ELECTROMYOGRAPHY (EMG)

1. DEFINITION

Electromyography (EMG) represents the graphical recording method of muscle action potentials with needle electrodes inserted into the muscle (elementary EMG) or with cutaneous electrodes (global EMG) and study their characteristics.

Electromyography is a modern paraclinical method of investigation, which complements medical examination.

2. RECORDING DEVICES

Recording is done using the electromyograph, which shows a collecting system of muscle action potentials, an amplifier unit and a graphical display and registration system.

- **Collecting system.** It is represented by electrodes, which can be:
  1. **Surface electrodes** are represented by small metal plates, with an area of about 1 cm^2, made out of silver, which are placed on the skin covering the muscle region studied (usually at the proximal and distal end of the muscle). These electrodes collect the electrical activity of the whole muscle, and the recording obtained represents **global electromyogram.**
  2. **Needle electrodes** (Adrian Bronck coaxial needle) are inserted into the muscle and allow the collection of electrical activity of single motor units, thereby achieving **elementary electromyogram.**
- **Amplification system.** It is equipped with an amplifier and a filter, which allow the registration of muscle action potentials which arise spontaneously and whose amplitude is very small.
- **Graphical display and registration system:** monitor, paper.
- **Speaker:** reproduces the variations of muscle action potentials under the form of sounds. The normal potentials are perceived as long and low frequency sounds, while pathological currents give a short sharp sound.
- **The stimulus system** is done by applying impulses with a specific pulse duration and intensity depending on the specific somatic particularities of the subject.

3. INDICATIONS AND CONTRAINDICATIONS

Electromyography is useful in the differential diagnosis of myopathic and neurogenic pathology.
EMG is useful in:

- *diagnosis of neuromuscular diseases* - neuropathy, myopathy - elementary EMG are preferred;
- *in work medicine and ergometry studies* - to assess muscle force exerted during physical activity;
- *sports medicine* - to measure muscle strength and onset of fatigue during exercise;
- *recovery and physiotherapy* - to diagnose the degree of neuro-muscular disease and for monitoring progress in the rehabilitation of post-traumatic patient.

Electromyography has no contraindications.

4. RECORDING METHOD

The subject should be relaxed, sit in a comfortable position, sitting or lying position, allowing a smooth muscle relaxation. The room temperature in which the exploration is made needs to be 21-24 °C and the patient should be informed properly about the course of the investigation. The skin is defattened with an alcohol solution and then the surface electrodes are fixed using elastic bands or needle electrodes are inserted into the muscle. To achieve good contact with the skin it is recommended to use a contact gel (electrolyte).

- *Surface electrodes* are placed between the motor point of the muscle and tendinous insertion, so that the axis intersecting both sensing electrodes is parallel to the muscle fibers;
- *Needle electrodes* are inserted into the muscle without prior anesthesia, preferably parallel with the muscle fibers. Reference electrode (indifferent) is placed as far away from the collecting electrode, as possible on electrically neutral tissue, usually on a prominence of bone.

EMG will be recorded while the muscle is at rest, at a minimum voluntary muscle contraction, and then, gradually, to more complex contractions up to a maximal contraction, the contraresistance.

Depending on the clinical symptoms presented by the patient, the following will be done:

- *EMG examination for limb muscles, the face, back and extrinsic muscles of the eyeballs;*
- *Symmetrical muscle examination* - in case of unilateral muscle atrophy;
- *Exam agonist-antagonist muscles* - in the case of central lesion;
- *EMG examination with activating route using the following methods:* electric (neurostimulation) using stimuli with variable intensity, duration and frequency; changing the temperature of the muscle; hyperpnoea, local ischaemia by applying a tourniquet to the root of the limb or by running a tensiometer cuff compression.

5. THE GRAPHYC ASPECT OF ELEMENTARY ELECTROMYOGRAPHY

5.1. Principle: the graphic aspect of the muscle action potentials depends on the number and size of motor unit (MU) of the motor mass investigated.

MU = all skeletal muscle fibers innervated by one motoneuron axon.

The number and size of the motor unit varies from one muscle to another:

- muscles which generate a large contraction force (e.g. quadriceps muscle) have an increased number and size of MU
- muscles performing fine movements (e.g. extrinsic muscles of the eyeballs) have a decreased in number and size of MU.

5.2. Characteristics of electrical muscle action potentials

Muscle electrical activity is characterized by recording the potential, which presents particularities in terms of amplitude, duration, frequency and morphology.

