BASICS OF THE ELECTROCARDIOGRAM

Educational and Methodological Guide

MINISTRY OF SCIENCE, HIGHER EDUCATION AND INNOVATION OF THE KYRGYZ REPUBLIC
OSH STATE UNIVERSITY
INTERNATIONAL MEDICAL FACULTY

BASICS OF THE ELECTROCARDIOGRAM

Educational and Methodological Guide
for Senior Medical Students
of Higher Medical Educational Institutions

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Reviewers:

1. Begimai Akbalaeva – Cardiologist, PhD, Head of Department of Public Health, Osh State University
2. Chyngyz Asanbaev - Interventional Cardiologist, Cardiac Electrophysiologist (Arrhythmologist),
Chief Medical Officer Medical Center “Cardio Asia”

Authors
1. Azhimamatova Rakhima Momunovna – Lecturer, Department of Clinical Disciplines-1, International Medical Faculty, Osh State University
2. Salieva Rana Sherbaevna – Candidate of Medical Sciences, Department of Clinical Disciplines-1, International Medical Faculty, Osh State University
3. Mamatova Sabirakhan Mirzaevna, MD, PhD – Candidate of Medical Sciences, Head of the Department of Clinical Disciplines-1, International Medical Faculty, Osh State University
4. Irisov Askar Paizildaevich, MD – Cardiologist, Cardiologist, Chairman of Southern Branch of the Kyrgyz State Medical Institute for Postgraduate Education and Advanced Training named after S. B. Daniyarov.
5. Madraimova Venera Saparbekovna - Lecturer, Department of Clinical Disciplines-1, International Medical Faculty, Osh State University

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Abbreviations

AV	atrioventricular node
aVF	augmented vector foot
aVL	augmented vector left
aVR	augmented vector right
ECG	electrocardiogram
HPT	arterial hypertension
HR	heart rate
LA	left atrium
LBBB	left bundle branch blocks
LV	left ventricle
LAH	left atrial hypertrophy
LVH	left ventricular hypertrophy
mm	millimeter
mV	millivolt
RA	right atrium
RAH	right atrial hypertrophy
RBBB	right bundle branch blocks
RV	right ventricle
RVH	right ventricular hypertrophy
SA	sinoatrial node
WPW	Wolff–Parkinson–White syndrome

I SECTION

What is Electrocardiogram (ECG)?

The heart's electrical activity produces currents that radiate through the surrounding tissue to the skin. When electrodes are attached to the skin, they sense those electrical currents and transmit them to an ECG monitor or on paper. The currents are then transformed into waveforms that represent the heart's depolarization and repolarization cycle.

How does an ECG device look like?

The 12-lead ECG machine (Fig.1) is the standard technology used in most medical outpatient and hospital settings.

fig.1 Portable ECG machine

Performing an electrocardiogram

Steps of performing an electrocardiogram

Collect necessary equipment and supplies:

electrodes connected to the recording cable of the electrocardiograph.

Prepare the patient

- ✓ Ensure the environment is at a comfortably warm temperature
- ✓ should ask to remove any jewelry or other objects that may interfere with the test.
- ✓ You should ask to remove clothing from the waist up.
- ✓ You should ask to lie flat on a table or bed for the test. It will be important for your patient to lie still and not talk during the ECG.
- ✓ Electrodes will be attached to your patient's chest, arms and legs.
- ✓ The lead wires will be attached to the electrodes.
- ✓ Once the leads are attached, the technician may enter identifying information about patient into the machine's computer.
- ✓ The ECG will be started. It will take only a short time for the tracing to be completed.
- ✓ Once the tracing is completed, the technician will disconnect the leads and remove the skin electrodes

Record the electrocardiographic tracing

- ✓ Make sure that the paper speed is set at 25 mm/sec or 50 mm/sec
- ✓ For each group of leads (3 or 6 depending on the type of electrocardiograph), press the calibration button to make sure it is set at 10 mV (or that this setting is reflected in the calibration signal that appears on the paper);
- ✓ The patient must be completely relaxed. This will prevent muscular tension or movements producing artefact on the ECG recording.
- ✓ Begin recording with the bipolar limb leads (I, II, and III) followed by the augmented limb leads (aVR, aVL, aVF). Next record the standard precordial leads (V1 through V6) (Fig.2) and when necessary, the additional precordial leads.
- ✓ After the recording has been completed, wash the electrodes and turn the electrocardiograph off.
- ✓ Make sure the machine is attached to an AC power source to keep the battery charged.
- ✓ Proper maintenance of the electrocardiograph is indispensable to ensure high quality recordings.

Lead Placement

Precordial Lead Placement

In order to find these correctly, the 'Angle of Louis' Method can be used:

- ✓ To locate the space for **V1**; locate the sternal notch (Angle of Louis) at the second rib and feel down the sternal border until the fourth intercostal space is found. V1 is placed to the right of the sternal border, and **V2** is placed at the left of the sternal border.
- ✓ Next, **V4** should be placed before V3. V4 should be placed in the fifth intercostal space in the midclavicular line (as if drawing a line downwards from the center of the patient's clavicle).
- ✓ **V3** is placed directly between V2 and V4.
- ✓ **V5** is placed directly between V4 and V6.
- ✓ **V6** is placed over the fifth intercostal space at the mid-axillary line (as if drawing a line down from the armpit).
- ✓ V4-V6 should line up horizontally along the fifth intercostal space.

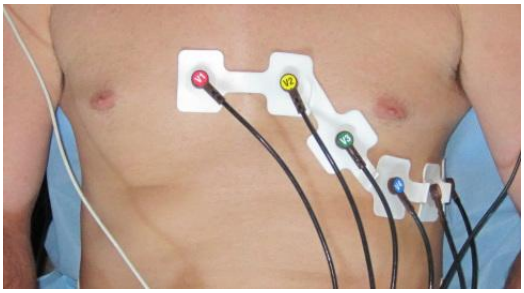

fig.2 Precordial Leads

Leads I, II, III, aVF, aVL and aVR are all derived using three electrodes, which are placed on the right arm, the left arm and the left leg (Fig3). Given the electrode placements, in relation to the heart, these leads primarily detect electrical activity in the frontal plane.

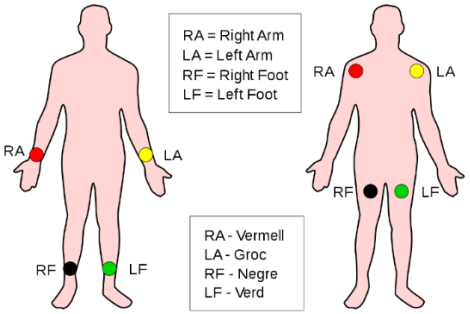

fig.3 Augmented Unipolar leads

Each lead has a specific quantity and direction (vector) produced by adding or subtracting voltages from the recording electrodes.
Bipolar leads

- Lead I is the voltage difference between the LA and RA electrodes (LA – RA)
- Lead II is the voltage difference between the LL and RA electrodes (LL – RA)
- Lead III is the voltage difference between the LL and LA electrodes (LL – LA)

Augmented Unipolar leads (fig.3)

- Lead aVL is directed towards the left arm

- Lead aVF is directed towards the left leg electrode
- Lead aVR is directed towards the right arm electrode

By convention, lead I has the positive electrode on the left arm, and the negative electrode on the right arm, and therefore measures the potential difference between the two arms. In this and the other two limb leads, an electrode on the right leg serves as a reference electrode for recording purposes. In the lead II configuration, the positive electrode is on the left leg and the negative electrode is on the right arm. Lead III has the positive electrode on the left leg and the negative electrode on the left arm. These three bipolar limb leads (Fig.4)roughly form an equilateral triangle (with the heart at the center) that is called Einthoven's triangle in honor of Willem Einthoven who developed the electrocardiogram in the early 1900s.

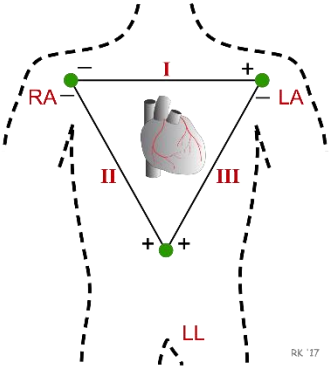

fig.4 bipolar limb leads
https://www.cvphysiology.com/Arrhythmias/A013a

Anatomical relations of leads in a standard 12 lead electrocardiogram (Fig. 5) (Fig. 6)

- ✓ **I** → left ventricle, lateral wall
- ✓ **II, III, and aVF** → right ventricle, inferior wall (inferior ECG leads)
- ✓ **aVL** → left ventricle, high part of the lateral wall
- ✓ **aVR** → reciprocal of the left lateral side leads (II, aVL, V_5 and V_6)
- ✓ **V_1 and V_2** → both ventricles, septum
- ✓ **V_3 and V_4** → anterior wall of the left ventricle and parts of the septum
- ✓ **V_5 and V_6** → lateral wall of the left ventricle and apex of the heart

