Description of ECG

We describe the standard twelve-lead ECG according to the so-called **ECG of ten**. We systematically measure the individual parameters of the ECG recording. From the values obtained in this way, a relatively accurate diagnosis can be determined, i.e. whether it is a o **pathology of the electrical activity of the heart**, or a o physiological finding. **It is important to always clarify the units and their ratio in the ECG recording before measuring !** This can be determined from the so-called standard, which is equal to 1 mV, and speed of the paper advance. Usually 1 mm on the ***y***- axis is equal to 0,1 mV. At a displacement of 25 mm/s, 1 mm on the ***x***-axis is equal to 0.04 s, at a displacement of 50 mm/s, 1 mm = 0.02s.

Summary of ECG ten

By following a uniform and clear procedure confusion and mistakes can be avoided even during a later inspection. Therefore, we immediately compare the measured values with the physiologigal ones, and we will visibly mark the pathologies found (to faciliate orientation). In the end, it is necessary to merge the data found and establish a diagnosis only from them.

ECG ten

1. **#heart action**,
2. **heart rhythm**,
3. **heart rate**,
4. **P vlna**,
5. **PQ interval**,
6. **QRS complex**,
7. **ST section**,
8. **T wave**,
9. **QT interval**,
10. **electrial cardiac axis**.

Heart action

In the first point, we examine **the regularity of heart action**. We measure the distances between the selected point of the ventricular complex (most often the R wave) in each cycle **in the entire ECG**. We calculate the average from the measured values and measure the same distances again.

- if the difference between the RR distances and the average is less than 0.16 s, we mark the action as **regular** = within the norm,
- if this is not the case, we mark the action as **irregular** = **pathology**,
  - if there is only one extrasystole in the record and the other distances are normal, we write **the action is regular with one extrasystole**.

Heat rhythm

Rhythm is the determination of the place **where** an action potential (controlling impulse) arises in the heart, **which leads to depolarization of the ventricles**. We monitor the presence of the P wave and its relationship to the ventricular QRS complex.

Heart rhythm Rhythm is the determination of the place **where** an action potential (controlling impulse) arises in the heart, **which leads to depolarization of the ventricles**. We monitor the presence of the P wave and its relationship to the ventricular QRS complex.

Sinus rhythm

Physiologically the excitation originates in the sino-atrial node **(SA)** and then spreads to the ventricular musculature via the atria, atrio-ventricular **(AV)** and budle of His. This is reflected in the ECG recording by a P wave, which is: a) positive in leads I and II (the impulse spreads through the atria from right down to left), and b) the QRS comples is preceded by a P wave in aconstant PQ interval (the exception is the lenghtening PQ interval in the Wnkebach period - see there). The fulfillment of these condition is evidence that the depolarization of the ventricles is controlled from the sinus node and therefor the ECG recording shows a **sinus rhythm.**

If the rhythm originates outside the SA noe (atrial muscle, AV node, transmission system/ventricular muscle), it is always a **pathology** and we are talking about a **non-sinus rhythm**, which can be determined more closely:

Atrial rhythm

An atrial rhythm means that the driving impulse originated in the atrial region, but outside the SA node. The wave of depolarization spreads along the atria in a different direction than from right to left down, and therefore the P wave is negative in lead I. or in lead II. If the P wave on the ECG is negative in lead I and the P wave is positive in lead II, then the impulse originated in the upper part of the left atrium and spread down to the right. If the P wave

is negative in lead II and the P wave is positive in lead I, then the impulse originated in the lower part of the right atrium and propagated upward to the left. The wave of depolarization also hits the AV node and the impulse spreads along the conduction system to the ventricles, where it causes depolarization of the ventricles. On the ECG, the QRS complex is preceded by a P wave with a constant PQ interval. Depolarization of the ventricles is controlled from the atria and therefore in this case the rhythm is atrial. The abnormal site of origin of the controlling impulse will not affect the distal conduction of the impulse through the ventricles and therefore the shape and duration of the QRS complex will not change on the ECG. In atrial rhythm, the frequency of atrial impulses can be up to 200/min. In normal AV conduction (1:1 AV conduction), all impulses are transmitted to the ventricles and the ventricular rate (QRS) will be the same as the atrial rate (P waves). From a didactic point of view, these are abnormal P waves indicating abnormal depolarization of the atria. If the frequency of atrial depolarizations is 220-350/min, then the waves on the ECG with this frequency are referred to as ***F waves*** and these are typical of atrial flutter. If the frequency of atrial depolarizations is 375-600/min, then the waves on the ECG with this frequency are referred to as ***f waves*** and these are typical for atrial fibrillation. In atrial fibrillation, the heart's action is markedly irregular. Under normal circumstances, fast atrial impulses (***F*** or ***f***) are transferred to the ventricles in a lower number. The ave conversion of excitations can then be in a ratio of 2:1, 3:1, 4:1. We do not measure PQ interval for atrial rhythms.