- *Amplitude:* 500-700 µV. Depends on: motor unit size, the distance between the electrode and the motor unit, surface registration (**Fig.1.)**
- *Duration:* 4 to 16 msec. Represents the time required electrical phenomena recording. Depends on: MU size, degree of dispersion of muscle fibers in the MU (is greater for muscles whose motor units contain more fiber and is lower in children) (**Fig.1**).
- *Morphology:* depends on the degree of synchronization of the contraction of muscle fibers in the MU. Can be single phase (passes through two zero values), biphasic (three null values), three-phase (four null values) and polyphasic. On a normal track the most common is the two-phase morphology and the rarest is polyphasic.

- *Frequency:* 4-12 cycles/s. Depends on: how often the motoneuron discharge is repeated; it increases proportional with the importance of muscle contraction.

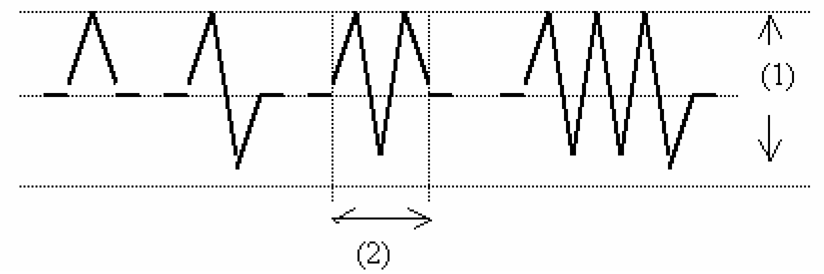

Fig.1. EMG muscle action potentials characteristics.

6. NORMAL EMG RECORDING

Depending on the intensity of muscle contraction, EMG has the following aspects (**Fig.2**)

1. *The rest recording* - isoelectric line (the muscle doesn't spontaneous action potential generate);
2. *Simple recording* - in case of minimal voluntary contraction only the potential derived from a single motor unit, having the characteristics presented above, is recorded;
3. *Intermediary recording* – in the case of medium intensity contractions the potential of neighboring motor units is also recorded; the peaks are numerous but can be distinguished from one another;
4. *Interference recording* – in the case of maximum contractions we obtain a route rich in graphics, with a rapid succession of peaks, which no longer allows verification of potential belonging to a particular motor unit.

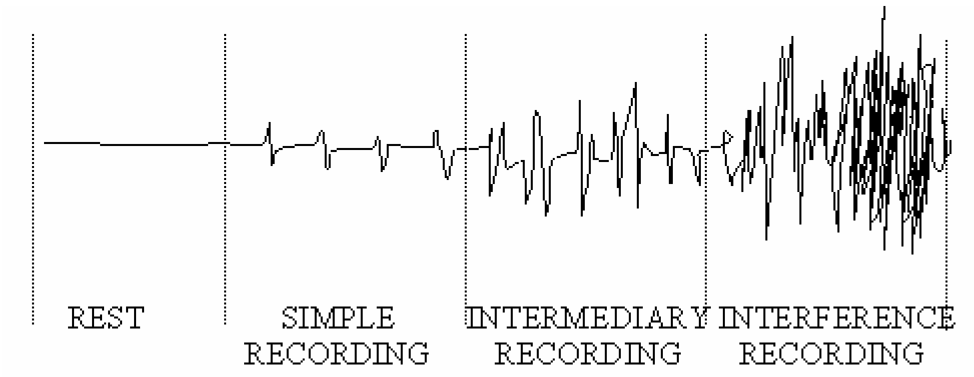

Fig.2. Normal EMG recording.

7. EMG RECORDING IN DIFFERENT DISEASES

The bioelectric potential changes its parameters in both a primary damage to the muscle fiber and in the case of damage to the motoneuron, motor nerve or local alterations of metabolism. EMG pathological aspects can be classified into myogen, neurogenic and endocrine-metabolic disorders (**Fig.3**).

- **Neurogenic type.** It appears in spinal motoneuron disease (neurogenic central route) or motor nerve (neurogenic peripheral route) such as radiculitis, neuritis, and trauma. It is characterized by:
  - occurrence at rest of potential action;

- potential with increased amplitude and duration, both at rest and during contraction. Neurogenic routes are generally poor in graphic elements and have giant potential with low frequency.