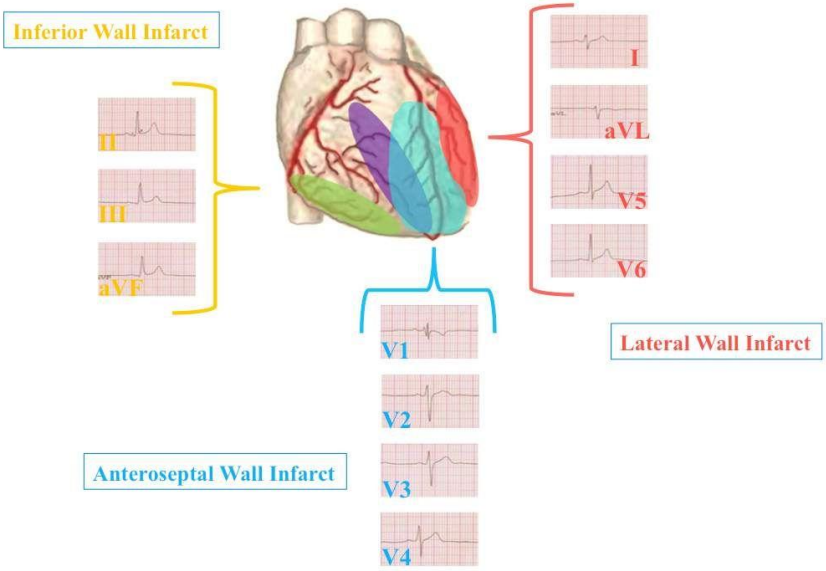

fig. 5 Anatomical relations of leads in a standard 12 lead electrocardiogram
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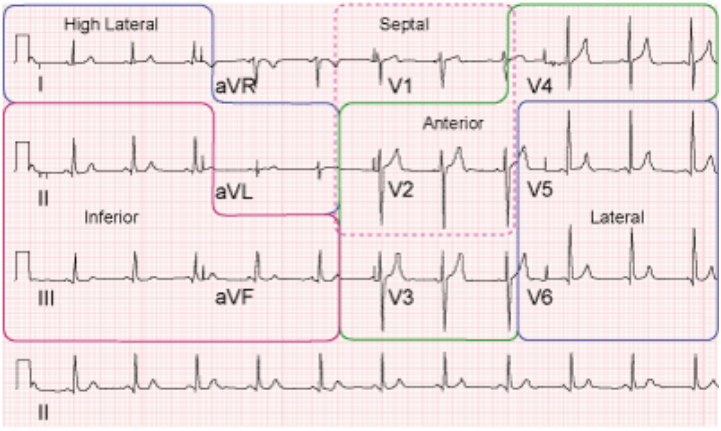


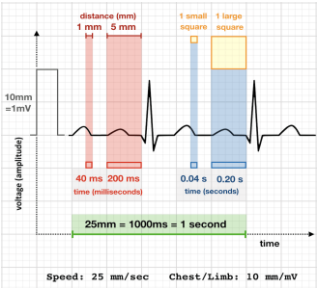
*fig. **6** 12- lead ECG with Anatomical relations of leads in a standard 12 lead electrocardiogram*

INTERPRETATION THE ECG

The activity is measured by looking at the amplitude and frequency of the waveforms.

Amplitude

The voltage recorded from the leads is also standardized on the paper where 1 mm = 1 mV (or between each individual block vertically) This results in: (Fig. 7)



1 mm = 0.1 mV
5 mm = 0.5 mV (or between 2 dark horizontal lines)
m = 1.0 mV

https://learn.canvas.net/courses/883/pages/cardiac-monitoring-ecg-circulation-advanced

Fig.7 Amplitude

Why use 50 mm/second? Doubling the standard rate can reveal subtle ECG findings hidden at the slower rates. When the heart rate is high, waves can overlap at 25 mm/s. (Fig. 7.1)

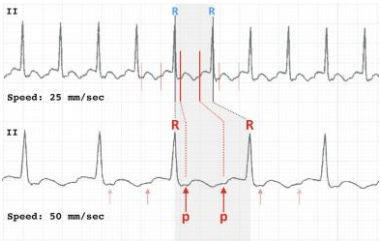


fig.7.1 Key reasons clinicians choose 50 mm/s. Adapted from Life in the Fast Lane (LITFL): ECG Basics – Paper Speed

ECG Heart Rate Interpretation

If a different paper speed is used, calculations will have to be modified appropriately.

A. The standard paper speed is 25mm/sec:

1mm (small square) = 0.04 sec (40ms)
5mm (large square) = 0.2 sec (200ms)
250 small squares = 50 large squares = 10 seconds
1500 small squares = 300 large squares = 1 minute

Б. **Paper speed: 50mm/sec**

1mm (small square) = 0.02 sec (20ms)
5mm (large square) = 0.1 sec (100ms)

There are multiple methods to estimate the heart rate:

Regular rhythms

- ✓ We can calculate the beats per minute (bpm) by dividing 300 by the number of large squares between two R waves (R-R interval = one beat)
- ✓ Very fast rhythms: We can calculate the beats per minute (bpm) by dividing 1500 by the number of small squares between two R waves (R-R interval = one beat).

Slow or irregular rhythms:

Rate = Number of R waves X 6

The number of complexes (count R waves) on the rhythm strip gives the average rate over a ten-second period. This is multiplied by 6 (10 seconds x 6 = 1 minute) to give the average beats per minute (bpm). A visual illustration is shown in (Fig. 8)

Example of 1500 (small squares) versus 300 (large square) method

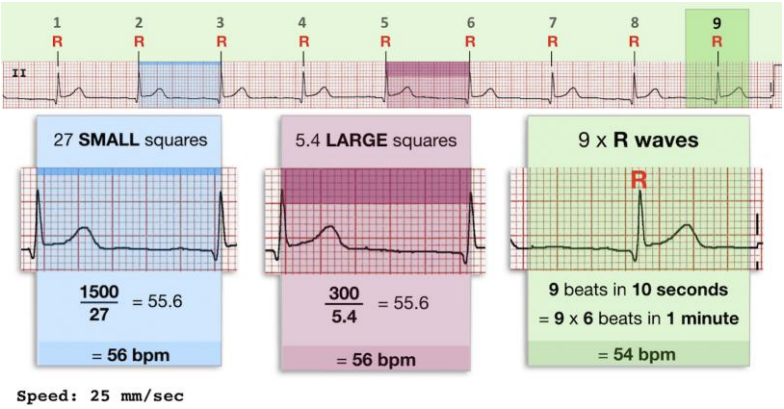


fig. 8 Heart rate small, large square and 10 sec methods. Adapted from Life in the Fast Lane (LITFL): ECG Basics – Heart Rate Calculation.

Notes:

Calculate atrial and ventricular rates separately if they are different (e.g. complete heart block). The machine reading can also be used and is usually correct — however, it may occasionally be inaccurate in the presence of abnormal QRS/T-wave morphology, e.g. may count peaked T waves as QRS complexes or miss QRS complexes with reduced amplitude.

Heart rhythm calculation. Rhythm can be quite variable. It could be

Normal sinus rhythm (NSR): indicates that the rate is between 60 and 100, inclusive, and that the P waves are identifiable and are of the same morphology throughout. The RR interval or PP intervals between beats are same. Fig.9

Criteria for normal sinus rhythm

A P wave (atrial contraction) precedes every QRS complex

- The P wave is positive in I and II, and biphasic in V1
- The P waves maximum height is 2.5 mm in II and/or III leads
- The rhythm is regular, but varies slightly while breathing (it is also called as a sinus arrhythmia or breathing arrhythmia)
- The frequency ranges between 60 and 100 beats per minute

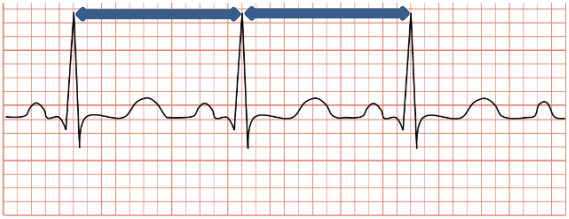


fig.9 normal sinus rhythm

Regularly irregular: RR interval variable but with a pattern. Normal and ectopic beats grouped together and repeating over and over. (Fig. 10)

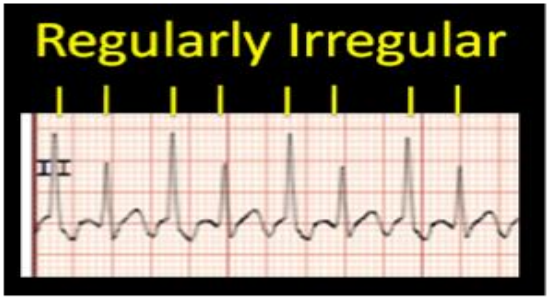


fig. 10 Regularly irregular rhythm

Irregularly irregular. RR interval variable with no pattern, totally irregular

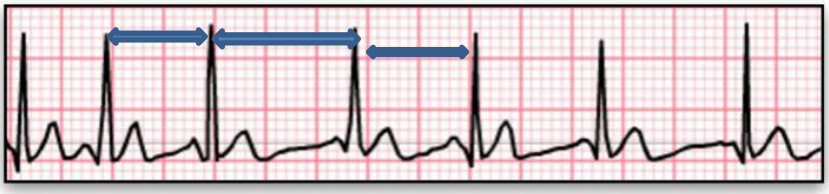


fig.11 Irregularly irregular

Cardiac axis

The cardiac axis refers to the mean direction of the wave of ventricular depolarisation in the vertical plane, measured from a zero-reference point. In a healthy heart direction of waves go toward the downward and slightly to the left.

