months: + 70° (range +10° to +125°)
- 3 months – 3 years: + 60° (range +10° to +110°)
- Over 3 years: + 60° (range +20° to +120°)
- Adult: + 50° (range -30° to 105°)
-

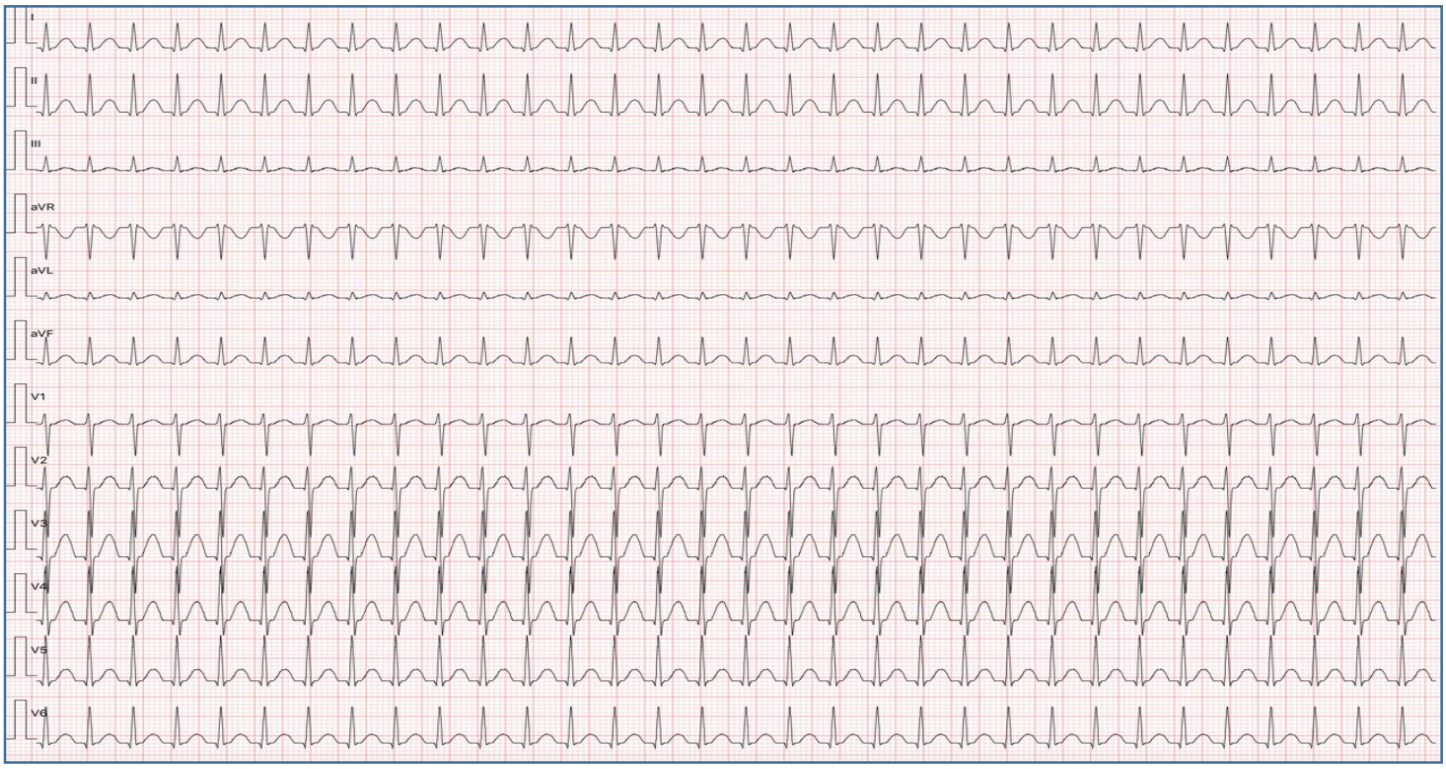
Hexaxial reference system





Chris Burghardt. et al.ECG interpretation made incredibly easy.5th edition. Lippincott Williams & Wilkins.2011

11 3-year-old was unwell for the last 24 hr. In ER was noticed to have tachycardia with no fever, dehydration or hypotension



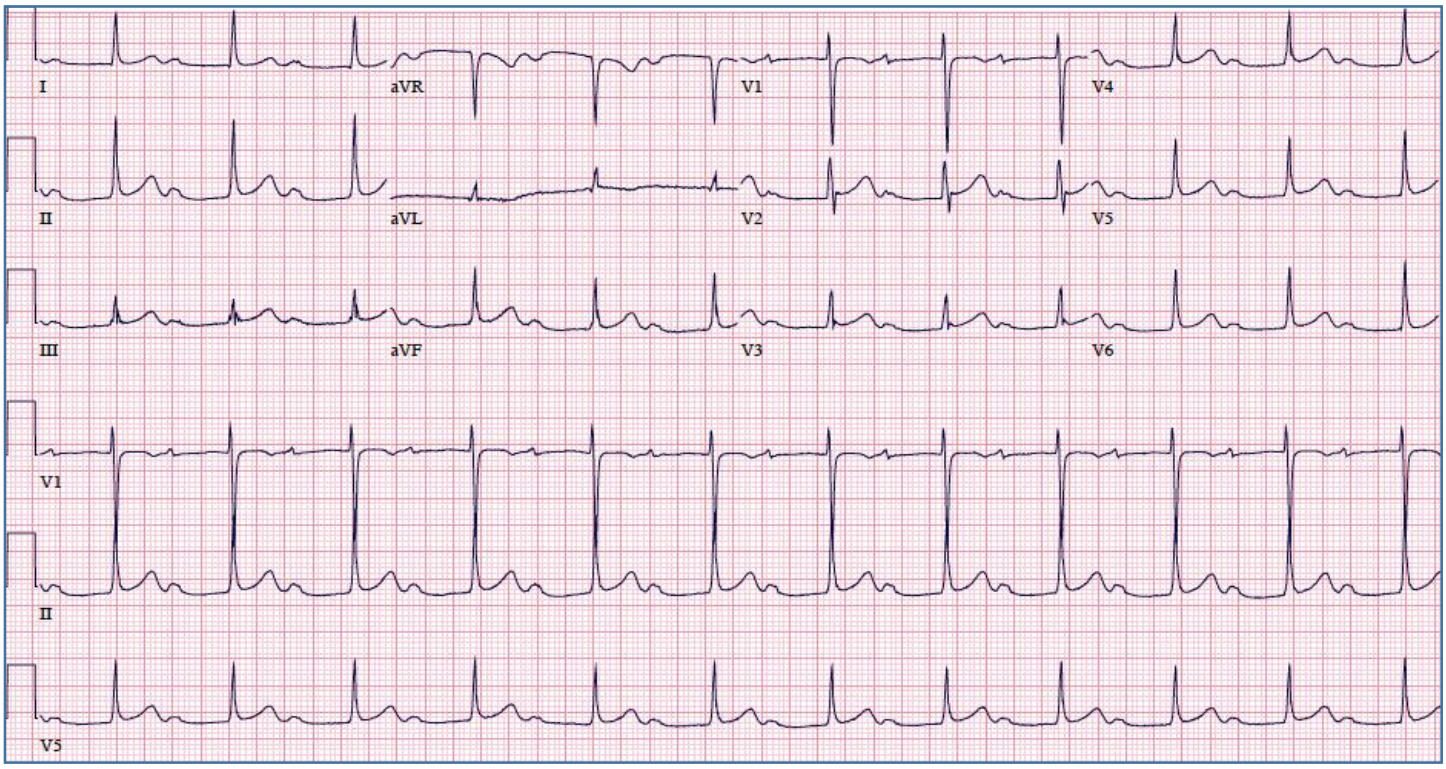
(4)

Interpretation:

- SVT:
  - Narrow complex tachycardia with heart rate of 200
  - No P wave is seen
  - Constant RR interval
- Remember: Supraventricular tachycardia is a description for tachycardia that arises from above the level of bundle of His. There are different types with different etiologies and management. Please read more details.
- Typically, is narrow complex unless aberrance conduction is present

12

6-year-old with perforated appendix post laparotomy



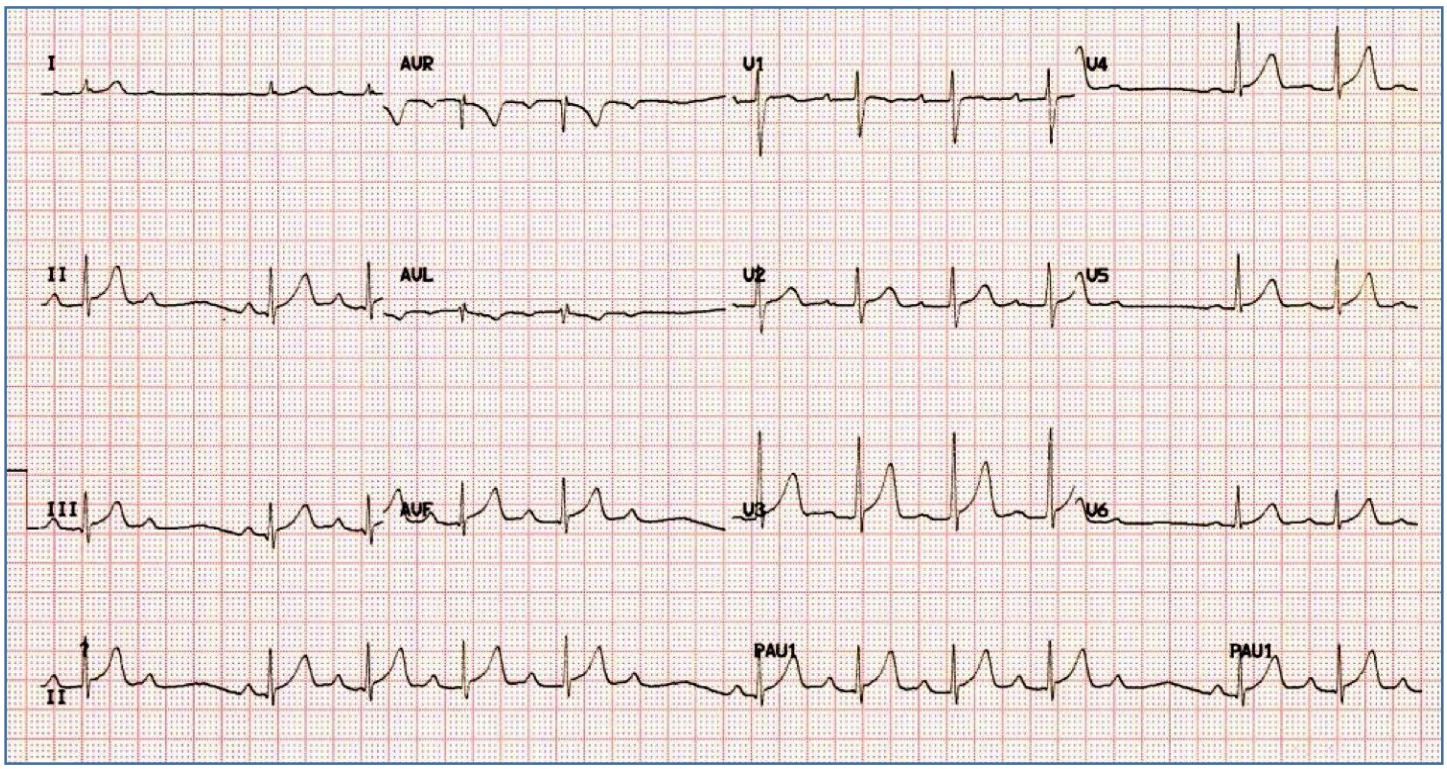
(12)

Interpretation:

- First degree heart block
- Prolonged constant PR interval
- Each single P wave is followed by QRS
- Remember that normal PR interval varies according to age

13

14-month old child post Tetralogy of Fallot repiar



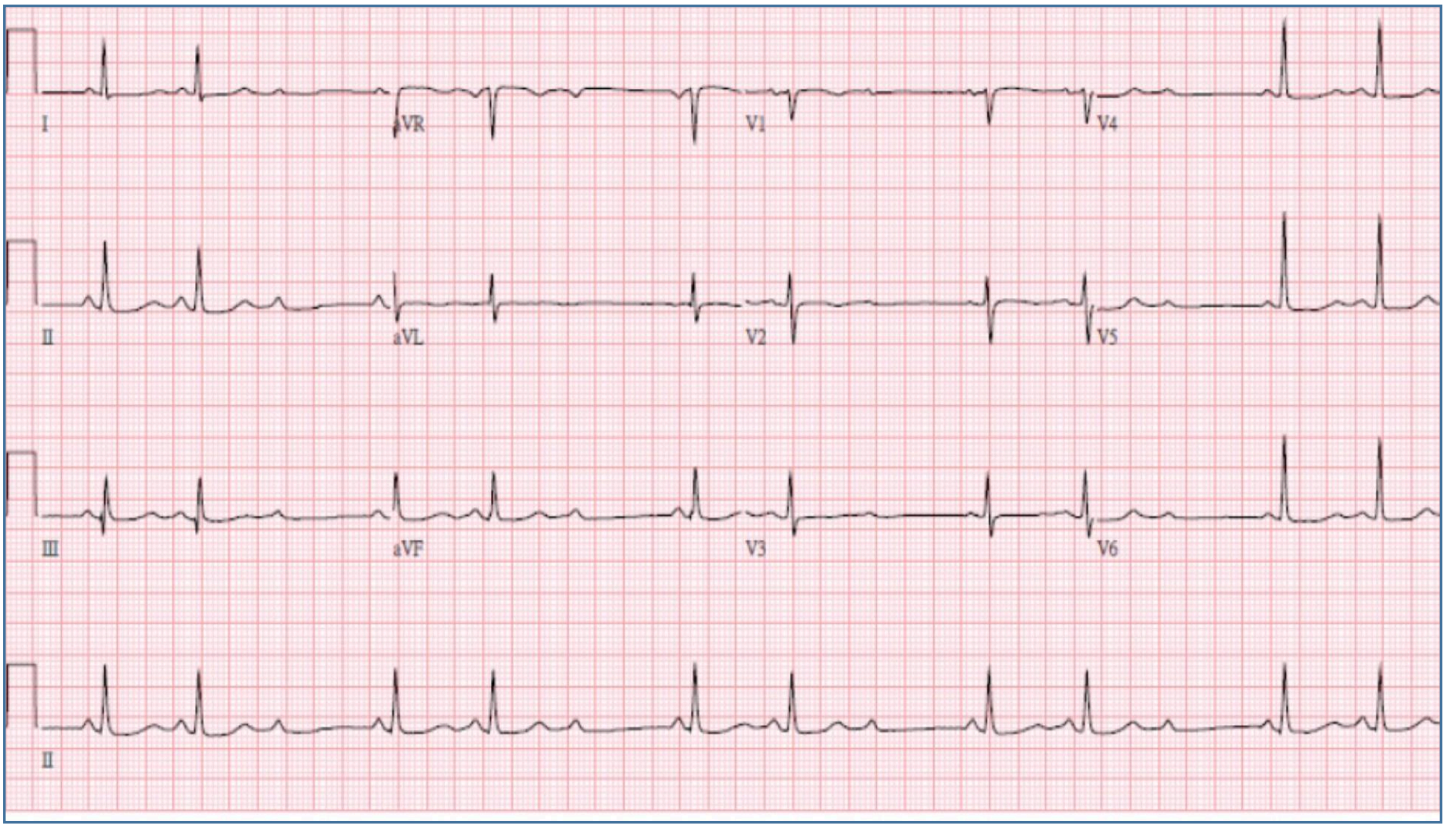
(8)