- **Myogenic type** occurs in primary disease of muscle fiber, such as myasthenia, muscular dystrophy, etc. It is characterized by:
  - no electrical activity at rest;
  - interference recording with polyphasic potential with amplitude and duration decreased at which specific electrical events are added, such as *myotonic salve* and *myasthenia*
- **Endocrine and metabolic disorders.** They occur most frequently in patients with hypocalcaemia. It is characterized by:
  - electric potential at rest with a repetitive aspect of the type doublets or triplets;
  - potential may occur spontaneously or only after activation of the recording through limb compression with the tensiometer cuff at mean BP for 10 min, which can add 5 minutes of hyperpnoea (ALAJOUANINE method).

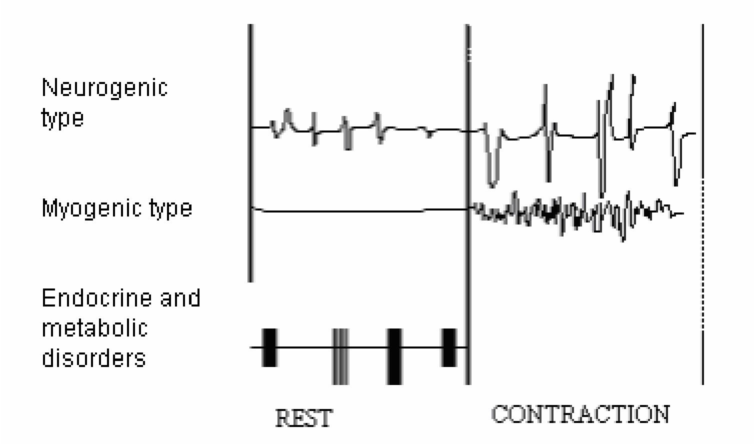

Fig.3. Pathological aspects of electromyographic recording

8. MODERN VERSIONS OF CLASSIC ELECTROMYOGRAPHY

Due to improvements in the technical performance of equipment, surface electromyography is gaining more ground, having the advantage that it is noninvasive, relatively fast and simple to perform. At the same time, new methods to explore the electrical activity of muscle performance (such as on a single fiber electromyography or in dynamic conditions) are found.

- **Single fiber electromyography.** Used for collecting the needle electrodes containing 1-14 platinum wire and has a collecting area located on the side of the needle. Computerized data analysis allows correct assessment of the parameters determined. With this method we can measure:
  - "jitter", due to discrete fluctuations in form and the potential occurrence of the same motor unit - parameter that declines early in a number of diseases such as myasthenia;
  - potential of individual fibers;
  - fiber density;
  - spatial distribution of fibers in the motor unit.
- **Dynamic electromyography.** It is a method that allows the investigation of cycles of *movements*, e.g. walking. It is indicated in kinematics studies, to assess the performance of athletes, sports accident investigations and pre-surgery studies of patients who suffer orthopedic corrections (for evaluation and prognosis). The collecting is carried out preferably using microelectrodes with a 50 µm diameter, inserted into the muscle with a guiding needle. They have a good flexibility and allow determining parameters of muscle activity in dynamic.

MOTOR NERVE CONDUCTION VELOCITY (NCV)

1. THE IMPORTANCE OF NCV DETERMINATION

The determination of nerve conduction velocity (NCV) in peripheral nerves has *a practical importance* because it allows the differentiation of peripheral neuropathy from primitive muscle damage, and also the place assessment of compression or ischaemia. The determination of NCV also presents *a theoretical importance* in elucidating the production mechanisms of peripheral nerve disorders, and of the central nervous system with consequences on the peripheral.

2. NCV DETERMINATION METHOD

For determining the NCV is used an electromyograph with a neurostimulator. The stimulator must generate isolated, rectangular, electrical impulses, with duration of 0.05 to 1 msec (in practice less than 0.5 msec are used), voltage 0-500 V. The oscilloscope is graded to be able to directly measure the latency and amplitude of the muscle action potential evoked by the stimulus.

- *Stimulation* is performed with surface electrodes. The cathode is applied to the nerve and the anode on its side. The distance between the two stimulating electrodes is 23 mm.
- *Collecting electrodes* are placed on the skin area where we want to do the recording, in full muscle mass and after a preliminary degreasing the skin area with an alcohol solution.