The normal range for the cardiac axis is between - 30° and 90°. An axis lying beyond −30° is termed left axis deviation, whereas an axis >90° is termed right axis deviation. (Fig 12) and (Fig. 12.1)

We may estimate the heart axis by looking at leads I and AVF:

II, III, and aVF leads are "inferior wall" leads, **I and aVL** the "high lateral wall" leads. When the heart's mean electrical vector (or QRS axis) moves toward a positive electrode, you get an upright complex in that lead. When it moves away from a positive electrode, you get a negative complex in that lead. When it moves perpendicular to a positive electrode, you get an equiphasic (and/or isoelectric) complex in that lead.

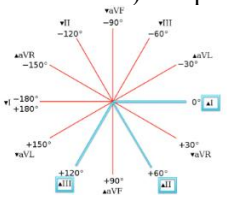
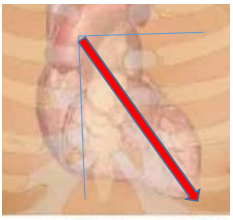


Fig 11 Normal cardiac axis
https://www.wikidoc.org/index.php/File:Leads_and_angles.png

Normal heart axis - - 30° and 90° is present when the QRS in lead is positive I and AVF.



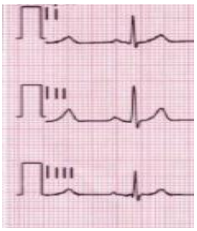
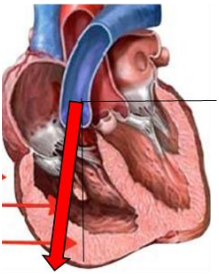
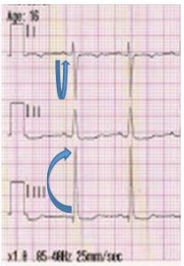


Fig 12.1. Normal cardiac axis

A **right heart axis** is present when lead I is negative and AVF positive. (between +90 and+180). Fig (12.2)





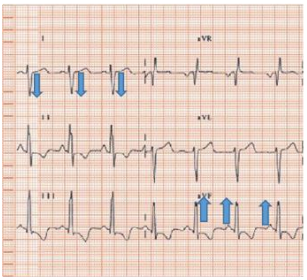


Fig 12.2 right heart axis

A **left heart axis** is present when the QRS in lead I is positive and negative in II and AVF. (between -30 and -90 degrees). (Fig 12.3)

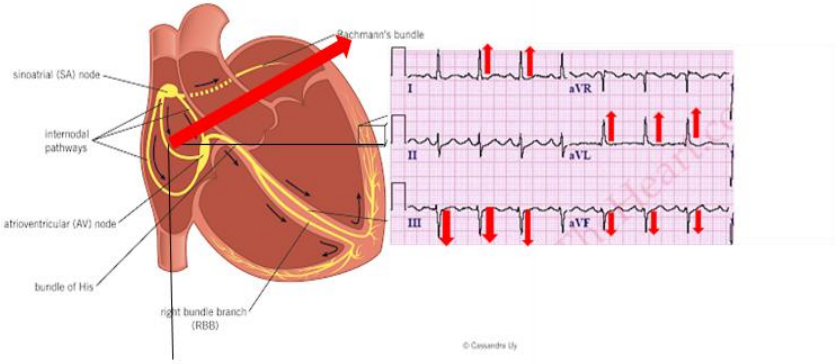


Fig 12.3 left heart axis

ECG waves, intervals and electrical pathway of the heart (Fig. 13)

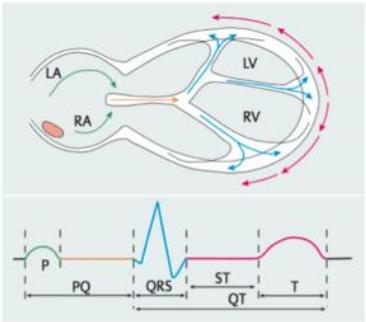


Fig. 13 Cardiac excitation sequence and ECG waveform. Adapted from ECGpedia:

Sinoatrial (SA) node:
Electrical signals arising in the SA node, which located in the right atrium. SA node is the main pacemaker and initiates 60 – 100 beats per minute.

Internodal tracts and Bachmann's bundle
There are three internodal tracts (anterior - Bachmann's bundle, middle - Wenckebach's and posterior - Thorel's) in the right atrium. Impulses travel from SA node to left atrium via Bachmann's bundle and along three internodal tracts (anterior, middle and posterior) to AV node.

Atrioventricular (AV) node
Positioned in the right atrium. Conducts atrial impulse to the ventricles. Upon reaching the atrioventricular (AV) node, the signal is delayed for 0.04 sec.

Bundle of His
Located between the atria and the ventricles in the interventricular septum. It has two branches (right and left). Transmits electrical impulses from AV node to the apex of the heart via the bundle branches. The left bundle branch splits into two branches or fascicles. Firing rate 40-60 beats/minute. The fascicular branches then lead to the Purkinje fibers.

Purkinje fibers
Purkinje fibers are located in the inner ventricular walls of the heart. Transmit impulses quicker than any other part of the conduction system. Firing rate 15-40 beats/minute

Accessory pathways
Some people are born with an extra piece of heart muscle tissue that connects directly between the atria and the ventricles, bypassing the AV node altogether. This abnormal piece of muscle is referred to as a bypass tract or an accessory pathway. Other names that may be used include anomalous AV pathway, connection, or tract.

P wave represents atrial depolarization. P wave in normal range, if

- Identifiable the II lead
- Each P wave followed by QRS complex
- Each P should be the same shape
- upright in leads I, aVF and V3 - V6
- normal duration of less than or equal to 0.11 seconds or 3 small boxes13
- biphasic in leads V1 and V3
- Look at the ECG strip paper and make sure

PR interval Normally between 0.12 and 0.20 seconds, 3-5 small squares or one big square. It indicates the time taken for electrical activity to move between the atria and the ventricles.

QRS complex

- ✓ mostly positive (upright) in leads II and I (Fig. 14.1)
- ✓ q-waves reflect normal septal activation (beginning on the LV septum); they are narrow (<0.04s duration) and small (<25% the amplitude of the R wave).
- ✓ Small r-waves begin in V1 or V2 and progress in size to V5. The R-V6 is usually smaller than R-V5
- ✓ In reverse, the s-waves begin in V6 or V5 and progress in size to V2. S-V1 is usually smaller than S-V2.
- ✓ In total the duration of QRS complex is equal to 0,11 sec or 3 small boxes
- ✓ The Q wave can be called pathological if the size 1 mm (1 small cell) in duration, i.e. 0.04 seconds... or if the Q wave is equal to 1/3 in amplitude (or more than 2 mm in depth) of the QRS complex. Post-infarction condition: the pathological Q wave (as a lesion) remains until the end of life (Fig. 14.2).

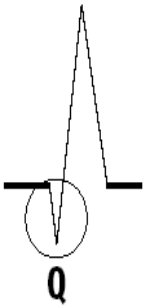


Fig. 14.1 Normal QRS

Fig. 14.2 Pathological QRS

The ST segment The ST segment represents ventricular repolarization. This process takes much more time than the depolarization. The ST segment is normally at or near the baseline. Normal ST segment and the normal

configuration is **concave upward**. ST segment elevation with concave upward appearance may also be seen in other leads; this is often called **early repolarization**, although it is a term with little physiologic meaning.

The elevation of the ST segment >1 mm in adjacent bipolar leads. It is characteristic for AMI.

The depression of the ST segment < 0, 5 mm in adjacent precordial leads. It is characteristic for angina.

T wave

The normal T wave is usually in the same direction as the QRS except in the right precordial leads. In the normal ECG the T wave is always upright in leads I, II, V3-6, and always inverted in lead aVR. The T-wave inversion = ischemia. It is usually located in leads with signs of acute infarction (Q waves and ST elevation) (Fig. 15)

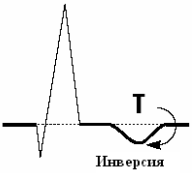


Fig. 15 T-wave inversion

QT interval

The QT interval is the time from the beginning of the QRS complex, representing ventricular depolarization, to the end of the T wave, resulting from ventricular repolarization. The normal QT interval is below 400 to 440 milliseconds (ms), or 0.4 to 0.44 seconds. (Fig. 16) Prolongation of the QT interval can result from multiple medications, electrolyte abnormalities — hypocalcemia, hypomagnesemia and hypokalemia — and certain disease states including intracranial hemorrhage.