Interpretation:

- Second degree heart block type 1 (Mobitz Type1)
  - PR interval is not constant. It is progressively increasing on each complex till it is not conducted. i.e: not followed by QRS
  - There is a repeating cycle of 5 P waves and 4 QRS complexes (5:4 conduction ratio)
  - Note that QRS complexes are clustering in groups and separated by short pauses
  - P-P interval is relatively constant
  - It occurs secondary to malfunctioning of AV node cells which tend to progressively fatigue until they fail to conduct an impulse

14

2-year-old post AVSD repair



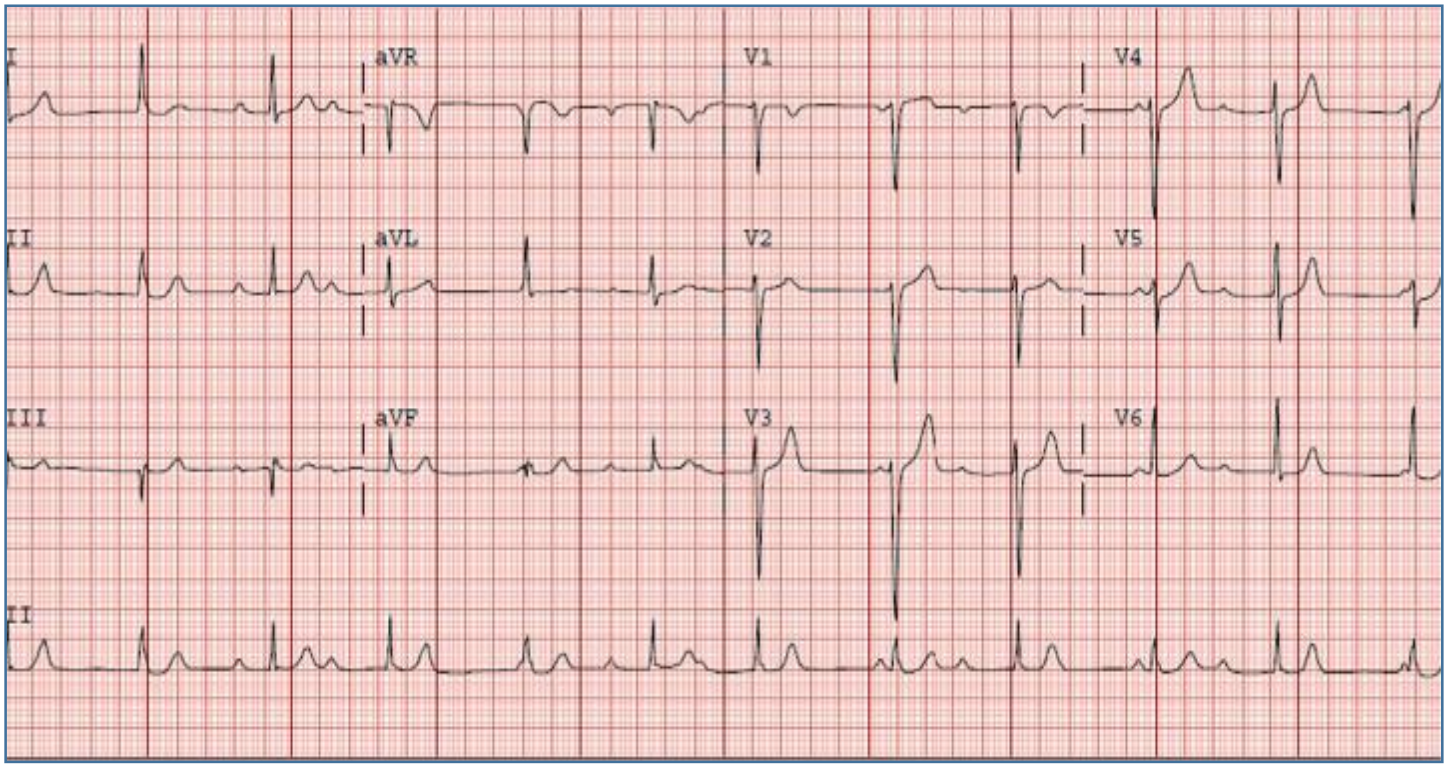
(8)

Interpretation:

- Second degree heart block Type II (Mobitz type II)
  - Not all P wave followed by QRS (3 P waves for 2 QRS. Ratio: 3:2)
  - P-P interval is constant even when QRS is missing (around 3.5 large square)
  - It is usually due to failure of conduction at the level of His-Purkinji system (below AV node)

15

4-month old post very large VSD repair



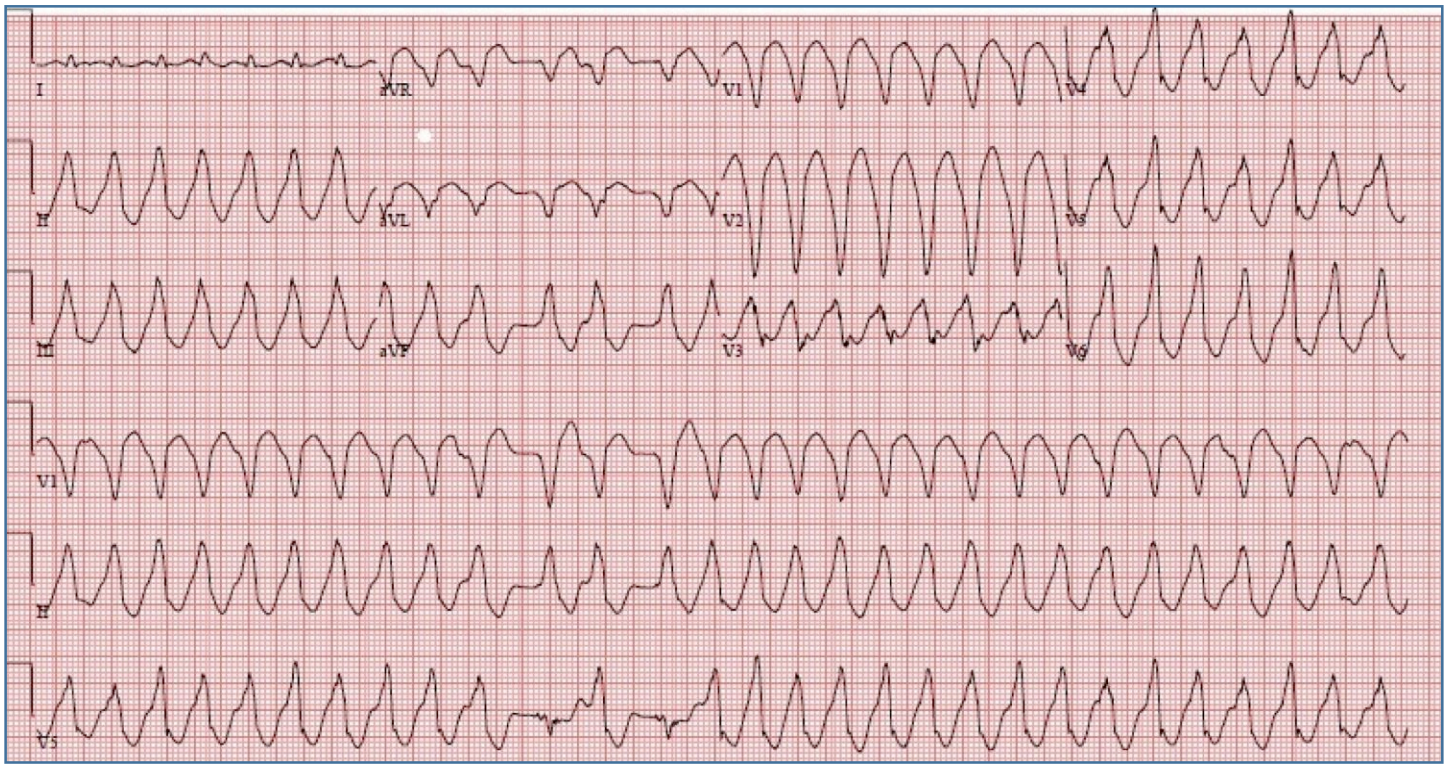
(13)

Interpretation:

- Complete (Third degree) heart block
  - No relation between P waves and QRS complexes
  - Atrial rate and ventricular rate are independent
  - In complete heart block there is complete absence of AV conduction. None of the supraventricular impulses are conducted to the ventricles
  - Perfusing rhythm is junctional or ventricular escape rhythm

16

8-year-old had pre syncope during exercise. On arrival of EMS was drowsy and cyanosed. She was tachycardiac and 12 lead ECG was done



(14)

Interpretation:

- Ventricular tachycardia
  - Wide complex tachycardia
  - Ventricular rhythm is regular and rate is about 200
  - Atrial rhythm and rate cannot be determined
- Patients with V.Tach can be stable with normal pulse and BP but can be with no perfusion and at risk of death if not immediately resuscitated. It can progress to ventricular fibrillation
- This patient has catecholamine induced ventricular tachycardia

17

6-year old boy fainted at school and was unconscious and pulseless. CPR was started by teacher till EMS arrival.

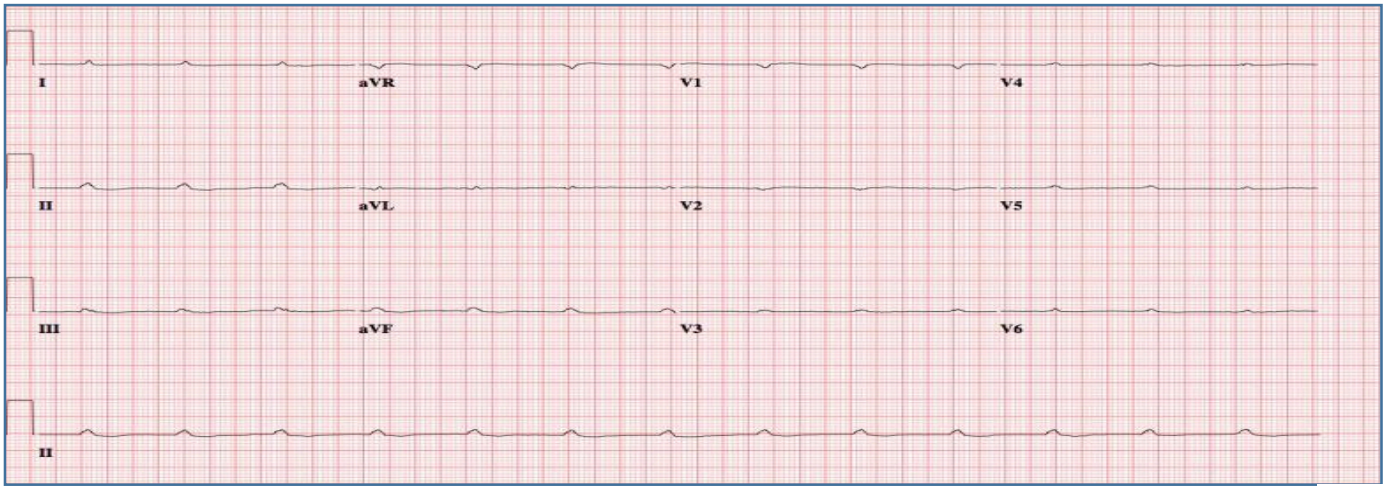
(13)

Interpretation:

- Ventricular Fibrillation
  - Fibrillatory waves
  - No atrial nor ventricular pattern
  - You cannot determine P wave, PR interval, QRS or T waves
- V. Fib patients are always on full cardiac arrest with no pulse or BP and need defibrillation to convert to sinus rhythm

18

5-year-old was hit by a truck while crossing the street and had multiple severe injuries including blunt chest trauma. After resuscitation with no response someone raised a suspicion of presence of a pulse.