Junctional rhythm

The driving impulse originates in the AV node or in the bundle of His (junction) and spreads through the bundles of Tawar to the ventricles and may or may not pass back and cause retrograde depolarization of the atria. If the impulse is transferred to the atria, then on the ECG there is a P wave in leads I. and II. negative (the wave of depolarization spreads through the atria from bottom to top). If the atrial impulse does not propagate, there is no depolarization of the atrial muscle and the P wave is missing in all ECG leads. The abnormal site of origin of the controlling impulse does not affect the distal conduction of the impulse through the ventricles and therefore the shape and duration of the QRS complex on the ECG do not change.

Ventricular rhythm

In ventricular rhythm, the impulses that trigger ventricular depolarization occur in the conduction system below the point where the bundle of His divides into the bundles of Tawar. The depolarization wave usually takes a different route through the ventricles and the depolarization always takes longer than normal. This changes the shape of the QRS on the ECG, but mainly **the duration of the QRS complex to 0.12 s and more than 0.12 s.** In the ventricular rhythm, the ECG recording either lacks P waves or the P waves that precede the QRS complex have a different frequency than the frequency QRS complexes (time continuity of QRS complexes with P waves is not proven).

Heart rate

One of the important signs of heart performance is the **frequency of ventricular contractions**. Together with the stroke volume it determines **minute cardiac output**.

Calculation of heart rate from ECG

$$SF = \frac{300}{N}$$ [beats/min]

N= number of large squares on the ECG recording

Physiological values of heart rate at rest range **from 55 to 90 beats per minute**.

- a slower frequency (< 55 beats/min) is called **bradycardia → bradyarrhythmia**,
- faster (> 90 beats/min) is called **tachycardia → tachyarrhythmia**.

Depending on the ECG rhythm, the bradycardia or tachycardia is called sinus, atrial, junctional or ventricular bradycardia/tachycardia.

P wave

Physiologically the **P wave** precedes each QRS complex, from which it is separated by the PQ interval. (see below). The frequency of its occurence is therefore the same as the frequency of ventricular contractions.

Description: A single P wave is present that precedes each QRS complex with a rate of (e.g.)…/min Next, we evaluate the **positivity and negativity**, **amplitude** and **duration** of the P wave of all bipolar limb leads (I., II. and III.). Physiologically, the P wave is in I. and II. lead positive, in III. lead can be positive, negative or absent. **Negative P wave in I. or II. lead is pathological (see rhythm)**.

With a normal finding, the amplitude of the P wave does not exceed **0,25 mV**. Higher values indicate possible enlargement of the atria. Slender tall P waves are referred to as **P pulmonale**, and may be on the ECG in patients with cor pulmonale. High P waves wider than 0.11 s, sometimes double-peaked, are called **P-mitral waves** and can be seen on the ECG in patients with left atrial enlargement, e.g. mitral valve stenosis.

AV conduction pathology

In **the case of atrial-to-ventricular conduction disorders**, the QRS complex may be preceded by multiple P waves, or QRS complexes may occur independently of P waves (see below).

PQ interval

The PQ interva is the ime from the moment of the initiation of the controlling impulse in the SA node to the start of depolarization of the ventricles. The PQ interval includes the beginning and end of atrial depolarization (beginning and end of the P waves) and the PQ section. The PQ segment is the time of passage of the control impulse through the AV node and the bundle of His to the conduction system of the ventricles (from the end of the P wave to the beginning of the QRS complex). The PQ interval is measured **from the beginning of the P wave to the beginning of the ventricular complex**. Physiological values range between 0.12-0.20 s.

Pathology
An extended PQ interval means a longer time for the control impulse to be transferred from the atria to the ventricles in the event of disturbances in the AV part of the conduction system. A shortened PQ interval means that the control impulse reached the conduction system of the ventricles earlier than normal because it usually bypassed the AV node through abnormal connections of the condution system.

If the P wave does not occur in the recording or is independent of the QRS complex, we do not measure the PQ interval.