A quick way to distinguish a prolonged QT interval is to examine if the T wave ends beyond the halfway point between the RR interval. If the T wave ends past the halfway point of the RR interval, it is prolonged. T-wave inversion

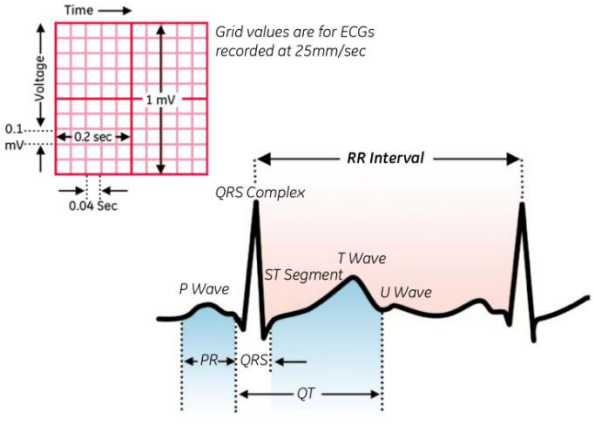


Fig 16 Normal QT interval duration (around two large squares in 25 mm/sec)

SELF - ASSESSMENT MCQs

1. Which artery is most likely to be affected in the context of ST elevation being present in leads V3 and V4?

A Left circumflex coronary artery
B Left anterior descending coronary artery
C All of the above
D Right coronary artery

2. Calculate small squares in the PR interval (25mm/sec) and indicate duration

A 0.04 - 0.08 seconds (1-2 small squares)
B 0.04 - 0.12 seconds (1-3 small squares)
C 0.08 - 0.12 seconds (2-3 small squares)
D 0.12 - 0.2 seconds (3-5 small squares)

3. Calculate the heart rate. If there are 2 large squares in an R-R interval (fig.17)

A 90 bpm
B 70 bpm
C 150 bpm
D 80 bpm

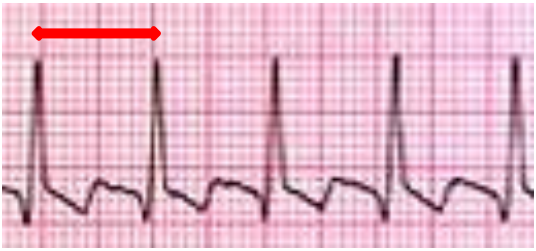


fig.17

4. What view of the heart do leads I, aVL V5 and V6 represent? Which wall of the heart is responsible for leads I, aVL V5 and V6?

A Septal
B Lateral
C Anterior
D. Inferior

5. What is the normal duration of a QRS complex?

A 0.08 seconds (2 small squares)
B. 0.16 seconds (4 small squares)
C. 0.12 seconds (3 small squares)
D 0.04 seconds (1 small square)

6. What view of the heart do leads II, III and aVF represent?

A. Lateral
B Anterior
C. Inferior
D Septal

7. Choose from the followings as a common cause of right axis deviation

A. Right ventricular hypertrophy
B. Ventricular septal defect
C. Atrial septal defect
D. Left ventricular hypertrophy

8. Evaluate heart axis according to giving leads (Fig.18)
A. Right axis deviation
B. Lest axis deviation
C. Normal heart axis
D. All of above

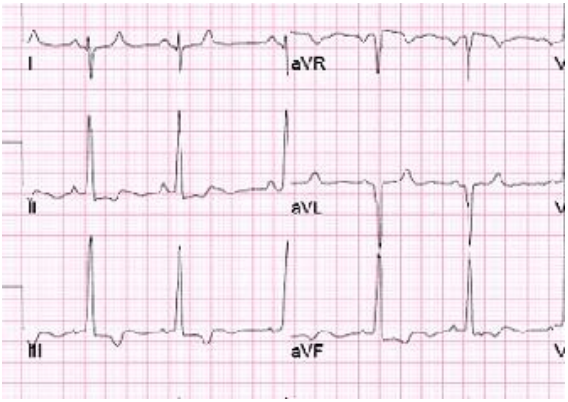


Fig 18.

9. What would it suggests if lead I became more positive than lead II and lead III became negative?

A. Right axis deviation
B. Left axis deviation
C. Normal heart axis
D. All of above

10. Evaluate heart axis in the given ECG (Fig. 19)

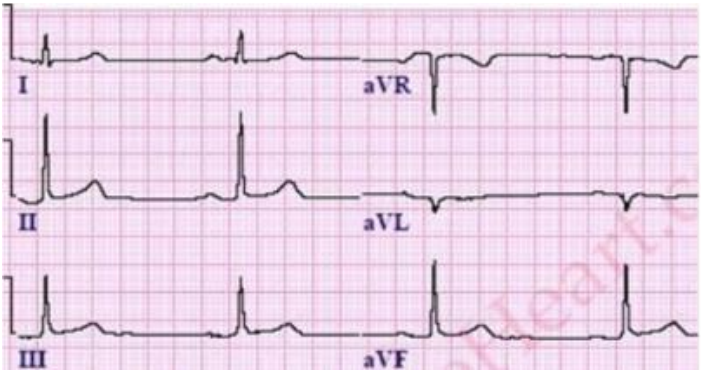


fig.19

A. Right axis deviation
B. Lest axis deviation
C. Normal heart axis
D. All of above

Answers

1 – B (Leads V3 and V4 represent the anterior portion of the heart. ST elevation in these leads would be suggestive of anterior myocardial infarction. The anterior portion of the heart is supplied primarily by the left anterior descending artery)

2 – C In healthy individuals, the PR-interval is between 0.12-0.2 seconds. A PR interval longer than 0.2 seconds suggests the presence of heart block. A short PR-interval may suggest the presence of an accessory pathway between the atria and ventricles (e.g. WPW syndrome)

3- C To calculate heart rate from an ECG you can count the number of large squares in an R-R interval then divide 300 by this number. Therefore 300/3 = 100 bpm.

4- B V5 and V6 leads represent lateral wall of the left ventricle

5- C In most healthy individuals, you would expect QRS complexes to be around 0.12 seconds in duration. If a QRS complex lasts longer it is described as a "wide QRS" and indicates inefficient conduction ventricular conduction (e.g. bundle branch block).

6- C leads II, III and aVF represent inferior wall of the heart

7- A In right ventricular hypertrophy, the increased muscle mass of the right ventricle causes an increased signal on the ECG. As a result, the axis of the heart is shifted to the right with lead III becoming more positive and lead I and II becoming less positive.

8- A (Negative S wave in I and positive in AvF indicate right axis deviation)

9- B (Positive R wave in I and negative in AvF indicate left axis deviation)

10- C (positive R wave in I and in AvF indicate normal axis of the heart)

SECTION II

Key points stepwise aproach

1. Rate
2. Rhythm
   - Ectopic beats
3. Axis determination
4. Itervals
   - Heart Blocks
5. Atrial and ventricular hypertrophies
6. ST/T changes
7. Ischemia, Injury, Infarction
8. Correlate to history, and clinical presentation

The First step: Analizing of The Rate

5 big boxes =1 sec

300 big boxes =60sec

Rate = 300/ big boxes R-R interval

The Second step: Analizing of the The Rhythm

1. Is the Rhythm sinus or ectopic?
2. Is the Rhythm slow or fast?
3. Is the Rhythm regular or irregular?
4. Is the P-R interval constant?
5. Are the QRS complexes narrow or wide?
6. Are the dropped beats?

Normal sinus rhythm (Fig. 1)

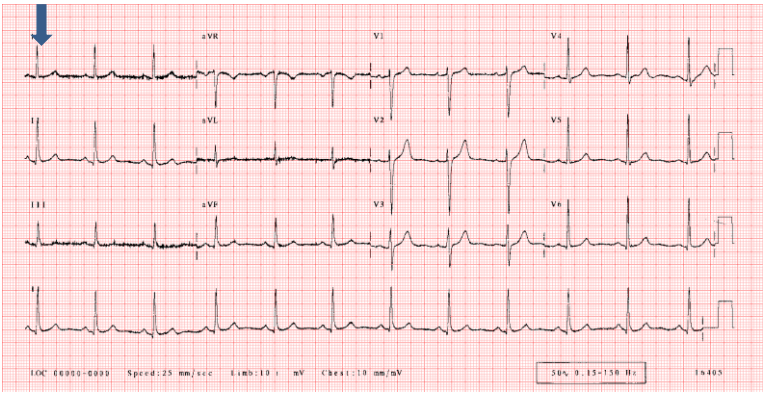


fig.1 Normal sinus rhythm

Criteria

1. Heart rate is 60-90 beats /min;
2. Constant R-R intervals in all lead (regular);
3. Presence of positive P wave in all leads (it is negative AVF and befase in V1);
4. PR intervals – 0.12 – 0.2 secs (3-5 small squares)
5. Width of the QRS - <0.12 secs (3 small squares)
6. None dropped comlexes

I. Supraventricular Rhythms/ Arrhythmias (Fig. 2)

Sinus bradicardia

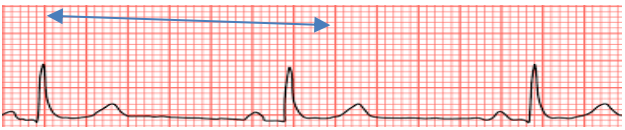


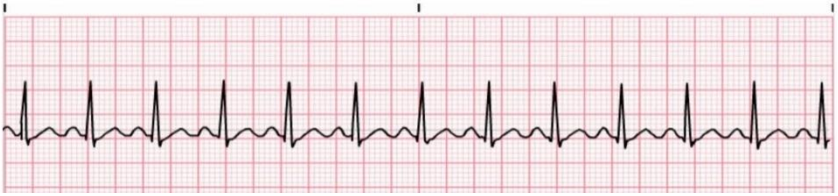
fig. 2 Sinus bradicardia

Criteria

1. *Heart rate less than 60beats /min;*
2. Constant R-R intervals in all leads (regular);
3. Presence of positive P wave in all leads (it is negative AVF and befase in V1);
4. PR intervals – 0.12 – 0.2 secs (3-5 small squares)
5. Width of the QRS - <0.12 secs (3 small squares)
6. None dropped comlexes

Sinus tachicardia (Fig. 3)

fig. 3 Sinus tachicardia



Criteria

1. Heart rate more than 100 beats /min;
2. Constant R-R intervals in all lead (regular);
3. Presence of positive P wave in all leads (it is negative AVF and befase in V1);
4. PR intervals – 0.12 – 0.2 secs (3-5 small squares)
5. Width of the QRS - <0.12 secs (3 small squares)
6. None dropped comlexes

Supraventricular tachicardia (Fig. 4)