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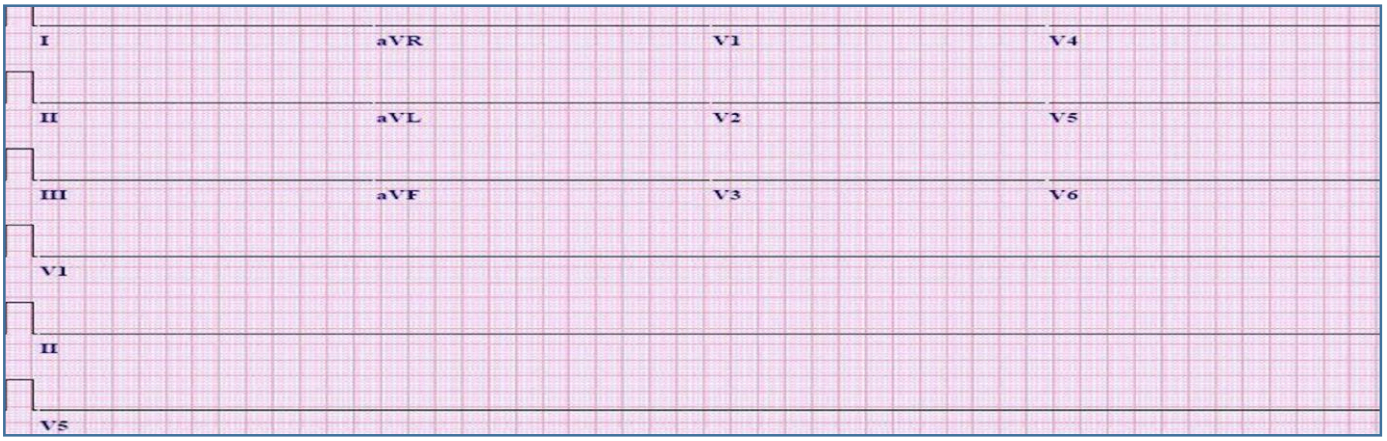


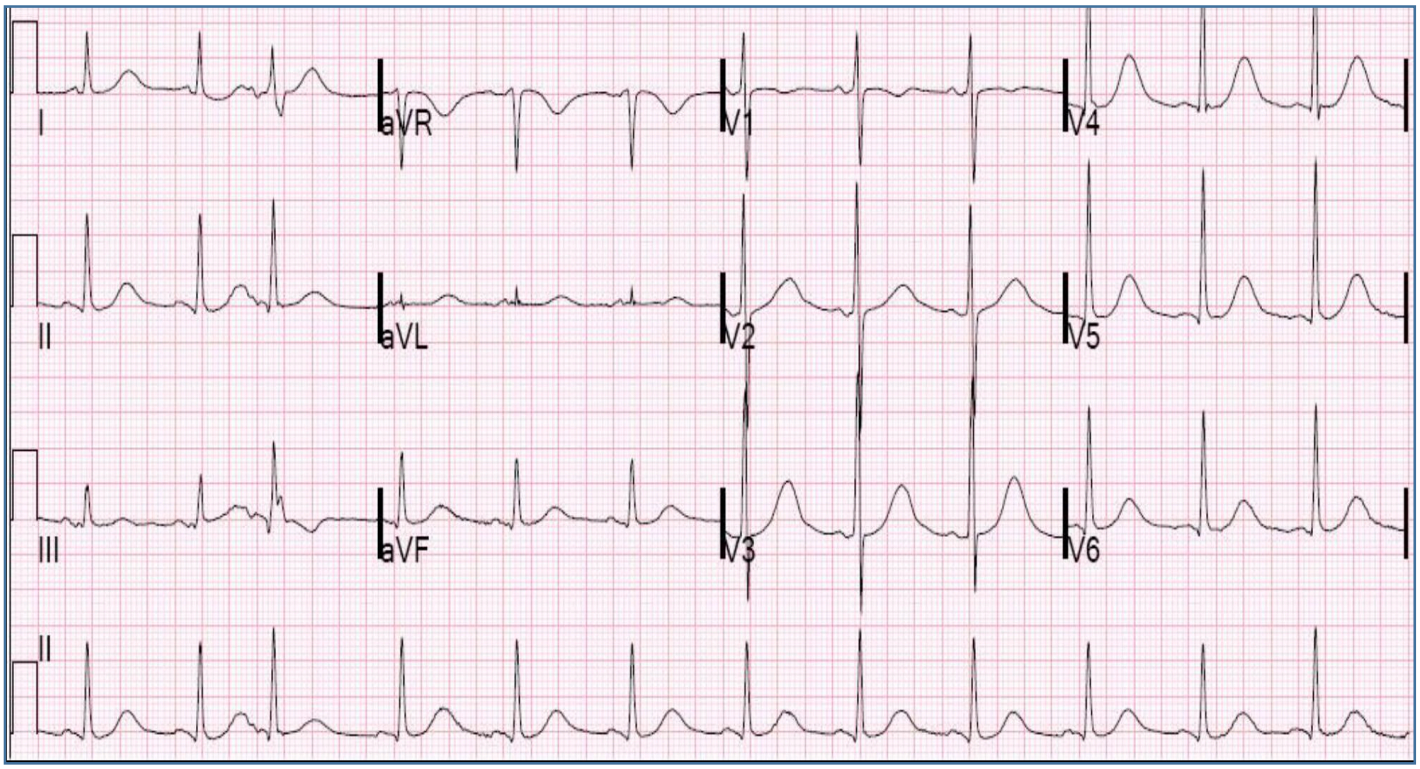
(18)

Interpretation:

- Asystole
  - First ECG shows ventricular asystole with preserved atrial function
  - Second ECG showed no cardiac electrical activity
  - During asystole you may see occasional P wave or QRS complexes. This is called agonal heart rhythm and considered as asystole

19

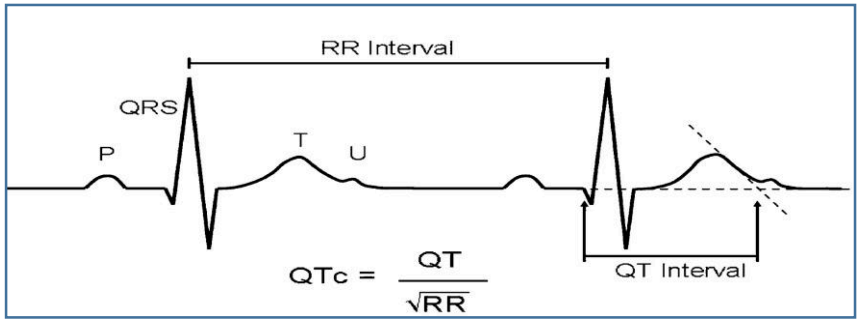
3-year-old child with recurrent episodes of syncope



(14)

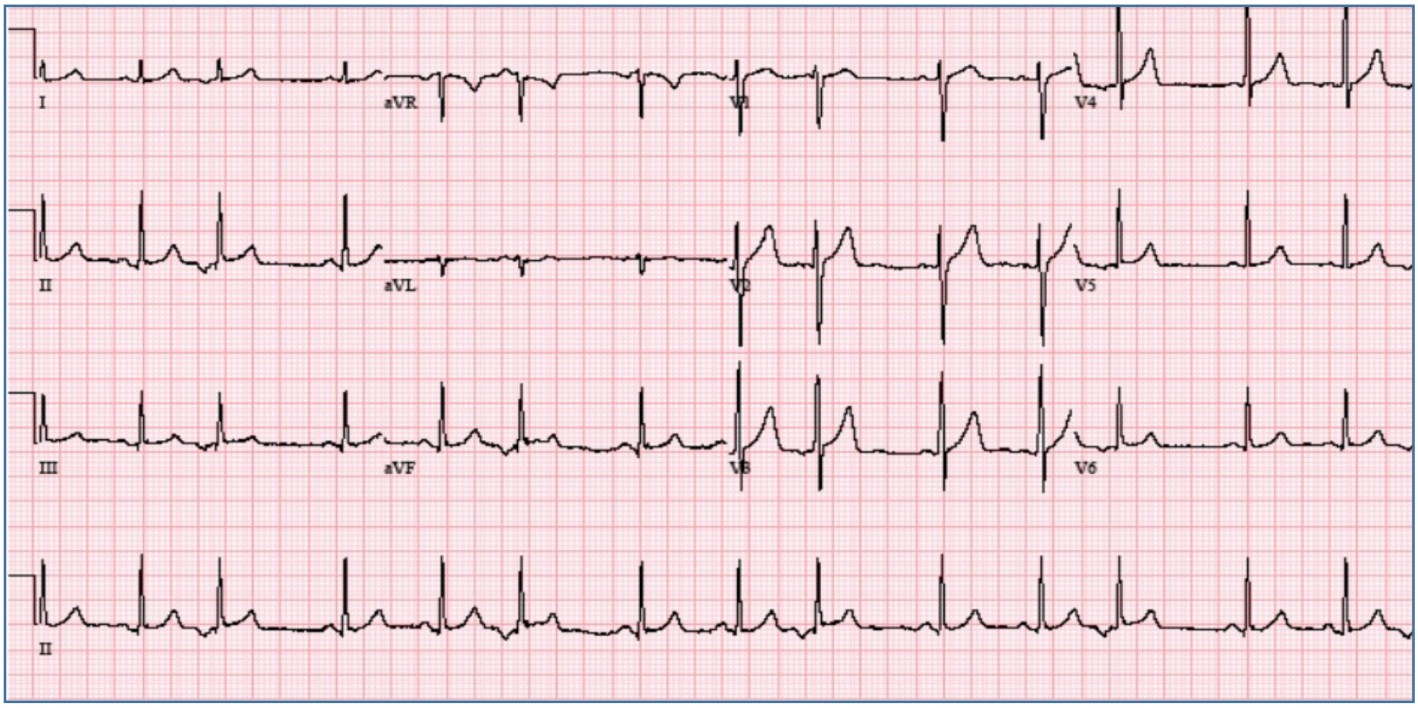
Interpretation:

- Long QT syndrome
  - QTc is more than 500ms
- Normal QT varies with age but in general more than 450ms is long
- It represents ventricular depolarization and repolarization
- It is calculated in lead II and V5-V6 from beginning of QRS to end of T wave
- It varies according to heart rate so calculated corrected QT



(15)

20 16-year-old girl admitted with toxic shock syndrome on norepinephrine infusion. The nurse noticed abnormal beats and did 12 lead ECG.



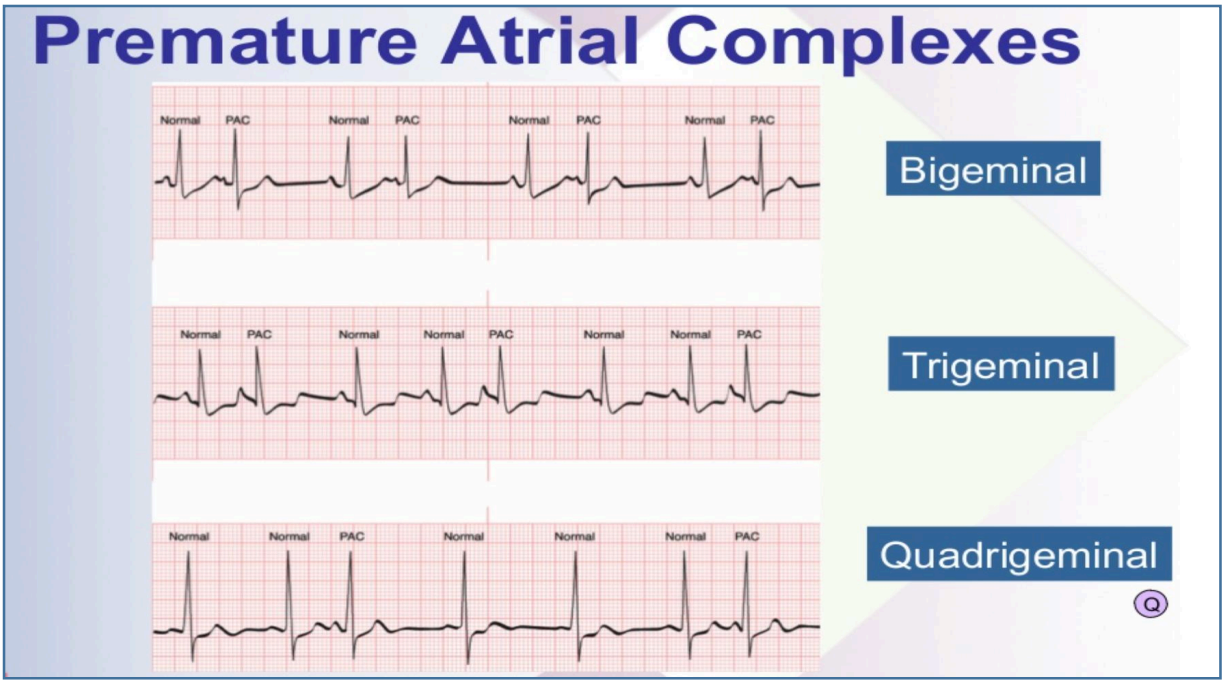
(17)

Interpretation:

- Premature atrial contractions (PACs)
  - Every three beats there is premature P wave occurring earlier than other P waves
  - P-P interval between ectopic P wave and normal P wave is shorter than P-P interval between normal P waves
  - The shape of these premature P waves is different from normal P waves with abnormal negative deflection
  - R-R interval after each PAC is slightly longer than R-R in other beats
  - QRS is narrow and normal even after these ectopic P waves