QRS complex

QRS complex is a general term for ventricular depolarization. It is a graph of the course and direction of electrical activation of the myocardium of the ventricles. The complex can have three types of oscillations depending on the position of the sensing electrode (the same event observed from different points of view).

- Q – only the first negative wave with which the complex begins, this wave may be absent in the complex.
- R – every positive wave of the complex. If there are more R wave in the complex, they are marked with an apostrophe (R,R´) or a numerical index (R1,R2 ...).
- S – all negative waves of the complex following the R wave. If there are more S wave, they are marked S,S ´nebo S1,S2...

We determine three parameters on the QRS complex:

- **duration**,
- **the presence and duration of the Q oscillation**,
- **Sokolow indeces**.

QRS duration

Physiologically, teh QRS complex lasts up to 0.11 s.

ORS prolongation above 0.12 s indicates a ventricular conduction defect.

Q wave

We are looking for a Q wave **in all leads**. The wave can be normally present. However, its duration does not exceed 0.03 s. The only exception is lead **aVR**, where even a wide Q is not pathological.

The Q wave longer than 0.04 clearly indicates a **myocardial infarction scar**. According to the findings in the individual leads, the location of the infarction can be determined (fron wall, septal, diaphragmatic...).

Sokolow indeces (Sokolow-Lyon ventricular hypertrophy criteria)

A larger volume of muscle during hypertrophy of the myocardium of the ventricles emits a greater tension and this can increase the amplitudes of the QRS complex. Normal sizes of QRS amplitudes are determined **Sokolow indeces**. The amplitude of the oscillation of the QRS complex in leads V_1 or V_2 is added to the amplitude of the oscillation in leads R_5 or R_6. From the amplitudes V_1/V_2 and amplitudes R_5/R_6, the amplitude that is larger is always selected for the calculation.

Right ventricular index

Normally, the sum of the oscillation amplitudes $\mathbf{R_{V1}}$ ($\mathbf{R_{V2}}$)$\mathbf{+ S_{V5}}$ ($\mathbf{S_{V6}}$) is ≤ 1,05 mV. Values greater than 1,05 mV indicated a possible enlargement of the right ventricle of the heart.

Indexes for the left ventricle

Normally, the sum of the amplitudes of the oscillations $\mathbf{S_{V1} + R_{V5} < 3,5\ mV}$ or $\mathbf{S_{V1} + R_{V6}}$ **is < 4 mV**. Greater values point to a possible enlargement of the left ventricle of the heart.

A greater value of the index is not evidence of hypertrophy of the ventricular myocardium. Hypertrophy of the myocardium can be reliably proven, e.g. by ultrasound examination of the heart.

If the QRS complex lasts 0.13 s and more than 0.13 s, we do not measure the Sokolow indeces.

ST segment

Depolarization of the ventricular muscle (QRS complex) is followed by a *plateau* phase. Physiologically, no electrical changes occur in the myocardium. Therefore, normally the ST segment is at the same level (height) as the PQ segment (between the end of the P wave and the beginning of the QRS complex), that is, **in the isoelectric plane**.

We describe the ST segment in all 12 leads. We look for **elevation** - an increase in the ST segment above the isoelectric line or **depression** - a decrease in the ST segment below the isolectric line. **Elevation** of the ST segment is considered normal if:

- in leads I., II., III., aVR, aVL, aVF does not exceed 0.1 mV,
- in leads V1-V6 does not exceed 0.2 mV.

Depression of the ST segment below the isoelectri line is**always pathological**.

Deviations from the norm are a sign of myocardial repolarization disorder. This occurs most often during **myocardial hypoxia**, when myocytes do not have enough energy to compensate for rapid changes in mebrane potentials.

Typical ST segment changes appear in the acute phase of **transmural myocardial infarction**.

T wave

The T wave represents repolarization of the ventricular myocardium on the ECG recording. Physiologically, it is **concordant** (same polarity as the largest oscillation of the QRS complex in leads I, II and III). If this is not the case, we describe the wase as **discordant**, which is pathological. We will also describe the T wave in unipolar leads, here only the positive or negative orientation of the T wave is evaluated.

Norm:

- I. and II. – positive, concordant;
- III. – concordant (polarity is not important);
- aVR – negative;
- V3–V6 – positive.

All deviations from the norm are pathological.

Sometimes the T wave can be **bipolar**, such wave is then described as **preterminally negative** (−/+), or **terminally negative** (+/−).

T wave deviations occur, similarly to ST segment pathology, during myocardial hypoxia.