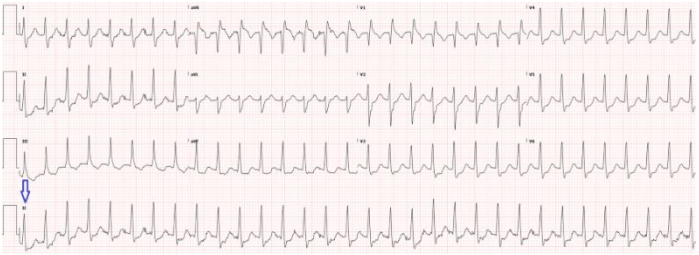


fig. 4 Supraventricular tachicardia

Criteria

- Heart rate 140-280 beats /min;
- Constant R-R intervals in all lead (regular);
- P waves hidden;
- Pseudo R waves may be seen in V1 or V2;
- Pseudo S waves may be seen in leeds I, II, II or aVF
- Width of the QRS - <0.12 secs (3 small squares)

None dropped comlexes

Sinus Arrhythmia (Fig. 5)

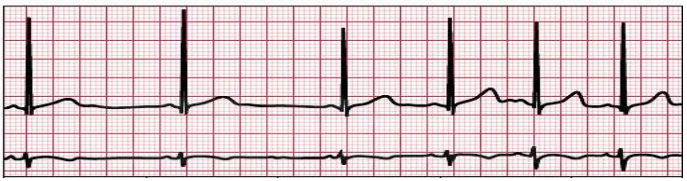


fig. 5 Sinus Arrhythmia

Criteria

1. Heart rate is 60-90 beats /min;
2. Irregularity R-R intervals (none constant);

3. Presence of positive P wave in all leads (it is negative AVF and befase in V1);
4. PR intervals – 0.12 – 0.2 secs (3-5 small squares)
5. Width of the QRS - <0.12 secs (3 small squares)
6. None dropped comlexes

Sinus pause/ arrest (Fig. 6)

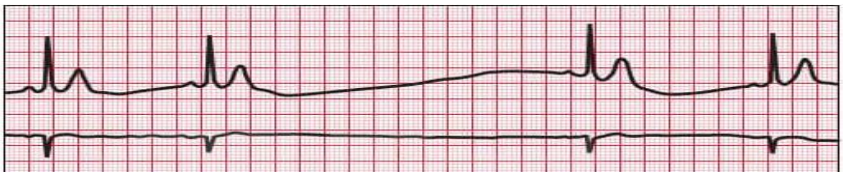


fig. 6 Sinus pause/ arrest

1. Rate varry;
2. Transient absence of P waves (P waves present in underling rhythm, absent during arrest / pause);
3. Irregular R-R intervals (none constant);
4. Presence of positive P wave in all leads (it is negative AVF and befase in V1);
5. PR intervals – normal or prolonged;
6. Width of the QRS – usually narrow;
7. None dropped comlexes;

Sinoatrial block (Fig. 7)

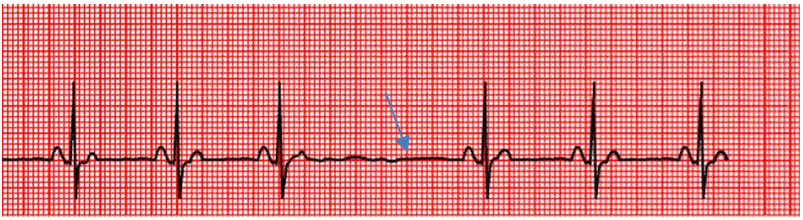


fig. 7 Sinoatrial block

Criteria

1. Rate: varies;
2. Irregularity R-R intervals (irregular rhythm);
3. Presence of positive P wave in all areas exept in droped beats;
4. PR intervals – 0.12 – 0.2 sec (3-5 small squares)
5. Width of the QRS - <0.12 sec (3 small squares)
6. Presence of dropped comlexes

Ectopic atrial tachycardia (Fig. 8)

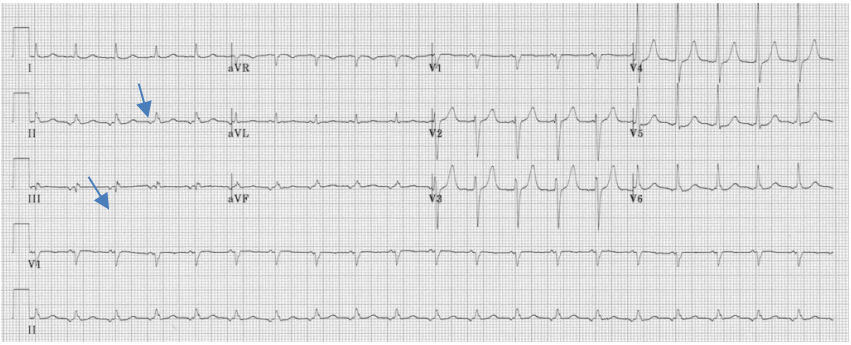


fig. 8 Ectopic atrial tachycardia

Criteria

1. Heart rate is greater than 100 beats /min;
2. Presence of positive P waves and morphology is abnormal when compared with sinus P wave due to ectopic origin.
3. An abnormal P-wave axis (e.g. inverted in the inferior leads II, III and aVF)
4. At least 3 consecutive identical ectopic P waves.
5. PR intervals – 0.12 – 0.2 secs (3-5 small squares)
6. Width of the QRS - <0.12 secs (3 small squares)
7. None dropped comlexes

Wandering Atrial Pacemaker (Fig. 9)

Criteria

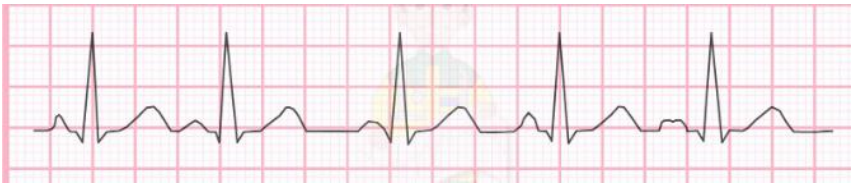


fig. 9 Wandering Atrial Pacemaker

1. Heart rate is 60-90 beats /min;
2. Irregular R-R intervals (none constant);
3. P wave morphologies three or greater than trhee;
4. PR intervals – varies
5. Width of the QRS - normal
6. None dropped comlexes

Multifocal atrial tachycardia (Fig. 10)

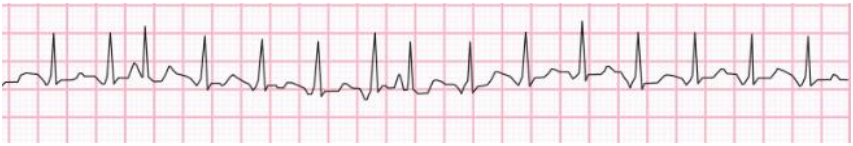


fig 10. Multifocal atrial tachycardia

Criteria

1. Heart rate is greater than 100 beats /min;
2. Irregular R-R intervals (none constant);
3. P wave morphologies three or greater than trhee;
4. PR intervals – varies
5. Width of the QRS – normal
6. None dropped comlexes

Junctional rhythm (Fig. 11)

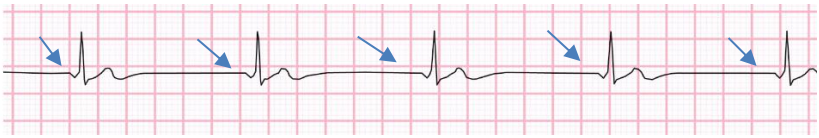


fig. 11 Junctional rhythm

Criteria

1. Heart rate is typically 40-60 beats /min;
2. Constant R-R intervals in all areas (regular);
3. P wave usually inverted or absent;
4. PR intervals – not applicable;
5. Width of the QRS – narrow
6. None dropped comlexes

Accelerated Junctional rhythm (Fig. 12)

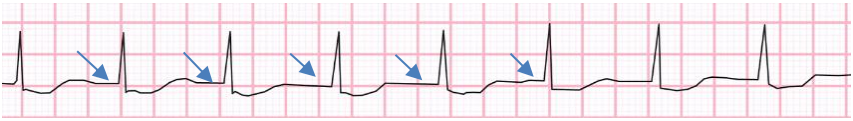


fig. 12 Accelerated Junctional rhythm

Criteria

1. Heart rate is typically 60-130 beats /min;
2. Constant R-R intervals in all areas (regular);
3. P wave usually absent or anterograde;
4. PR intervals – not applicable or short;
5. Width of the QRS – normal
6. None dropped comlexes

Atrial fibrillation (Fig. 13)

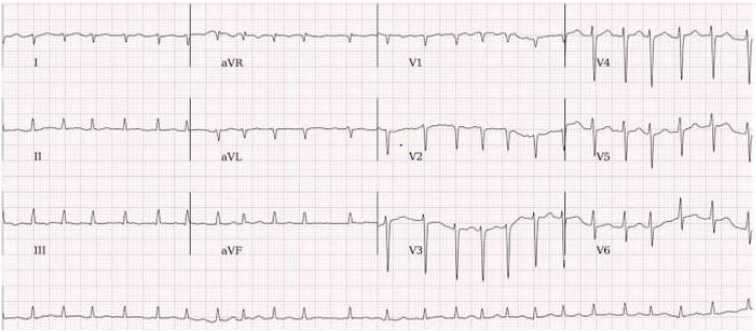


fig. 13 Atrial fibrillation

Criteria

1. Rate is variable;
2. Irregular R-R intervals (none constant);
3. P waves are chaotic;
4. PR intervals – none
5. Width of the QRS – normal
6. None dropped comlexes