Characteristics of PACs

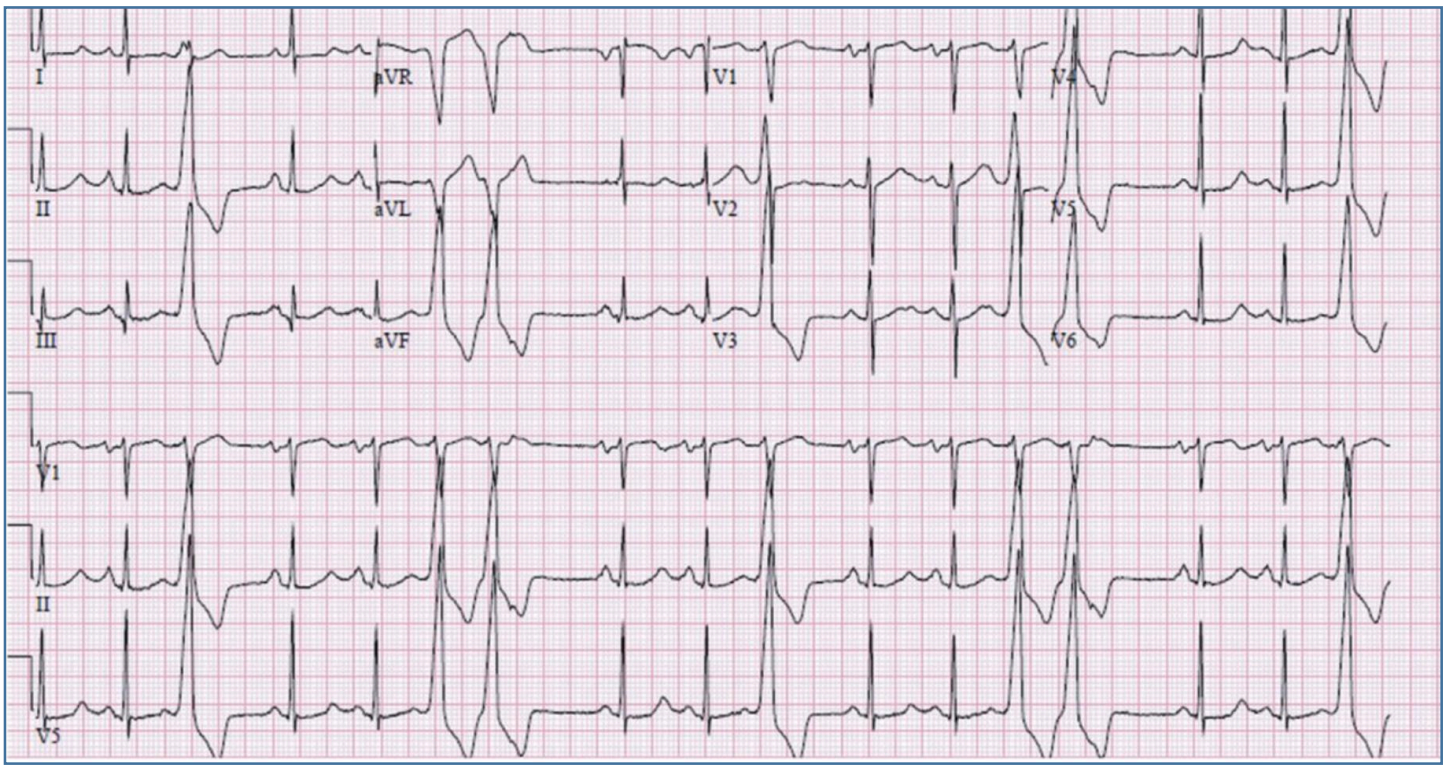
1) Premature: occur earlier than normal P wave so P-P interval is shorter than in normal beats. Sometime ectopic P wave is attached to the end of T wave or hidden in T wave and cannot be seen
2) Ectopic: originate outside SA node so morphology is different than normal P wave. It may have different deflection depending on atrial site that it is originating from
3) Narrow complexes: since it is originating from atria, it travels through AV node to the ventricle so QRS will be as in normal beat
4) Compensatory pause after each PAC as it produces extra action potential making SA node refractory to generate its next scheduled beat
5) Called atrial bigeminy if happened every other beat, trigeminy every three beats etc.
6) Usually it is benign and does not cause hemodynamic instability



(18) slideshare.net: Shadechapter09.ppt

21

15-year-old boy with submersion injury post resuscitation suffering from hypoxic injury



(19)

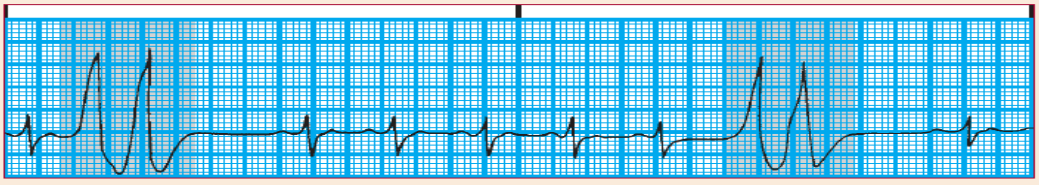
Interpretation:

- PVCs
  - Wide QRS complexes occurring every 3 beats demonstrating ventricular rhythm
  - Those QRS complexes occur prematurely compared to other normal QRS complexes (compared R-R interval of normal beats and premature beats)
  - One single PVC or double consecutive PVCs happen after tow normal beats

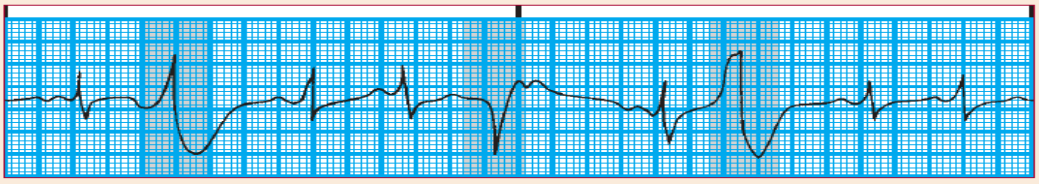
Characteristics of PVCs

1) Premature: Occur earlier than normal QRS complexes
2) Ectopic: As they originate outside SA node (from ventricles), QRS morphology is different from normal QRS.You may see retrograde P waves
3) Wide complexes: they do not use the normal ventricular conduction system, the action potential needs to travel from myocyte to myocyte instead which is much slower, thus the QRS complex is wide
4) Compensatory pause after the PVC as it produces extra action potential making SA node refractory to generate its next scheduled beat
5) Called ventricular trigeminy if happened every other beat, trigemini every three beats, couplets if 2 PVCs occur consecutively.
6) If three or more PVCs occurred in a row, it is considered a run of ventricular tachycardia
7) PVCs can be asymptomatic with no clinical significance but can progress to Ventricular Tachycardia or Fibrillation

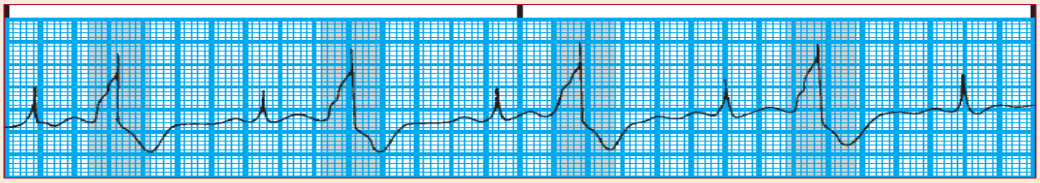
Paired PVCs
Two PVCs in a row are called a pair, or *couplet* (see highlighted areas). A pair can produce ventricular tachycardia because the second depolarization usually meets refractory tissue. A salvo—three or more PVCs in a row—is considered a run of ventricular tachycardia.



Multiform PVCs
PVCs that look different from one another arise from different sites or from the same site with abnormal conduction (see highlighted areas). Multiform PVCs may indicate increased ventricular irritability.



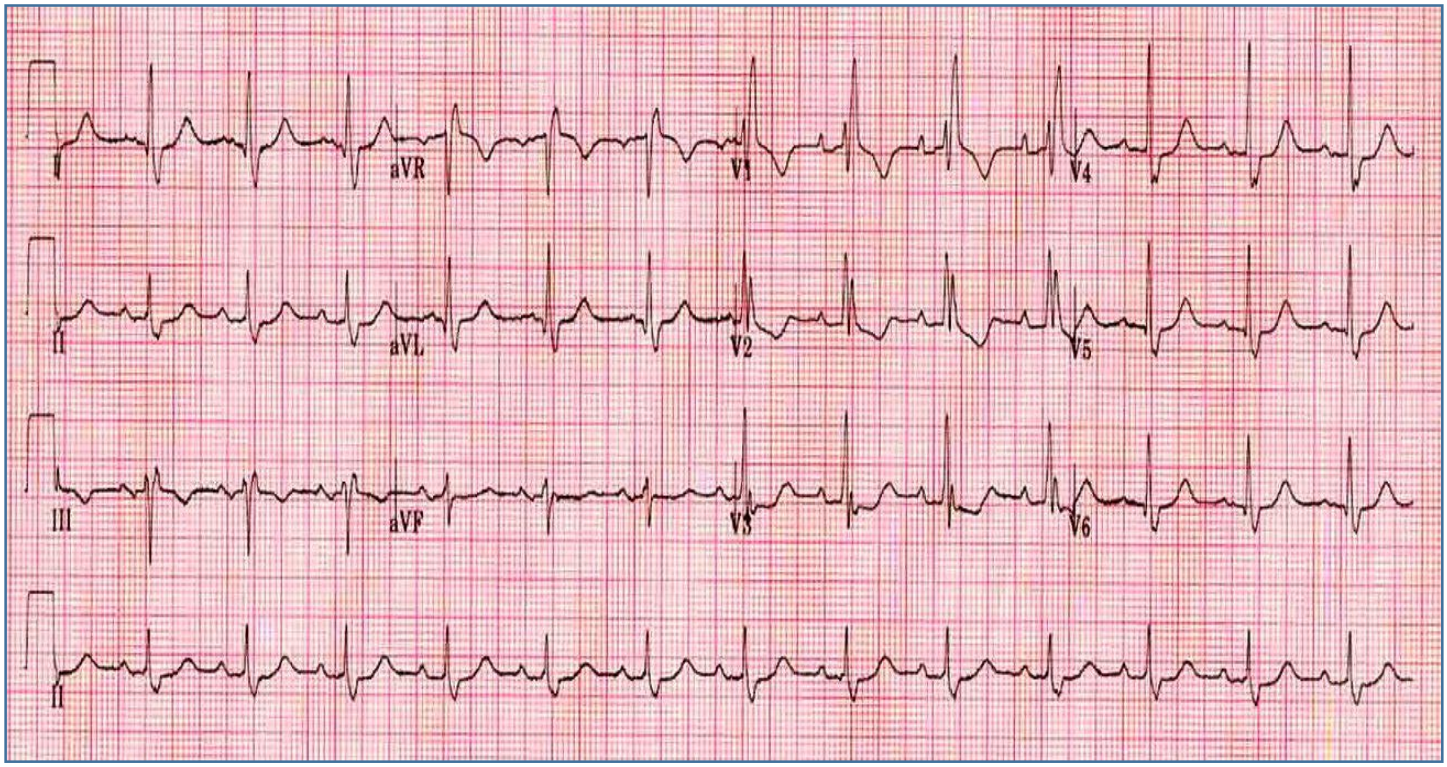
Bigeminy and trigeminy
PVCs that occur every other beat (bigeminy) or every third beat (trigeminy) may indicate increased ventricular irritability (see highlighted areas).



(1) Chris Burghardt. et al.ECG interpretation made incredibly easy.5th edition. Lippincott Williams & Wilkins.2011

22

4-year-old with metabolic disorder associated cardiomyopathy

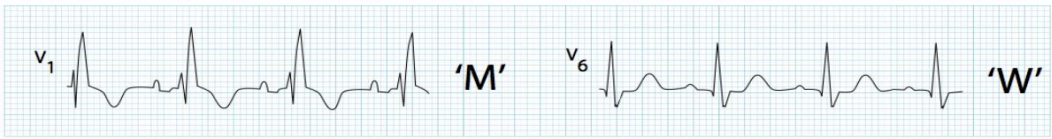


(8)

Interpretation:

- Right bundle branch block
- rsR pattern in lead V1 with wide QRS and T wave inversion
- Deep slurred S wave in lead V5 &V6

- **Diagnostic criteria of RBBB:** (8)
    - Broad QRS of more than 120ms (see difference duration according to age)
    - RSR' pattern in lead V1-V3(M-shaped QRS complex)
    - Wide slurred S wave in the lateral leads (I, aVL, V5-V6)

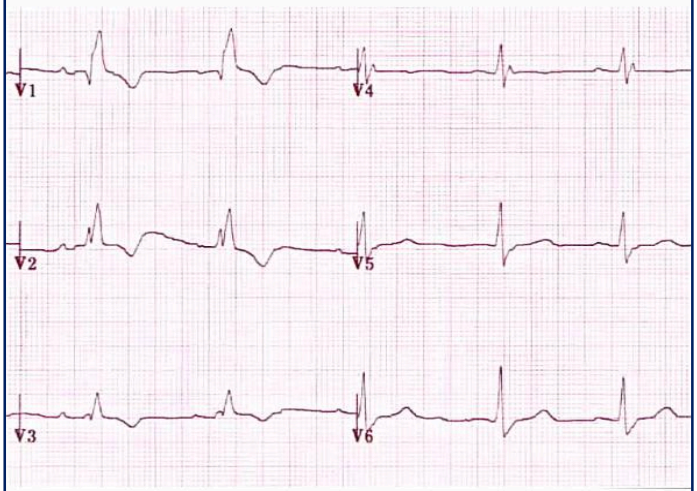


Tall R' wave in V1 ("M" pattern) with wide, slurred S wave in V6 ("W" pattern)

(8)