QT interval

The distance from **the beginning of the QRS complex** to **the end of the T wave** is measured. The total length corresponds to the duration of depolarization and repolarization of the ventricular of the ventricular muscle. **Normal values are from 0.25 s to 0.50 s.** From the point of view of the mechanical work of the heart, the QT interval roughly corresponds to ventricular systole. Prolongation of the QT interval is a sign of an increased risk of malignant polymorphic ventricular tachycardia (so-called t*orsade de pointes)*, which can turn into ventricular fibrillation.

Electrical cardiac axis

The cardiac electrical axis expresses the direction of the vector of electrical cardiac activity in the frontal plane during ventricular depolarization. Under normal circumstances, it goes from right down to left. Under physiological conditions, the direction of the electrical axis of the heart is approximately identical to the anatomical axis of the heart. With damage to the myocardium or the conduction system, the electrical axis of the heart can be significantly different from the anatomical position of the heart.

We determine the electrical cardiac axis using leads I., II. and III. We transfer the measured amplitude from the QRS complex of each lead to the Einthoven triangle. Then we sum these three vectors and measure the angle of the resulting vector.

Physiologically the electrical cardiac axis angle ranges from −30° to +110°. If the angle is greater than 110°, we label the axis as **pathological right**, values below −30° are labeled **pathological left**.

In the case of finding **pathological Q waves** in two leads, the electrical axis of the heart is not constructed. A pathological Q wave is created by sensing the ECG potential from the ventricular cavity. The resulting QRS complex is a mirror image of the epicardial QRS complex - it has the opposite direction to the epicardial QRS complex. Epicardial vectors cannot be combined with endocardial vector for the construction of the electrical cardiac axis.

Links

Related Articles

- Practicing: EKG (1. LF UK)
- Electrocardiography
- Manifestations of disturbances in the generation and conduction of excitation on the electrocardiogram
- Blockade of left arm of Tawar • Blockade of right arm of Tawar

External links

- w:en: Electrocardiography#Axis
- ECGpedia (https://en.ecgpedia.org/index.php?title=Main_Page)
- ECG learning website (http://ekg.kvalitne.cz/)
- MUDr. Jiří Štefánek: Medicine, diseases, studies at the 1st Faculty of Medicne, UK (https://www.stefajir.cz/):
  - ECG (https://www.stefajir.cz/?q=ekg)
    - Prolonged QT interval - ECG (https://www.stefajir.cz/?q=prodlouzeny-qt-interval-ekg)
- ECG MD content (https://ekg.md/content/)
  - ECG A-Z (https://ekg.md/ekg-a-z/) glossary of terms
    - RP interval (https://ekg.md/content/rp-interval/)
- Case reports with ECG description (http://kardioblogie.blogspot.com/search/label/kazuistika)
- 1400 page ECG book (TECHmED) (https://www.techmed.sk/ekg-a-arytmologia-kniha/)
  - QT interval (https://www.techmed.sk/qt-interval/) and the influence of the U wave
- Introduction to ECG – prof. Jan Malík (http://www.medicalmedia.eu/cs/Detail/1272%7C)
- ucebnice-ekg.cz (http://www.ucebnice-ekg.cz/) – theory & number of curves
- How to Calculate the Heart Axis (https://en.my-ekg.com/how-read-ekg/heart-axis.html)
- Heart Axis Calculator (https://en.my-ekg.com/calculation-ekg/heart-axis-calculator.php)
- Analysis and Interpretation of the Electrocardiogram (https://elentra.healthsci.queensu.ca/assets/modules/ts-ecg/index.html) – A Self-Directed Learning Module, Technical Skills Program, Queen’s University
- Corrected formula for the calculation of the electrical heart axis (https://www.researchgate.net/publication/13355162_Corrected_formula_for_the_calculation_of_the_electrical_heart_axis)
- Assessment of the inclination of the electrical heart axis (https://www.vutbr.cz/www_base/zav_prace_soubor_verejne.php?file_id=84332) – Kristýna Temelová, VUTBr, Bakalářská práce
- Analysis of animal ECG (https://dspace.vsb.cz/bitstream/handle/10084/119181/STR0264_FEI_N2649_3901T009_2017.pdf) Alžběta Straškrábová, dipl. práce 2017, VŠB – Ostrava University of Technology - well-described technique and other types of connections (e.g. Frank's orthogonal system and relevant transformations), most of the information also applicable to human ECGs and especially instructive for ECGs in laboratory animals.

Source

- BORSKÁ, Lenka. *EKG desatero.* 2. edition. [Brno] : MSD, 2010. ISBN 9788073921224.