Atrial flutter (Fig. 14)

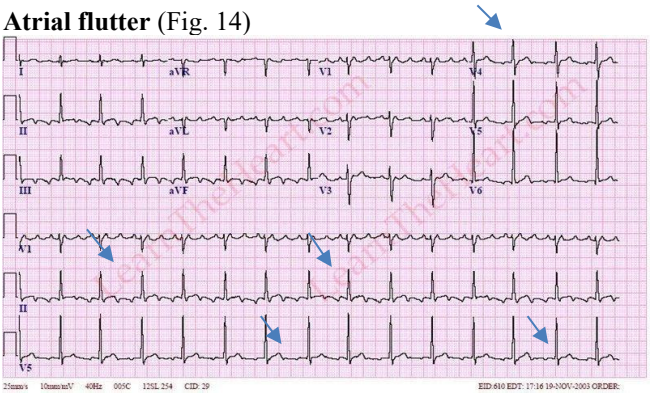


fig. 14 Atrial flutter

Criteria

1. Atrial rate is 250-350, ventricular 125-180;
2. Usually regular R-R intervals;
3. P waves are as flutter waves;
4. PR intervals – variable;
5. Width of the QRS – normal;
6. None dropped comlexes

Premature supraventricular contractions (Fig. 15)

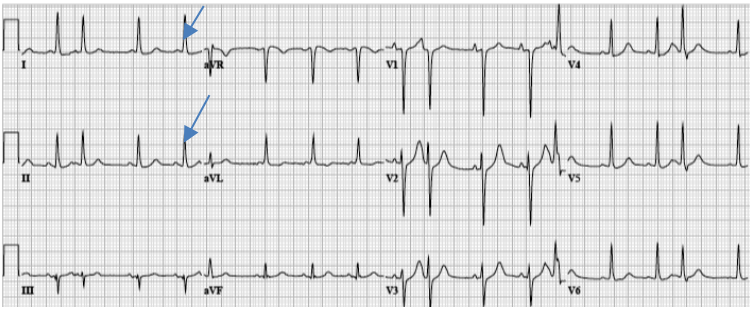


fig. 15 Premature supraventricular contractions

Criteria

Rate is variable;

1. Ectopic complex QRS with compensatory pause following the contractions;
2. Irregular R-R intervals (none constant);
3. P wave morphology can be defferent from the sinus P wave morphology;
4. PR intervals – normal
5. Width of the QRS – normal
6. None dropped comlexes

ii. The Ventricular Rhythms/ Arrhythmias

Idioventricular rhythm (Fig. 16)

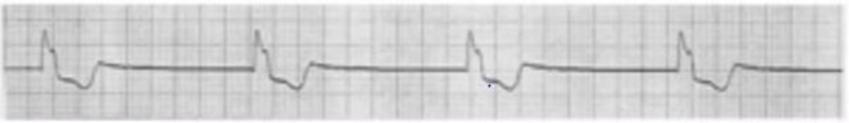


fig. 16 Idioventricular rhythm

1. Rate is 20-40 beats per min;
2. Regular R-R intervals (constant);
3. P wave is absent;
4. PR intervals – none
5. QRS complexes - unusual, wide
6. None dropped comlexes

Accelerated Idioventricular rhythm (Fig. 17)

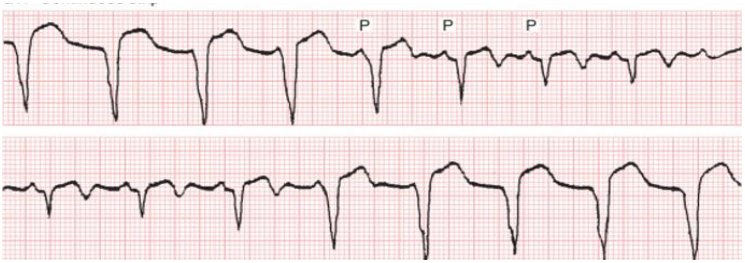


fig. 17 Accelerated Idioventricular rhythm

Criteria

1. Rate is 40-100 beats per min;
2. Regular R-R intervals (constant);

3. P wave is absent;
4. PR intervals – none
5. QRS complexes - unusual, wide
6. None dropped comlexes

Ventricular tachicardia (Fig. 18)

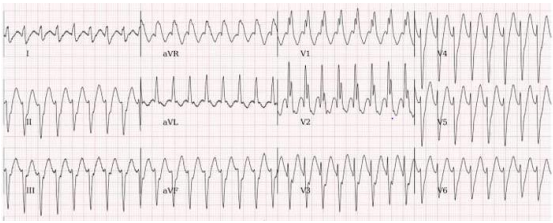


fig. 18 Ventricular tachicardia

Criteria

1. Rate is 100-200 beats per min;
2. Regular R-R intervals (constant);
3. P wave is absent;
4. PR intervals – absent;
5. QRS complexes – unusual morphology and wide
6. None dropped comlexes

Ventricular febrillation (Fig. 19)

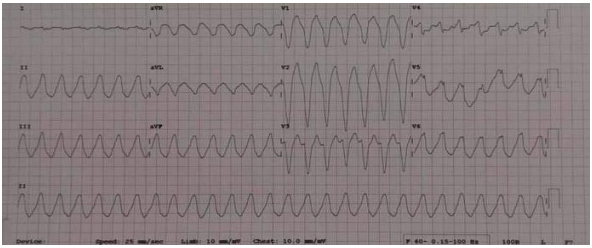


fig. 19 Ventricular febrillation

Criteria

1. Rate indefinite;
2. irregular R-R intervals;
3. P wave is absent;
4. PR intervals – absent;
5. QRS complexes – absent;

Premeture Ventricular Contractions

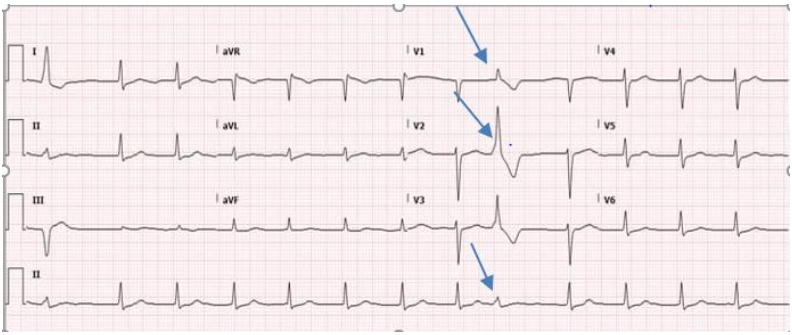


fig. 20 Premeture Ventricular Contractions

Criteria

1. Rate is variable;
2. Ectopic complex QRS with compensatory pause following the contractions;
3. Irregular R-R intervals (none constant);
4. P wave morphology can be defferent from the sinus P wave morphology;
5. Width of the QRS – wide;

The 4th step: Analizing of the Intervals (PR & QRS)

The P-R Interval

Normal PR interval - 0.12 – 0.20 sec (3-5 small squares)

Short PR interval

Wolff–Parkinson–White syndrome Fig. 25

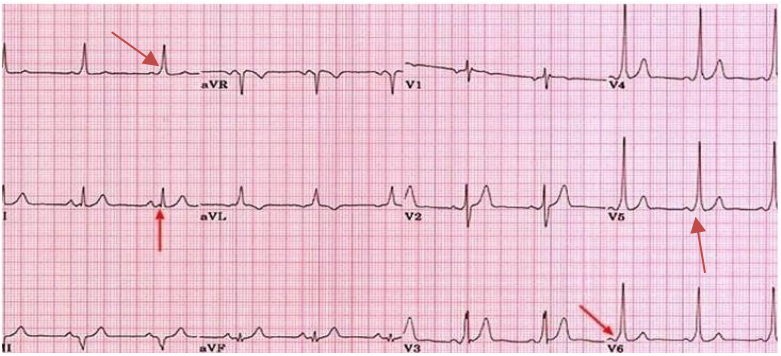


fig. 25 Wolff–Parkinson–White syndrome

Criteria

1. Short PR interval, <0.12 sec with normal P waves;
2. A wide QRS complex longer than 120 ms with a slurred onset of the QRS waveform (delta wave);
3. ST-T wave chenges;

i. Lown–Ganong–Levine syndrome Fig. 26

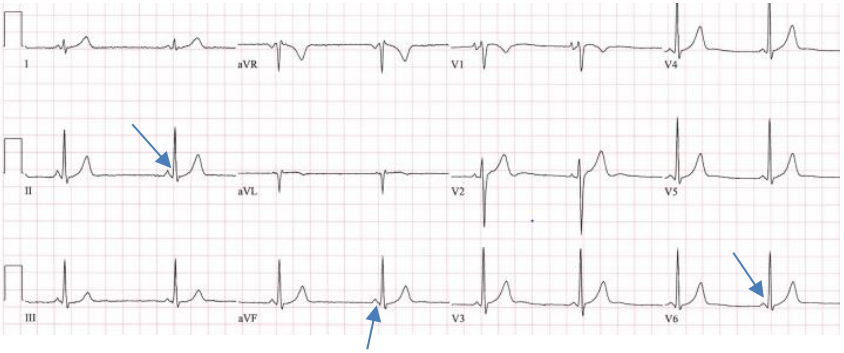


fig. 26 Lown–Ganong–Levine syndrome

Criteria

1. Short PR interval, <0.12 sec with normal P waves;
2. A normal QRS complex < 120 ms;

Prolonged PR intervals/ AV blocks

1st degree AV block Fig. 27

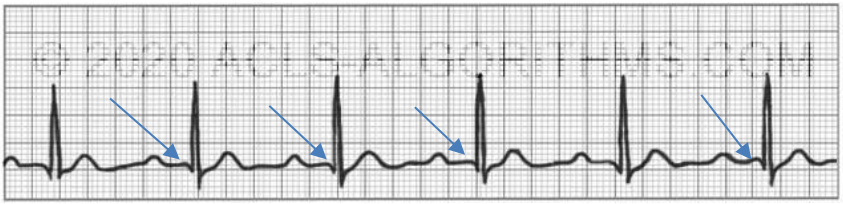


fig. 27 1st degree AV block

Criteria

- PR intervals greater than 0.20 sec (5 small squares) in all areas;