Typical RSR' pattern ('M'-shaped QRS) in V1

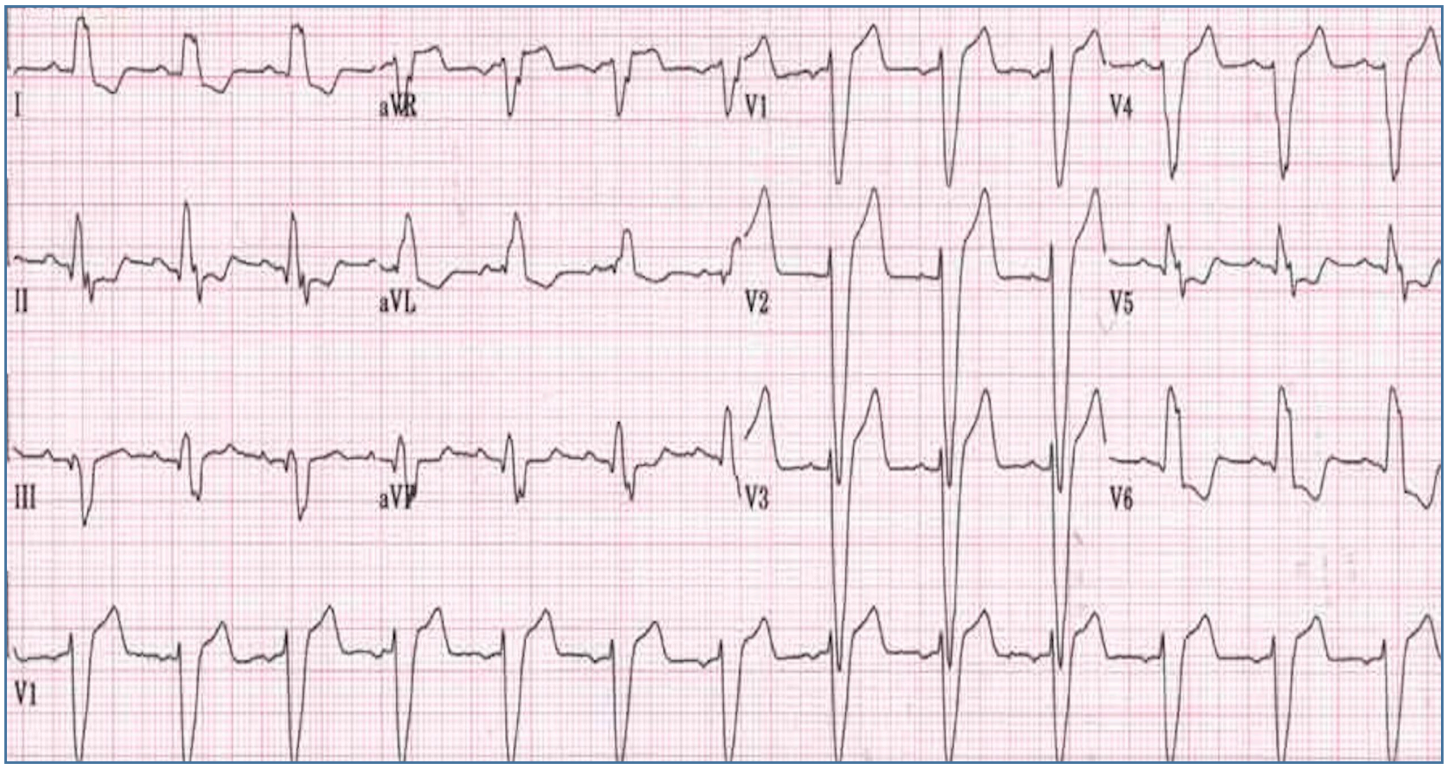
Wide slurred S wave in lead I



Typical pattern of T-wave inversion in V1-3 with RBBB

(8)

23 15-year-old child post aortic valve replacement

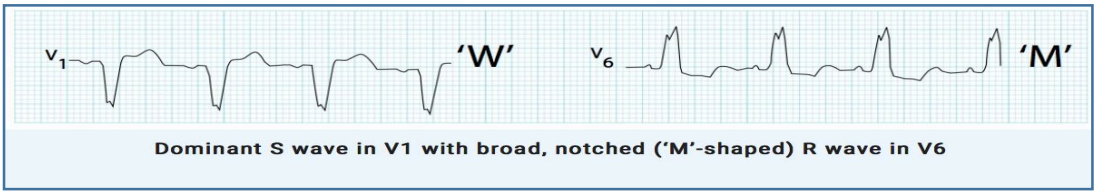


(20)

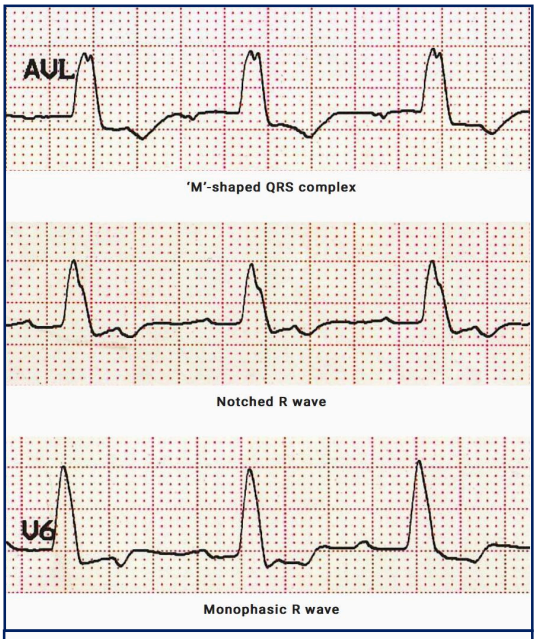
Interpretation:

- Left bundle branch block (LBBB)
  - Deep **wide** S wave in lead V1, V2, V3, V4
  - Notched tall R wave in lateral leads (I, aVL, V5, V6)
  - T wave is inverted in lateral leads

- **Diagnostic criteria of LBBB:** (8)
  - QRS duration of > 120 ms (see different range according to age)
  - Dominant S wave in V1
  - Broad notched or slurred R wave in lateral leads (I, aVL, V5-V6) and occasional RS pattern in V5-V6
  - Absent Q wave in lateral leads, small Q wave may be seen in lead aVL
  - ST segments and T waves always go in the opposite direction to the main vector of the QRS complex



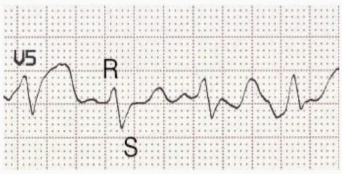
Dominant S wave in V1 with broad, notched ('M'-shaped) R wave in V6



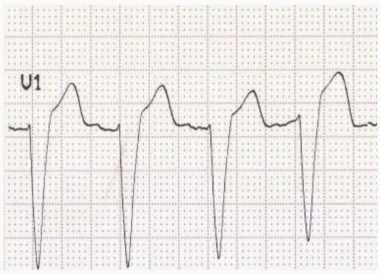
'M'-shaped QRS complex

Notched R wave

Monophasic R wave



RS complex

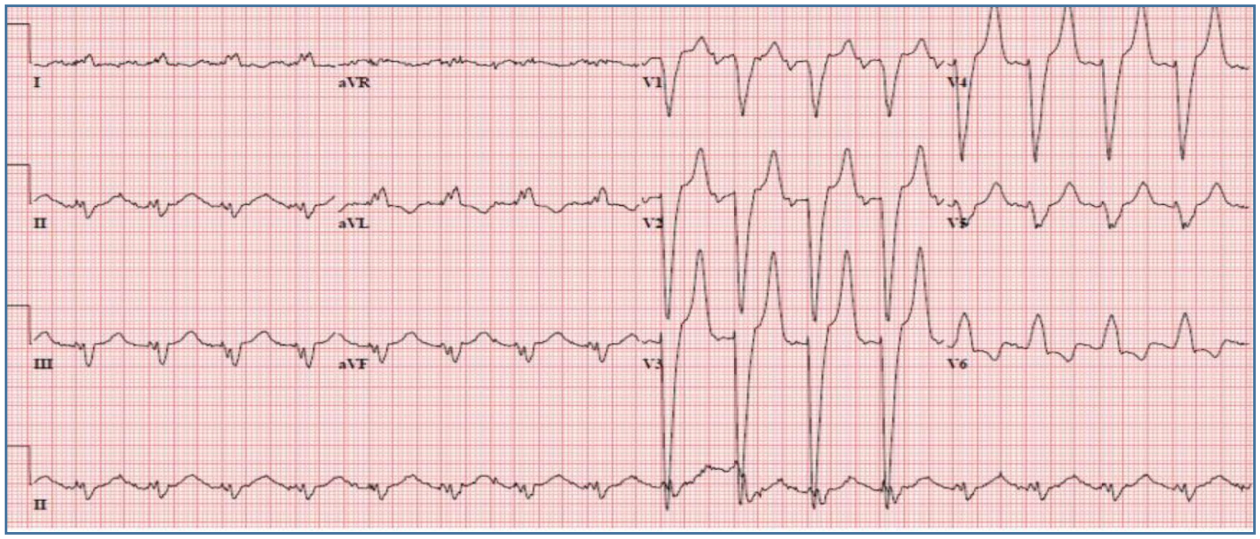


Typical appearance of LBBB in V1 with rS complex (tiny R wave, deep S wave) and appropriate discordance (ST elevation and upright T wave)

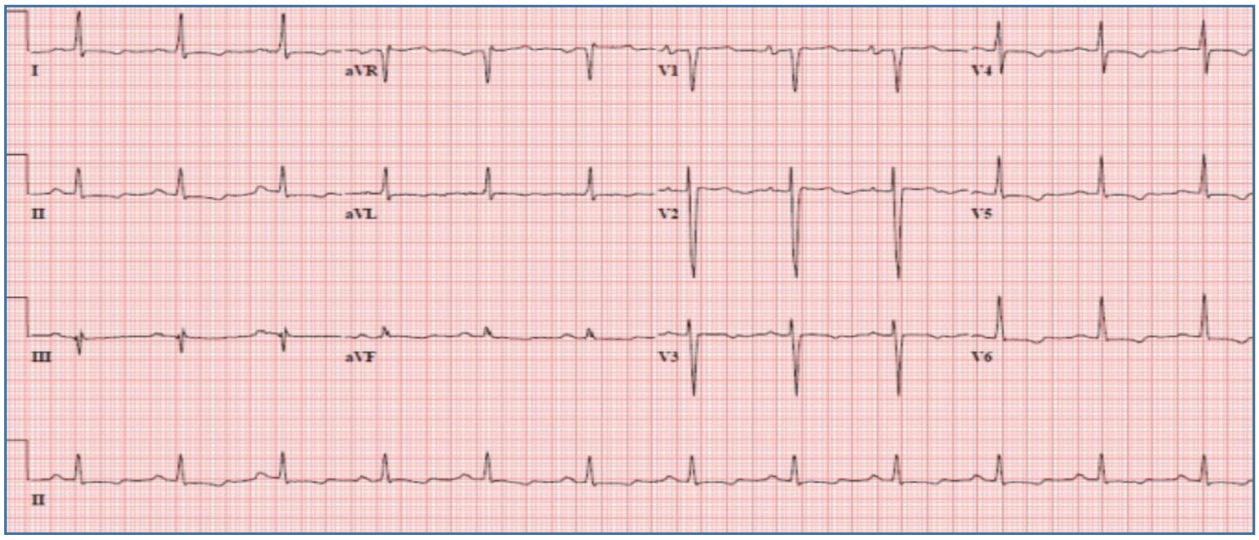
(8)

24

14-year old with end stage renal disease on dialysis. He was admitted with septic shock and acute on chronic renal failure. He had severe electrolyte abnormalities. These are 2 ECGs before and after dialysis.



(5)



Interpretation:
- First ECG showed: Peaked tented T wave, wide QRS with LBBB
- These changes were caused by hyperkalemia
- In second ECG, above changes has resolved after correction of serum potassium
- Hyperkalemia can cause various ECG abnormalities. See next page

Serum potassium > 5.5 mEq/L is associated with **repolarization abnormalities**:

- Peaked T waves (usually the earliest sign of hyperkalaemia)

Serum potassium > 6.5 mEq/L is associated with **progressive paralysis of the atria**:

- P wave widens and flattens
- PR segment lengthens
- P waves eventually disappear

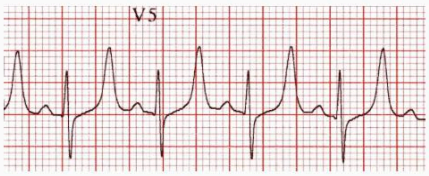
Serum potassium > 7.0 mEq/L is associated with **conduction abnormalities** and **bradycardia**:

- Prolonged QRS interval with bizarre QRS morphology
- High-grade AV block with slow junctional and ventricular escape rhythms
- Any kind of conduction block (bundle branch blocks, fascicular blocks)
- Sinus bradycardia or slow AF
- Development of a sine wave appearance (a pre-terminal rhythm)

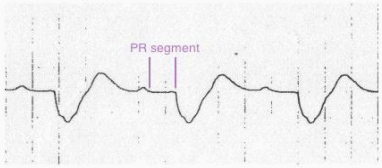
Serum potassium level of > 9.0 mEq/L causes **cardiac arrest** due to:

- Asystole
- Ventricular fibrillation
- PEA with bizarre, wide complex rhythm

(*Warning! In individual patients, the serum potassium level may not correlate closely with the ECG changes. Patients with relatively normal ECGs may still experience sudden hyperkalaemic cardiac arrest.*)