2nd degree - AV blocks (Mobitz I- Wenckebach) Fig. 28

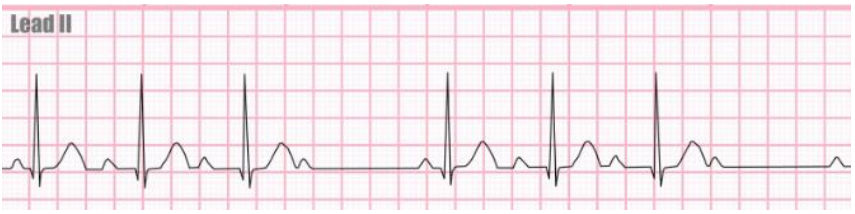


fig. 28 2nd degree - AV blocks (Mobitz I- Wenckebach

Criteria

1. Progressive prolongation of the PR interval, until an atrial impulse is completely blocked with dropped QRS complex

2nd degree - AV blocks (Mobitz II) Fig. 29

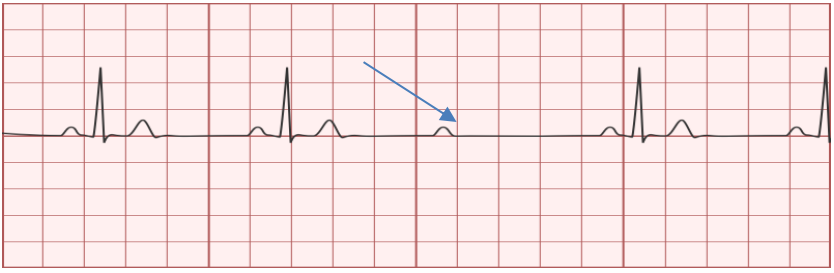


fig. 29 2nd degree - AV blocks (Mobitz II)

Criteria

1. Constant PR intervals before and after noncunducted atrial beats, with sudden dropped QRS complexes

3d degree - AV blocks(complete heart block) Fig. 30

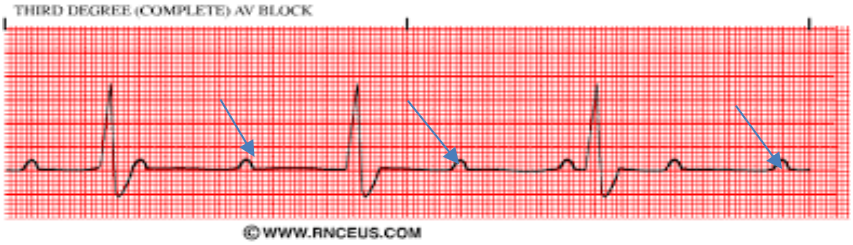


fig. 30 3d degree - AV blocks(complete heart block)

1. Complete absence of the AV conduction
2. Variable P-R intervals
3. Regular R-R or P-P intervals

Bundle branch blocks

The His bundle gives rise to the right and left bundle branches.
With Bundle Branch Blocks we can see two changes on the ECG.

- QRS complex widens (> 0.12 sec or > 3 small boxes);
- QRS morphology changes (varies depending on ECG lead, and if it is a right vs. left bundle branch block)

Right Bundle Branch Blocks (RBBB) Fig. 31

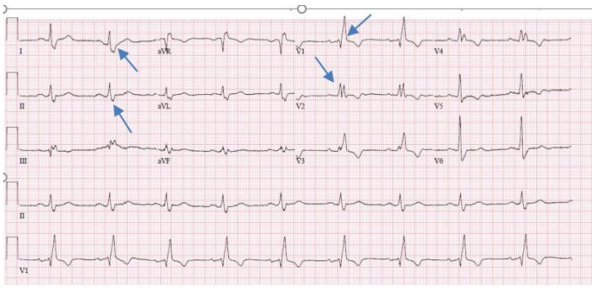


fig. 31 Right Bundle Branch Blocks (RBBB)

Criteria

1. The QRS complex > 0.12sec (3 small boxes);
2. M shape QRS or RSR, RSr, rSR pattern in V1 (it's also called as a rabbit ears);
3. Slurred S waves in I and V6;

Left Bundle Branch Blocks (LBBB) Fig. 32

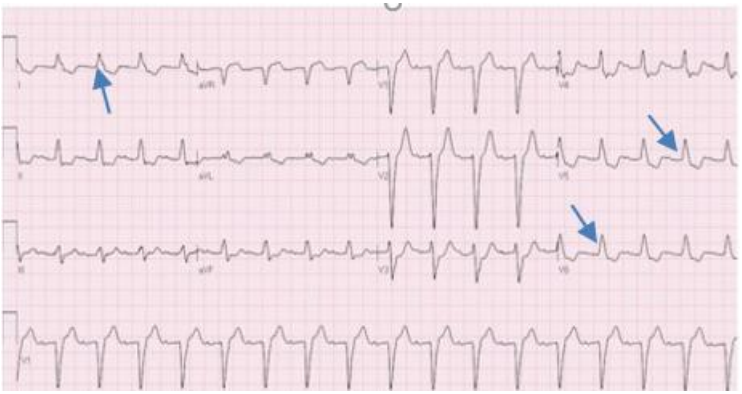


fig. 32 Left Bundle Branch Blocks (LBBB)

Criteria

For LBBB the wide QRS complex assumes a characteristic change in shape in those leads opposite the left ventricle (right ventricular leads -V1 and V2).

1. The QRS complex > 0.12sec (3 small boxes);
2. Broad, monomorphic S waves in V1;
3. Broad, monomorphic R waves I and in V6;

The 5th step: Determining Atrial and ventricular hypertrophies

Left ventricular hypertrophy Fig. 33

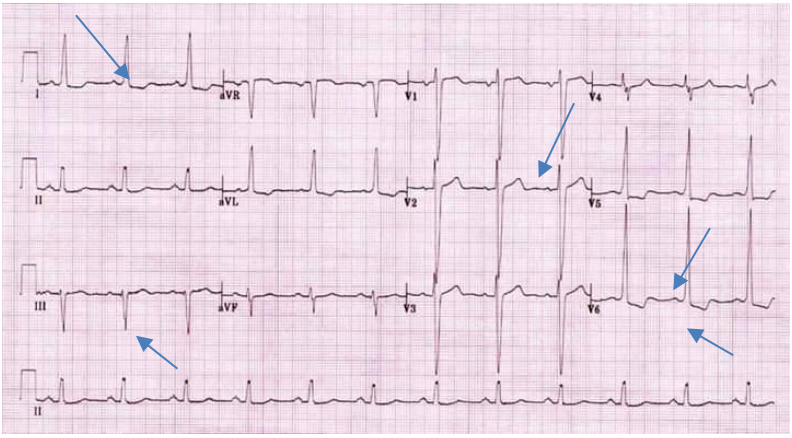


fig. 33 Left ventricular hypertrophy

1. Left axis deviation is one non-voltage criterion for LVH;
2. SV1+R (V5 or V6)>35;
3. ST-T abnormalities;

Left atrial hypertrophy (P-mitrale) Fig. 34

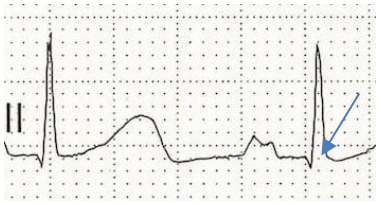


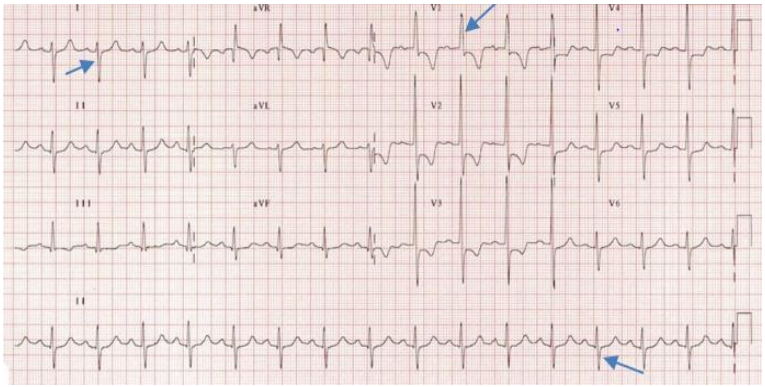
fig. 34 Left atrial hypertrophy (P-mitrale)