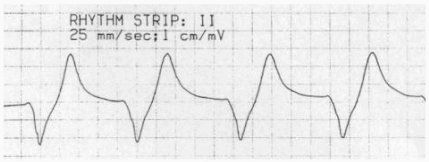
Peaked T waves



Prolonged PR segment

Loss of P waves

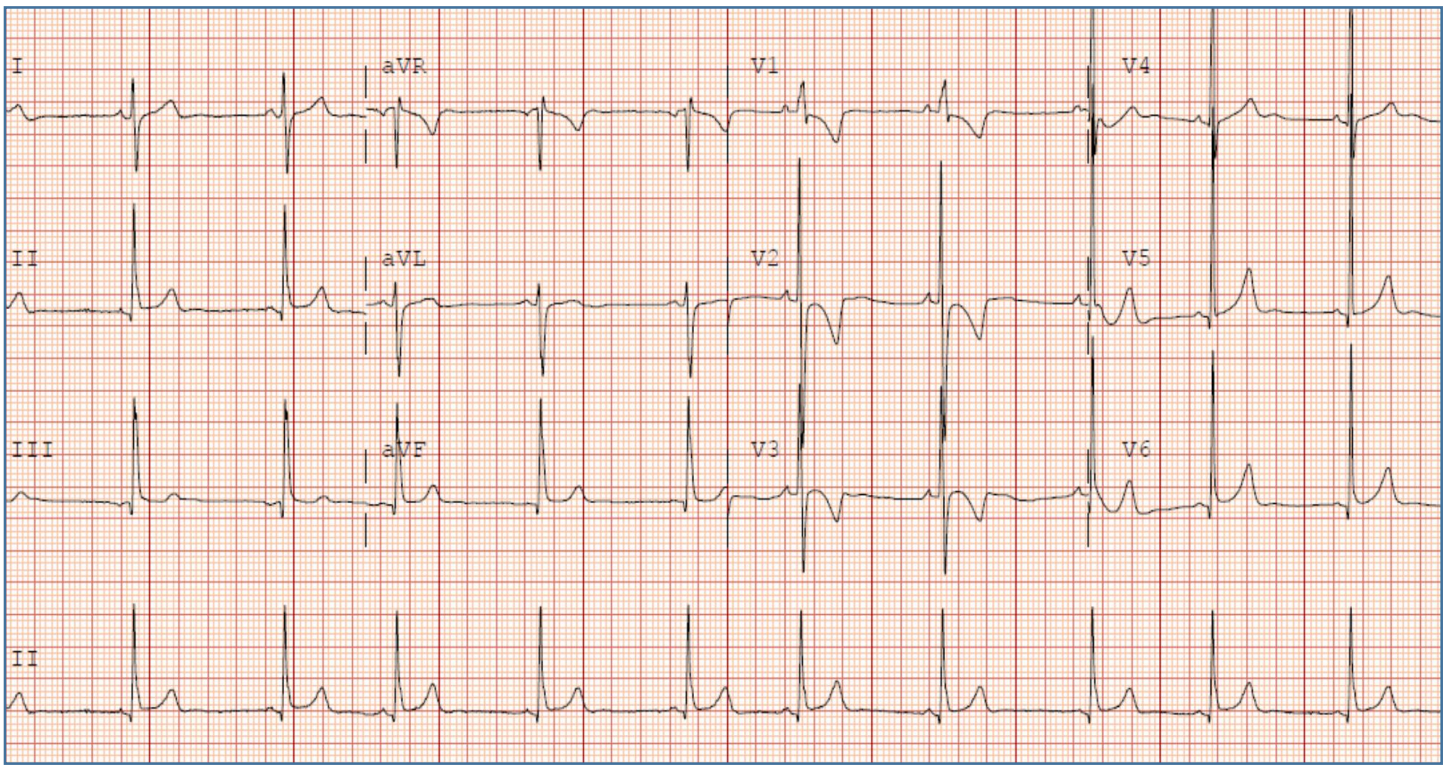
Bradycardia



Sine wave

25

10-year-old child with storage disease. ECG was done for evaluation of cardiac involvement.

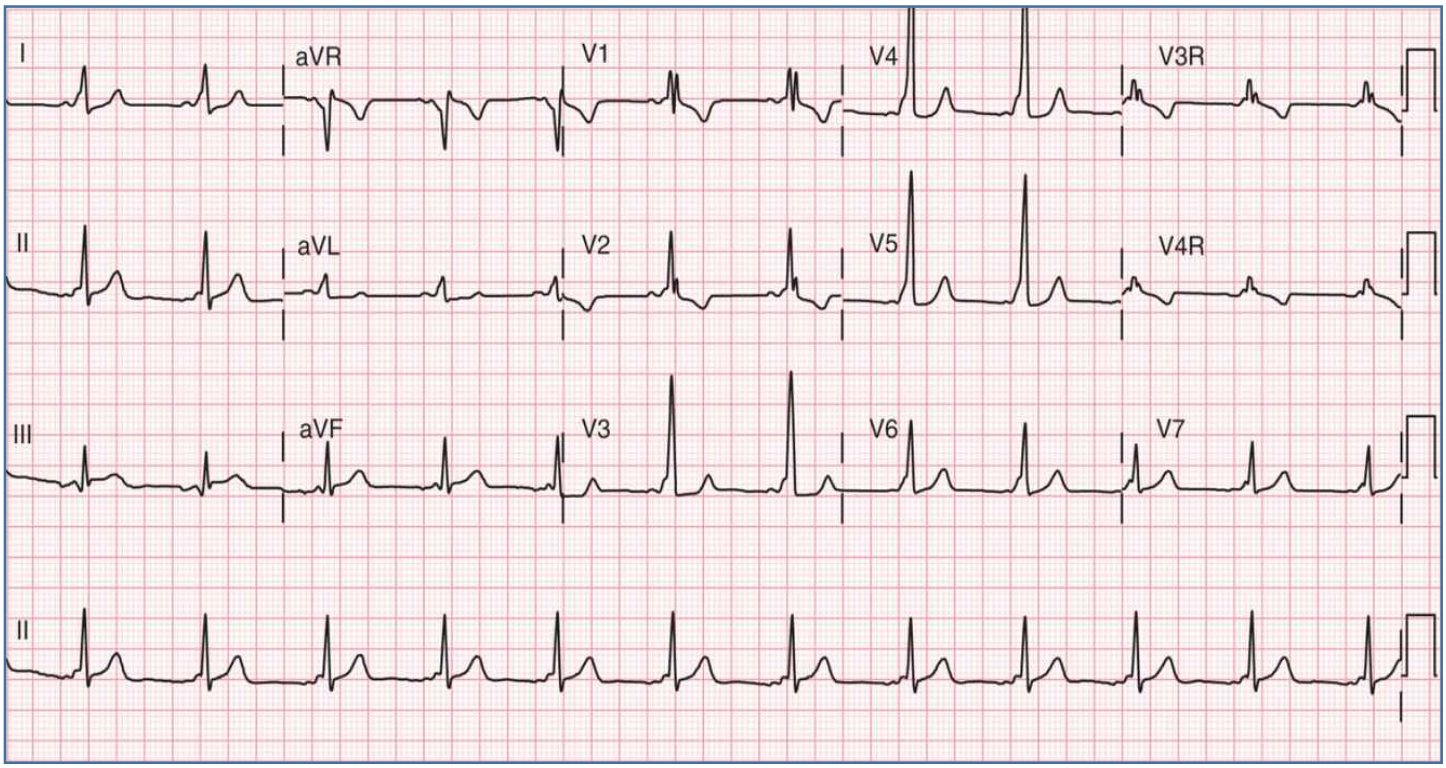


(7)

Interpretation:

- Biventricular hypertrophy
  - Right and Left ventricle hypertrophy voltage criteria (refer to normal values tables)
  - Secondary ST-T changes

26 12-year-old brought from school with syncopal attack



(21)

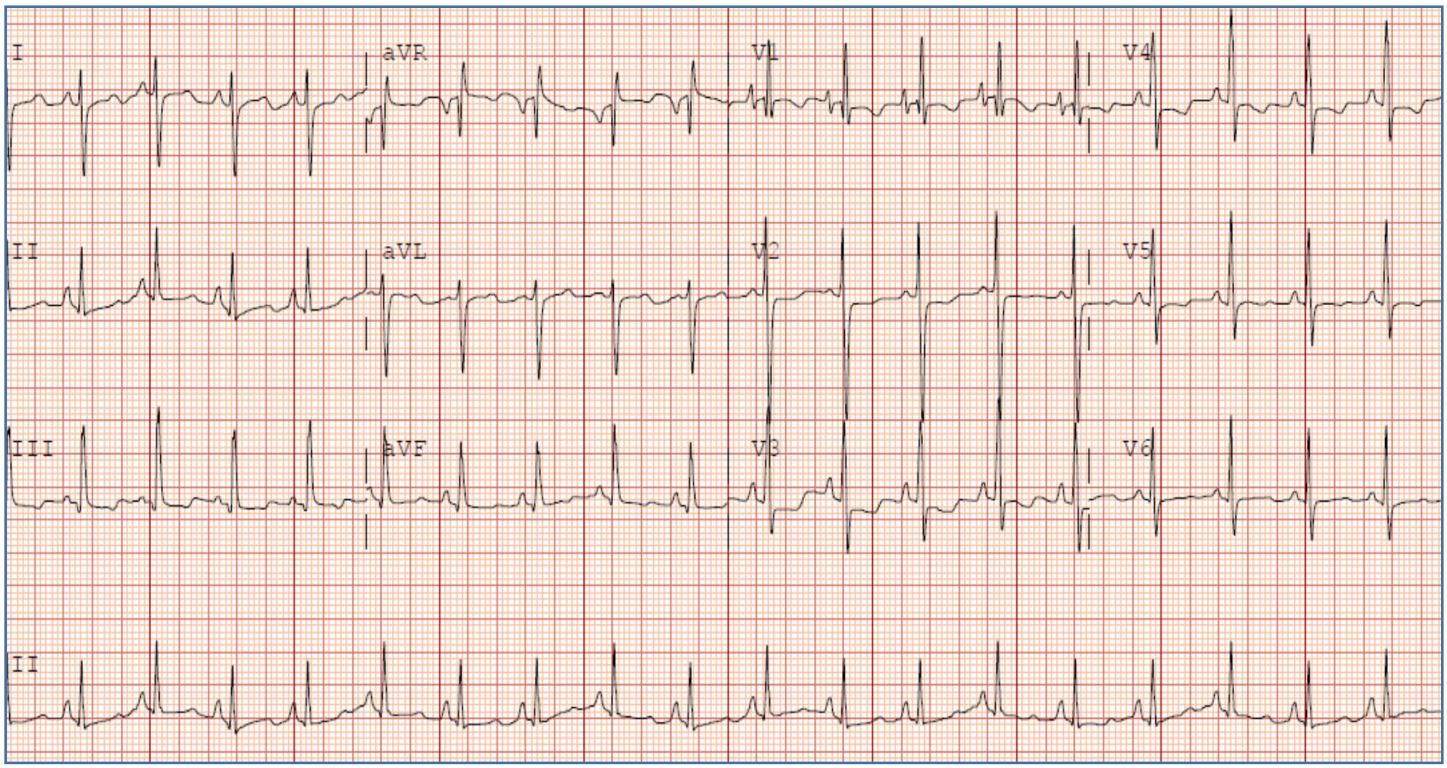
Interpretation:

- Wolff-Parkinson-White Syndrome
  - Delta wave (slurred upstroke of QRS complex)
  - Short PR interval

- In WPW there is accessory pathway causing pre excitation

27

9-year-old presented with substernal chest pain and short of breath. He has past medical history of Chronic Interstitial Lung Disease and secondary pulmonary HTN

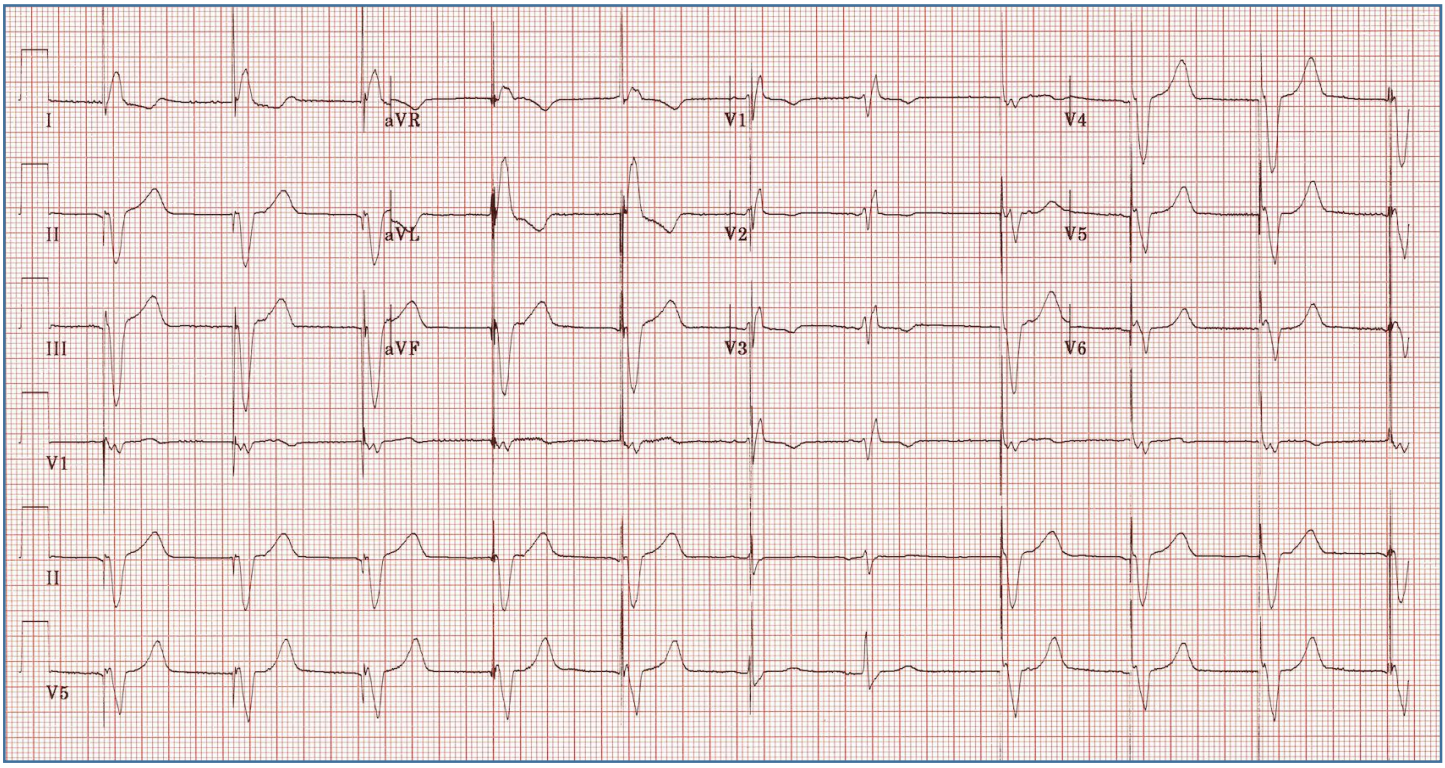


(7)

Interpretation:

- Pulmonary Hypertension ECG changes
  - Right atrial enlargement (Tall P waves)
  - Right ventricular hypertrophy (R > 7mm in lead V1-V2)
  - Right axis deviation
  - ST segment depression in precordial leads (ventricular repolarization abnormalities