Criteria

1. Bifid P-wave in lead II;
2. Negative component is greater than one small square wide and deep in I lead;
3. Duration of the P-wave is > 0.12s;

Right ventricular hypertrophy Fig. 35

fig. 35 Right ventricular hypertrophy



Criteria

1. The major voltage criteria in RVH is a dominant or tall R-wave in lead V1;
2. Right axis deviation ≥ 110 degrees
3. Deep S-waves in leads V5 and V6
4. Secondary ST-T abnormalities

Right atrial hypertrophy (P-pulmonale) Fig. 36

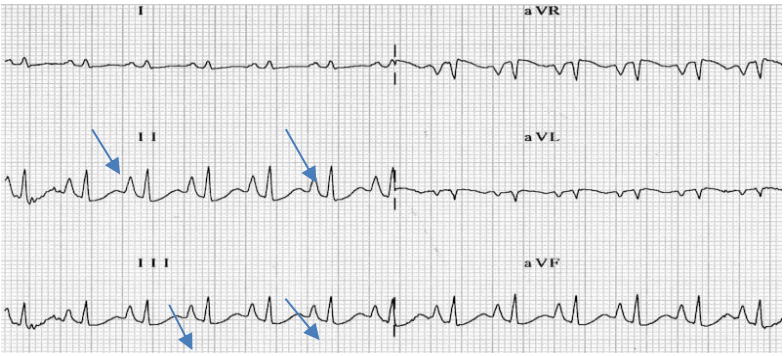


fig. 36 Right atrial hypertrophy (P-pulmonale)

Criteria

1. P-wave in the anterior and inferior leads (II, III and aVF);
2. Height of the P-wave is greater than or equal to 2.5mm
3. P-wave duration is usually normal.

The 6th Step: Analyzing of the segment ST-T Fig. 37

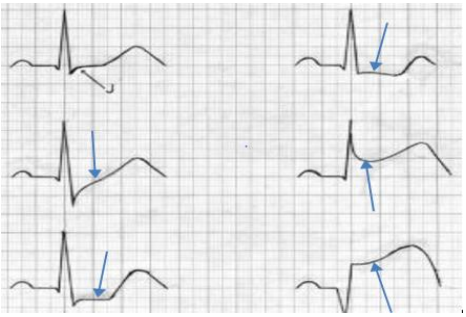


fig. 37 Analyzing of the segment ST-T

The ST segment starts from the termination of the QRS complex (J-point) and ends with T wave. It is normally located on the isoelectric line, however can be somewhat elevated or depressed. ST elevation is considered significant if the vertical distance inside the ECG trace and the baseline at a point 0.04 seconds after the J-point.

Duration of the ST segment can be varying and depend of the its rate. Duration of the ST segment does not play clinical significance. There are a lot of causes of ST segment abnormality. That requires to analyze deference using history, risk factors, clinical presentations and laboratory data.

Causes and criteria of the ST segment changes

- **Normal** – seen approximately 90% healthy young men, common marked in V2 as male pattern; normal variant in V3-V5 with inverted T waves and high QRS voltage;
- **Early repolarization** – common marked in V4;
- **Left ventricular hypertrophy**- concave + other criteria of LVH;
- **LBBB**- concave, ST segment deviation discordant from the QRS;
- **Acute MI**- reciprocal ST segment behavior between aVL and III (ST elevation in one lead is followed by ST depression in the opposing lead);
- **Prinzmetal`s angina**- same as AMI, but transient;
- **Acute pericarditis-** diffuse ST segment elevation, elevated seldom >5mm, PR segment depression;
- **Burugada syndrome -** Coved ST segment elevation >2mm in >1 of V1-V3 followed by a negative T wave, typically downsloping;
- **Pulmonary embolism-** changes simulating AMI, however in PE can be found right axis deviation, P-pulmonale, and tall, peaked R in II, III and aVF, sings of RVH;
- **Hyperkalemia –** presence of other features of hyperkalemia: widened QRS and tall, peaked T waves; usualy downsloping ST segment, low amplitude or absent P waves.

The 7th step: Determining Ischemia, Injury & Infarction

Ischemia

In case of Ischemia can be change T waves.

- Tall T-waves (also called hyper-acute T waves) with a reciprocal change deeply inverted symmetrical T waves.
- Horizontal or down sloping ST segment depression of 1 mm or more and T-wave inversion.

Injury and Infarction

It is histological damage of the myocardium caused by coronary artery occlusion.

1. Change segment ST;
2. Tall, peaked T waves; and symmetrical T-wave inversion;
3. Reciprocal changes (Mirror image: Reciprocal changes include taller-than-normal R waves (mirror image of Q waves), ST depression (mirror image of ST elevation), and tall T waves (mirror image of T-wave inversion). Fig. 38

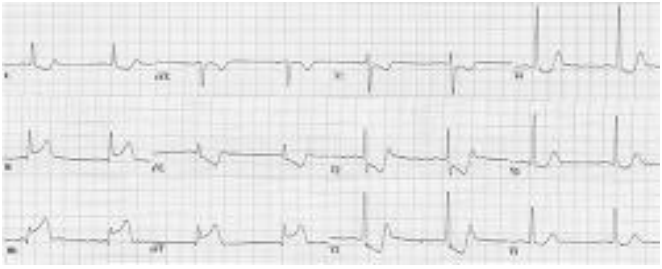


fig. 38 Injury and Infarction of myocardium

Necrosis

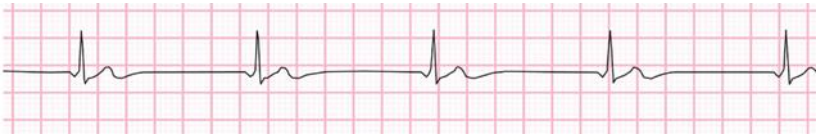
Q waves indicating necrosis.

Many leads can record normal Q waves, which are less than 0.03 seconds in width and usually small (no more than 25% the height of the following R wave).

The abnormal (pathological) Q wave (greater than 1/3 of the R wave) indicates necrosis in the myocardium

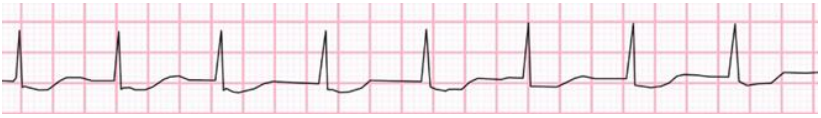
SELF - ASSESSMENT MCQs

1. Describe a correct answer for following ECG:



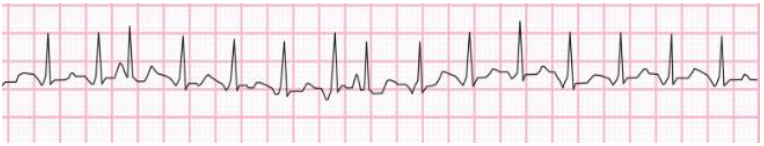
a. Junctional rhythm
b. Accelerated Junctional rhythm
c. Wandering Atrial Pacemaker
d. Sinoatrial block

2. Identify the following ECG:



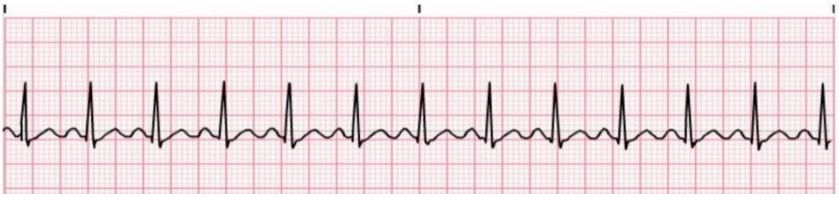
a. Junctional rhythm
b. Accelerated Junctional rhythm
c. Wandering Atrial Pacemaker
d. Sinoatrial block

3. Choose a correct answer for following ECG:



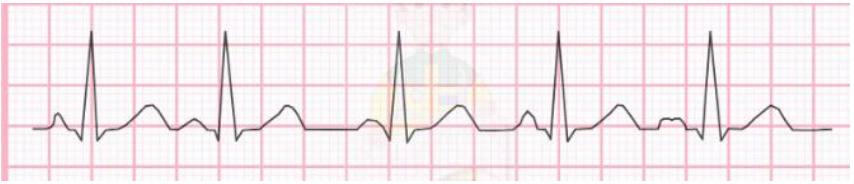
a. Junctional rhythm
b. Accelerated Junctional rhythm
c. Wandering Atrial Pacemaker
d. Multifocal atrial tachycardia

4. Describe the following ECG:



a. Sinus tachicardia
b. Supraventricular tachicardia
c. Wandering Atrial Pacemaker
d. Multifocal atrial tachycardia

- Choose a correct answer for following ECG:



a. Junctional rhythm
b. Accelerated Junctional rhythm
c. Wandering Atrial Pacemaker
d. Multifocal atrial tachycardia

Answers and comments

1-A

The heart rate is 50b/min, RR interval regular, P wave absent, non-dropped and normal QRS complex.

2-B

The heart rate is 100b/min, RR interval regular, P wave absent, non-dropped and normal width QRS complex.

3-D

Heart rate is 15-200 b/m, RR interval irregular, different P wave morphologies, non-dropped and normal width of QRS complex.

4-A

Heart rate is 125 b/m, RR interval regular, P wave present, non-dropped and normal width of QRS complex.

5-C

Heart rate is 75-100 b/m, non-constant RR intervals, different P wave morphologies, various PR intervals, non-dropped and normal width of QRS complex.

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