28 14-year-old with complete heart block



(8)

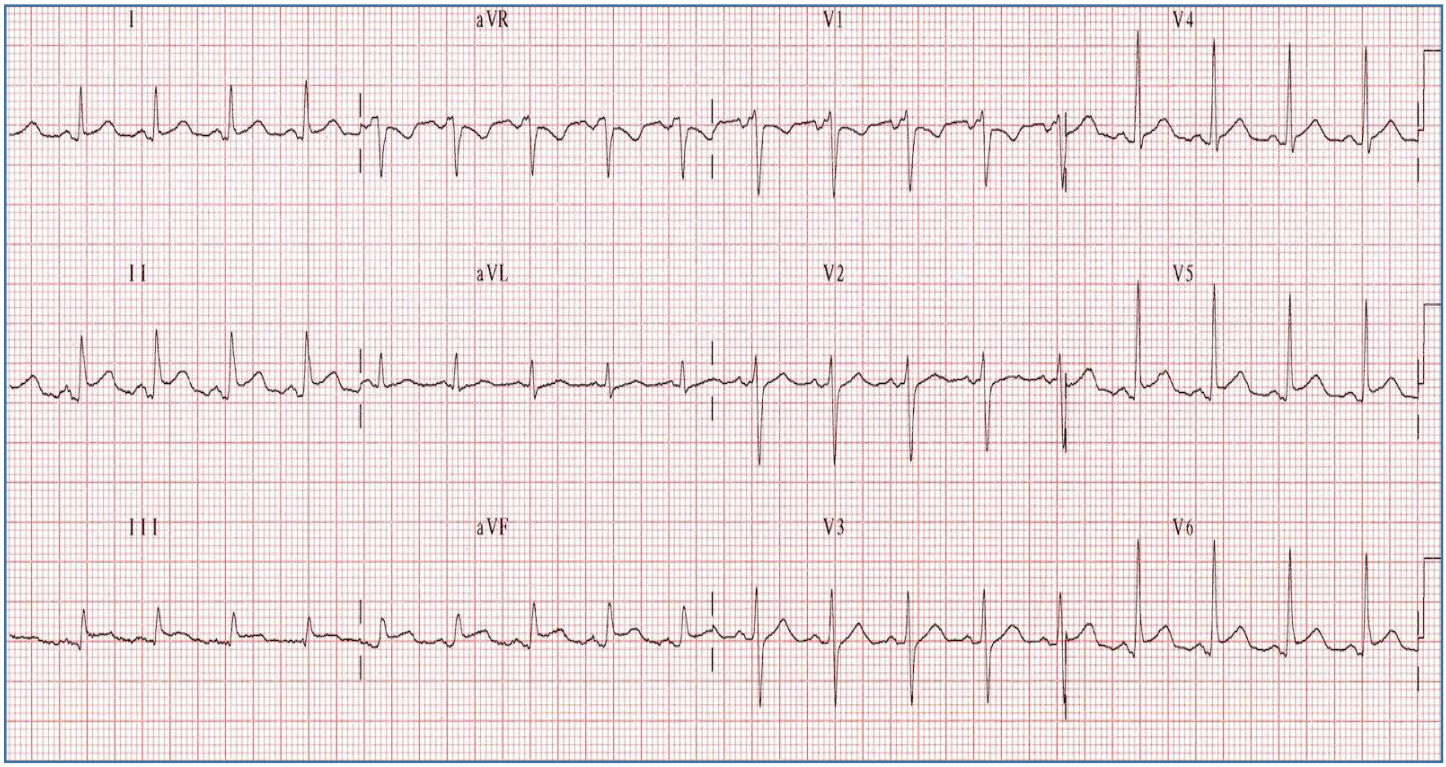
Interpretation:

- Ventricular pacing
  - Pacing spike before each QRS complex
  - QRS is wide

- Read more about different type of pacing and pacemaker

29

6-year-old with mycoplasma pneumonia complaining of chest pain that is relieved with leaning forward but worsens with deep breath



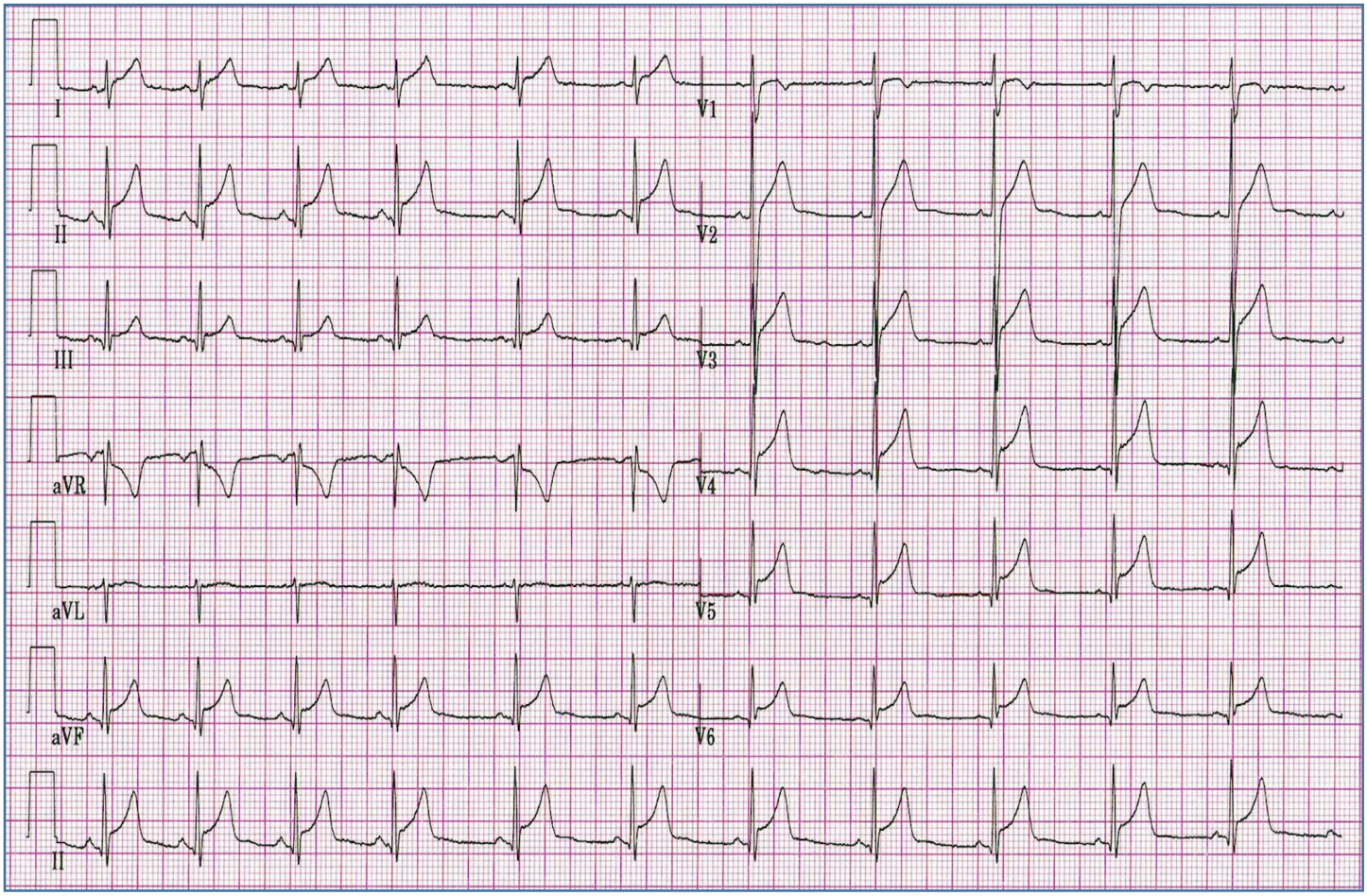
(8)

Interpretation:

- Pericarditis
  - PR depression and ST elevation in lead I, II, III, aVF, V5, V6
  - Reciprocal changes (PR elevation and ST depression in lead V1 and aVR)

30

10-year-old previously healthy admitted with fever, viral illness and cardiogenic shock. Troponin is very high.



(22)

Interpretation:

- Myocarditis
  - Widespread ST elevation

- Myocarditis can cause sinus tachycardia, ST changes, Prolong QT, AV conduction problem etc.
- Correlate ECG findings with clinical picture as ECG changes in myocarditis are non-specific.

Normal values tables

Lead-independent ECG measurements for boys (upper row) and girls (lower row): median (2nd percentile, 98th percentile)

Lead	0–1 months	1–3 months	3–6 months	6–12 months	1–3 years	3–5 years	5–8 years	8–12 years	12–16 years
Heart rate (beats . min^{-1})	160 (129, 192)	152 (126, 187)	134 (**112**, **165**)	128 (106, 194)	**119** (97, **155**)	98 (73, 123)	88 (62, 113)	78 (55, **101**)	73 (**48**, **99**)
	155 (136, 216)	154 (126, 200)	139 (**122**, **191**)	134 (106, 187)	**128** (95, **178**)	101 (78, 124)	89 (68, 115)	80 (58, **110**)	76 (**54**, **107**)
P axis (°)	56 (13, 99)	52 (10, 73)	49 (− 5, 70)	49 (9, 87)	48 (− 12, 78)	43 (− 13, 69)	41 (− 54, 72)	39 (− 17, 76)	40 (− 24, 76)
	52 (24, 80)	48 (20, 77)	51 (16, 80)	50 (14, 69)	47 (1, 90)	44 (− 6, 90)	42 (− 13, 77)	42 (− 15, 82)	45 (− 18, 77)
P duration (ms)	78 (64, 85)	79 (65, 98)	81 (64, 103)	80 (66, 96)	80 (63, 113)	87 (67, 102)	92 (73, 108)	98 (78, 117)	100 (82, 118)
	79 (69, 106)	78 (62, 105)	78 (63, 106)	80 (64, 07)	83 (62, 104)	84 (66, 101)	89 (71, 107)	94 (75, 114)	98 (78, 122)
PR interval (ms)	99 (77, 120)	98 (85, 120)	106 (87, 134)	114 (82, 141)	118 (86, 151)	121 (98, 152)	129 (99, 160)	134 (105, 174)	139 (107, 178)
	101 (91, 121)	99 (78, 133)	106 (84, 127)	109 (88, 133)	113 (78, 147)	123 (99, 153)	124 (92, 156)	129 (103, 163)	135 (106, 176)
QRS axis (°)	97 (75, 140)	87 (37, 138)	66 (− 6, 107)	68 (14, 122)	64 (− 4, 118)	70 (7, 112)	70 (− 10, 112)	70 (− 21, 114)	65 (− 9, 112)
	110 (63, 155)	80 (39, 121)	70 (17, 108)	67 (1, 102)	69 (2, 121)	69 (3, 106)	74 (27, 117)	66 (5, 117)	66 (5, 101)
QRS duration (ms)	67 (50, 85)	64 (52, 77)	66 (54, **85**)	**69** (52, **86**)	**71** (54, 88)	**75** (58, 92)	**80** (63, 98)	**85** (67, 103)	**91** (**78**, 111)
	67 (54, 79)	63 (48, 77)	64 (50, **78**)	**64** (52, **80**)	**68** (54, 85)	**71** (58, 88)	**77** (59, 95)	**82** (66, 99)	**87** (**72**, 106)
QTc interval (ms)*	413 (378, 448)	419 (**396**, 458)	422 (391, 453)	411 (379, 449)	412 (383, 455)	412 (377, 448)	411 (371, 443)	411 (373, 440)	407 (362, 449)
	420 (379, 462)	424 (**381**, 454)	418 (386, 448)	414 (381, 446)	417 (381, 447)	415 (388, 442)	409 (375, 449)	410 (365, 447)	414 (370, 457)

Bold values indicate that the 95% confidence intervals of the percentile estimates for boys and girls do not overlap.

*Corrected QT interval, according to Bazett's formula: $QTc = QT \cdot \sqrt{\frac{\text{heart rate}}{60}}$.

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R-wave amplitudes (mV) for boys (upper row) and girls (lower row): median (98th percentile)

Lead	0–1 months	1–3 months	3–6 months	6–12 months	1–3 years	3–5 years	5–8 years	8–12 years	12–16 years
I	0·25 (**0·45**)	0·56 (1·12)	0·80 (**1·52**)	0·82 (1·52)	0·77 (1·37)	0·63 (1·09)	**0·62** (**1·16**)	0·59 (1·04)	**0·58** (1·09)
	0·31 (**0·62**)	0·55 (1·09)	0·74 (**1·26**)	0·75 (1·38)	0·68 (1·52)	0·65 (1·20)	**0·49** (**1·00**)	0·54 (1·21)	**0·48** (1·02)
II	0·64 (1·28)	1·08 (1·76)	1·27 (**1·97**)	1·27 (2·09)	1·27 (2·47)	1·36 (2·20)	1·24 (2·42)	1·39 (2·23)	1·31 (2·08)
	0·70 (1·21)	1·15 (2·04)	1·33 (**2·24**)	1·35 (2·21)	1·27 (2·34)	1·38 (2·24)	1·33 (2·27)	1·32 (2·29)	1·32 (2·03)
III	0·79 (1·44)	0·76 (1·60)	0·72 (**1·50**)	0·82 (**1·65**)	0·80 (1·96)	0·94 (1·82)	0·80 (1·92)	0·89 (1·86)	0·85 (1·74)
	0·85 (1·50)	0·91 (1·82)	0·95 (**1·85**)	0·90 (**1·95**)	0·96 (2·00)	0·94 (1·96)	1·03 (2·09)	0·92 (1·88)	0·88 (1·66)
aVR	0·32 (0·52)	**0·36** (**0·63**)	**0·32** (0·58)	**0·30** (**0·62**)	0·21 (0·53)	0·21 (**0·48**)	**0·23** (**0·51**)	**0·24** (**0·49**)	**0·23** (**0·46**)
	0·30 (0·61)	**0·27** (**0·49**)	**0·23** (0·51)	**0·21** (**0·48**)	0·25 (0·48)	0·17 (**0·39**)	**0·18** (**0·40**)	**0·18** (**0·41**)	**0·18** (**0·37**)
aVL	0·16 (0·32)	**0·35** (0·66)	0·40 (1·09)	0·44 (1·04)	0·38 (0·86)	0·26 (0·58)	0·22 (0·70)	0·17 (0·52)	0·19 (0·69)
	0·18 (0·45)	**0·25** (0·69)	0·37 (0·78)	0·40 (0·92)	0·38 (1·02)	0·24 (0·70)	0·18 (0·55)	0·17 (0·69)	0·16 (0·53)
aVF	0·59 (1·36)	0·88 (1·58)	0·93 (1·70)	0·96 (1·81)	1·00 (2·20)	1·13 (1·97)	**1·00** (2·19)	1·16 (2·00)	1·06 (1·88)
	0·72 (1·26)	0·98 (1·91)	1·07 (1·82)	1·11 (2·04)	1·10 (2·08)	1·14 (2·06)	**1·20** (2·17)	1·09 (2·06)	1·10 (1·84)
V_{3R}	0·62 (1·04)	0·58 (**1·24**)	0·57 (1·20)	0·48 (1·24)	0·49 (1·06)	0·41 (**0·81**)	0·23 (0·63)	0·22 (0·51)	0·19 (0·54)
	0·68 (1·26)	0·55 (**0·93**)	0·49 (1·11)	0·42 (0·98)	0·43 (0·92)	0·34 (**0·64**)	0·21 (0·57)	0·19 (0·47)	0·17 (0·49)
V_1	1·10 (2·05)	1·23 (2·07)	1·32 (2·20)	1·12 (2·14)	1·08 (2·11)	0·95 (**1·78**)	0·63 (1·48)	0·54 (1·14)	**0·48** (1·18)
	1·35 (2·22)	1·17 (1·99)	1·14 (2·04)	1·01 (1·92)	1·01 (1·91)	0·77 (**1·38**)	0·55 (1·24)	0·49 (1·14)	**0·35** (1·10)
V_2	1·83 (**2·67**)	1·82 (2·63)	**2·08** (2·54)	1·94 (**2·51**)	1·82 (2·41)	1·58 (2·26)	1·21 (**2·22**)	**1·02** (1·90)	**0·94** (**1·87**)
	1·83 (**2·17**)	1·81 (2·45)	**1·88** (2·60)	1·82 (**2·36**)	1·75 (2·38)	1·41 (2·25)	1·06 (**1·91**)	**0·90** (1·86)	**0·69** (**1·57**)
V_4	1·80 (**2·62**)	2·30 (3·05)	2·32 (3·23)	2·27 (3·32)	2·37 (3·38)	2·42 (3·30)	2·11 (3·11)	1·86 (3·16)	**1·87** (**3·06**)
	1·68 (**2·21**)	2·26 (3·26)	2·26 (3·31)	2·23 (3·09)	2·21 (3·54)	2·24 (3·38)	1·84 (3·04)	1·72 (3·23)	**1·24** (**2·55**)
V_6	1·00 (1·78)	1·55 (**2·23**)	1·65 (2·73)	1·70 (2·79)	1·79 (2·96)	1·94 (3·14)	1·97 (2·98)	**2·18** (3·24)	**2·02** (**3·05**)
	0·93 (1·64)	1·51 (**2·67**)	1·60 (2·80)	1·68 (2·74)	1·68 (2·67)	1·89 (2·91)	2·05 (3·25)	**2·00** (3·04)	**1·65** (**2·52**)
V_7	0·45 (0·93)	0·90 (**1·41**)	1·01 (1·76)	1·04 (1·84)	1·14 (1·99)	1·34 (2·12)	1·26 (2·01)	1·38 (2·24)	1·41 (**2·31**)
	0·52 (0·96)	0·95 (**1·68**)	0·96 (1·80)	1·13 (1·85)	1·15 (1·86)	1·35 (2·12)	1·36 (2·31)	1·35 (2·10)	1·34 (**1·98**)

Bold values indicate that the 95% confidence intervals of the percentile estimates for boys and girls do not overlap.

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Table 6 S-wave amplitudes (mV) for boys (upper row) and girls (lower row): median (98th percentile)

Lead	0–1 months	1–3 months	3–6 months	6–12 months	1–3 years	3–5 years	5–8 years	8–12 years	12–16 years
I	0·42 (0·71)	**0·46 (0·94)**	**0·41** (0·77)	**0·40 (0·81)**	0·27 (0·82)	0·21 (0·69)	0·22 (0·56)	**0·22** (0·50)	**0·19** (0·48)
	0·51 (1·01)	**0·35 (0·71)**	**0·32** (0·73)	**0·33 (0·73)**	0·35 (0·70)	0·20 (0·52)	0·22 (0·54)	**0·16** (0·47)	**0·13** (0·40)
II	0·24 (0·46)	0·29 (0·55)	0·29 (**0·61**)	**0·30** (0·62)	0·25 (0·55)	**0·28 (0·58)**	**0·27 (0·64)**	**0·30 (0·63)**	0·27 (**0·63**)
	0·26 (0·53)	0·22 (0·53)	0·24 (**0·46**)	**0·23** (0·54)	0·26 (0·56)	**0·20 (0·46)**	**0·19 (0·46)**	**0·20 (0·52)**	0·22 (**0·54**)
III	0·16 (**0·28**)	0·27 (0·54)	0·30 (**0·87**)	0·34 (0·86)	0·30 (0·72)	0·22 (0·51)	0·21 (**0·65**)	0·19 (0·56)	0·20 (0·57)
	0·19 (**0·34**)	0·24 (0·50)	0·28 (**0·63**)	0·33 (0·77)	0·32 (0·86)	0·19 (0·54)	0·18 (**0·41**)	0·16 (0·48)	0·17 (0·61)
aVR	0·41 (0·68)	0·76 (1·30)	0·98 (1·47)	0·98 (1·47)	0·95 (1·63)	0·93 (1·40)	0·90 (1·51)	0·96 (1·45)	0·91 (1·39)
	0·44 (0·64)	0·81 (1·31)	0·96 (1·49)	0·97 (1·48)	0·92 (1·61)	0·95 (1·49)	0·90 (1·40)	0·91 (1·51)	0·89 (1·35)
aVL	0·47 (**0·77**)	0·51 (1·02)	0·44 (**0·83**)	0·47 (0·98)	0·40 (1·00)	0·34 (0·87)	0·33 (**0·84**)	0·28 (0·88)	0·28 (0·94)
	0·63 (**1·17**)	0·53 (1·04)	0·46 (**0·98**)	0·52 (1·03)	0·44 (1·06)	0·33 (1·12)	0·43 (**1·02**)	0·30 (0·88)	0·28 (0·84)
aVF	0·18 (**0·27**)	0·22 (0·39)	0·23 (0·57)	0·23 (0·59)	0·23 (0·53)	**0·22** (0·52)	0·21 (**0·57**)	0·21 (**0·56**)	0·22 (0·54)
	0·18 (**0·38**)	0·20 (0·35)	0·20 (0·44)	0·24 (0·51)	0·24 (0·60)	**0·16** (0·40)	0·16 (**0·37**)	0·17 (**0·45**)	0·18 (0·55)
V_{3R}	0·12 (0·22)	**0·24** (0·86)	0·31 (0·90)	0·34 (1·04)	0·45 (1·21)	0·53 (0·99)	0·53 (1·06)	0·60 (1·17)	0·57 (1·14)
	0·25 (0·62)	**0·35** (0·76)	0·31 (0·98)	0·34 (0·95)	0·42 (1·08)	0·50 (1·16)	0·52 (1·07)	0·55 (1·20)	0·50 (1·04)
V_1	0·74 (1·41)	0·63 (1·57)	0·69 (2·02)	0·69 (1·88)	0·95 (2·27)	1·09 (2·11)	1·15 (2·29)	1·30 (2·46)	1·30 (**2·44**)
	0·72 (1·48)	0·82 (1·59)	0·74 (1·64)	0·76 (1·86)	0·86 (2·13)	1·03 (2·11)	1·23 (2·49)	1·32 (2·58)	1·15 (**2·05**)
V_2	1·53 (2·40)	1·26 (2·54)	1·49 (2·48)	1·50 (2·78)	1·77 (2·95)	2·01 (3·08)	2·17 (3·25)	2·28 (3·44)	**2·39 (3·58)**
	1·47 (2·47)	1·55 (2·61)	1·47 (2·48)	1·56 (2·52)	1·70 (2·91)	1·96 (2·93)	2·17 (3·49)	2·29 (3·46)	**1·87 (3·14)**
V_4	1·17 (1·71)	1·11 (2·25)	1·22 (2·42)	**1·25** (2·35)	**1·16** (2·16)	**1·25 (2·51)**	**1·28 (2·68)**	**1·31** (2·44)	**1·16 (2·23)**
	1·04 (1·87)	1·18 (1·87)	1·19 (2·18)	**0·98** (2·04)	**0·91** (2·00)	**0·97 (1·75)**	**1·05 (2·33)**	**1·00** (2·28)	**0·73 (1·60)**
V_6	0·49 (0·77)	0·51 (**1·12**)	0·46 (1·25)	**0·46 (1·21)**	0·37 (0·91)	0·34 (**0·86**)	**0·34** (0·89)	**0·34** (0·79)	**0·37 (0·85)**
	0·44 (1·07)	0·39 (**0·77**)	0·41 (0·97)	**0·31 (0·70)**	0·33 (0·88)	0·30 (**0·61**)	**0·29** (0·77)	**0·27** (0·75)	**0·30 (0·67)**
V_7	0·18 (0·31)	**0·24** (0·46)	0·22 (0·50)	**0·26 (0·58)**	0·22 (0·53)	0·21 (0·41)	0·17 (0·39)	**0·16** (0·39)	**0·20 (0·38)**
	0·16 (0·37)	**0·18** (0·39)	0·19 (0·43)	**0·20 (0·37)**	0·21 (0·48)	0·17 (0·36)	0·13 (0·40)	**0·12** (0·33)	**0·16 (0·34)**

Bold values indicate that the 95% confidence intervals of the percentile estimates for boys and girls do not overlap

Story of the AV Block Family

Key	Wife = P Wave Husband = QRS Complex
Normal Sinus Rhythm	The wife (P wave) waits at home for the husband (QRS). The husband (QRS) comes home on time every night.
1st Degree AV Block	The wife (P wave) is waiting at home. The Husband (QRS) comes home late every night, but he always comes home, and it is the same time every night.
2nd Degree Block, Type 1 ("Wenckebach")	The wife (P wave) is waiting at home. The husband (QRS) comes home later and later every night until one night he doesn't come home at all. Note: Husband (QRS) must come home at least 2 nights in a row to see this pattern.
2nd Degree Block, Type 2	The wife (P wave) is waiting at home. Sometimes the husband (QRS) comes home, sometimes he doesn't. When he does come home, it's always at the same time.
3rd Degree AV Block	Wife (P wave) is no longer waiting at home. She and her husband (QRS) are now on separate schedules, have no relationship to one another, and are no longer talking. Each spouse has a regular, individual schedule.

❖ References

1) Chris Burghardt. et al. **ECG interpretation made incredibly easy**.5th edition. Lippincott Williams & Wilkins.2011
2) David F Dickinson. **The normal ECG in childhood and adolescence**. Heart 2005; 91:1626–1630. doi: 10.1136/hrt.2004.057307
3) Richard E. Klabunde, Ph.D. **Cardiovascular Physiology Concepts**. http://www.cvphysiology.com
4) Purchased ECG apple apps **(www.ecgcases.co)** (Permission was taken to use app ECGs for this booklet)
5) Kishore Kuma et.al, **Transient Left Bundle Branch Block due to Severe Hyperkalemia**, Cardiol Res. 2017 Apr; 8(2): 77–80.doi: 10.14740/cr538w
6) Rijnbeek PR, Witsenburg M, Schrama E, et al. **New normal limits for the paediatric electrocardiogram**. Eur Heart J 2001; 22:702–11
7) www.ems12lead.com
8) www.lifeinthefastlane.com/ecg-library. (Open access website that invites anybody to use its content anyway to help others to learn)
9) Intro to EKG Interpretation - Chamber Enlargement, YouTube channel: **Strong Medicine, free on-demand videos for medical trainees and professionals.**
10) **Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 7th ed.** ÕûÀí fengqz 2005-10-23
11) www.umem.org/educational_pearls/2229/ (Website of University of Maryland School of Medicine)
12) www.slideshare.net/thrs/arrhythmia-ecg-bradycardia20120909
13) Dolbec KW, Higgins GL, Saucier JR. **Lyme Carditis with Transient Complete Heart Block**. West J Emerg Med. 2010 May;11(2):211-2
14) Dr. Smith's ECG Blog. **Instructive ECGs in Emergency Medicine Clinical Context**.
15) Stephen Zanoni, MD et al**. Complete ventricular asystole in a patient with altered mental status**. West J Emerg Med. 2014 Mar;15(2):149-51. doi: 10.5811/westjem.2013.10.18884.
16) J N Johnson, M J Ackerman, **QTc: how long is too long?** Br J Sports Med 2009; 43:657–662. doi:10.1136/bjsm.2008.054734
17) slideshare.net: **Stepwise interpretation of ECG** - #2 ID352
18) slideshare.net: **Shadechapter09.ppt**
19) Siva K. Mulpuru, MD; Gregory K. Feld, MD; Michael Madani, MD; Navinder S. Sawhney, MD. **A Novel, Minimally-Invasive Surgical Approach for Ablation of Ventricular Tachycardia Originating Near the Proximal Left Anterior Descending Coronary Artery.** doi: 10.1161/CIRCEP.112.975284 2012;5: e95-e97 *Circ Arrhythm Electrophysiol.*
20) emedu.org
21) www.obgynkey.com
22) www.en.ecgpedia.org

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