NCV in motor nerves is determined based on collecting muscle potentials evoked by stimulation of the motor nerve at two points - the proximal and distal (**Fig.4**). Typically, they are working with surface electrodes, on the nerves easily accessible, such as **cubital, median and external popliteal sciatic nerve**. Distance **S (mm)** between two points is measured using a craniometer. On the screen of the electromyograph the onset latency of the two responses is measured. Proximal latency – **PL** and distal latency and - **DL** are defined as the interval between the time of the appearance of the stimulus artifact and the first deflection of the action potential. In other words, latency represents the necessary time for impulse to travel the distance from stimulation place at collecting place.

Observation: the method of stimulating in two-points is preferred because of the advantage that it eliminates the inaccuracies caused by the fact that measured time is not only the conduction in the nerve fiber, but also the conduction through the motor plate and sarcolemma. The difference between PL and DL (t) will be exactly the time required for the pulse to travel between two points of stimulation. Nerve conduction velocity is calculated as follows:

$$\mathbf{NCV = s/t = \frac{S}{PL - DL}}$$

3. NORMAL VALUE OF NCV

Conduction velocity in motor nerve fibers is 45-65 m/s, depending on the thickness of the nerve fiber.

4. PHYSIOLOGICAL VARIATIONS OF NCV IN MOTOR FIBERS

Peripheral motor nerve fibers belong to the group Aα, having a diameter between 10 and 20 μm, the lowest threshold of excitability and the fastest conduction velocity. There are a number of factors, which can influence the nerve fiber conduction, among which:

- *Age.* NCV is lower in young children (incomplete myelination of neurons), then increases in the case of adults and decreases slightly in the case of the elderly. (circulatory and metabolic alterations).
- *Peripheral temperature.* It influences in direct proportion conduction in nerve fibers. It was found that between 38°C and 29°C, low local temperature induces a relatively linear decrease of conduction, with 2.4 m/sec for each ° C.
- *Perfusion of nerve trunks*. Arm ischaemia, caused by compression of the tensiometer cuff, at a pressure of 200 mmHg, for 30 min, reduces NCV by one third. After lifting the tourniquet, NCV returns to normal in 6-8 min. If ischaemia persists over 35 min there is a complete blockage of the nerve conduction.

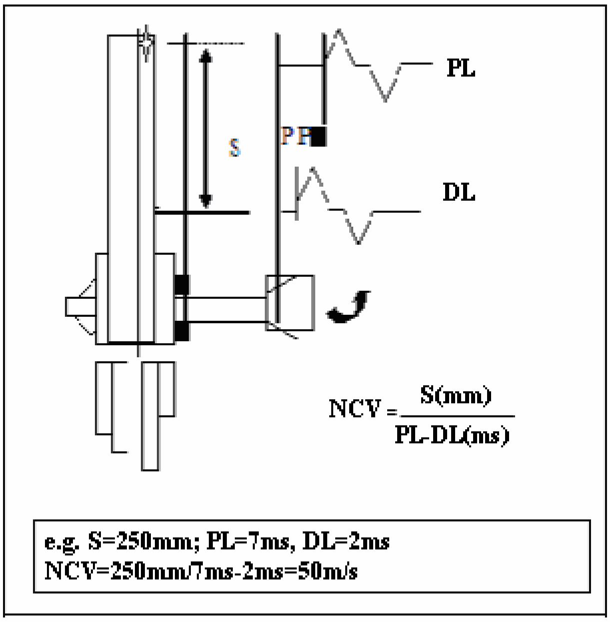

Fig.4. NCV determination by cubital nerve stimulation in two points: proximal – at the elbow and distal - at the wrist.

5. PATHOLOGICAL CHANGES OF NCV

Conduction velocity in motor nerve fibers is an important electrodiagnosis method. This method allows assessment of polyneuropathies installation from an early stage, when clinical signs and subjective complaints are very limited.

The etiology of neuropathy, defined by decreasing NCV <40 m/sec, can be:

- metabolic (diabetic),
- toxic (mercury, carbon disulphide)
- alcohol
- compressive (radial nerve paralysis, carpal tunnel syndrome), etc.

6. THE MEASURING OF CONDUCTION VELOCITY IN SENSITIVITY FIBERS

This determination is of particular interest because of a number of neuropathies that start with a faster damage of sensitive components. Even after the beginnings of mixed neuropathy, sensory deficit is more pronounced. In this sense the development of *diabetic neuropathy* can be seen. In this case, the measurement of conduction in sensitivity fibers would allow an early diagnosis of this complication.

In practice, the method is rarely used, due to technical difficulties and possible causes of error. The technique described by Buchtal and Rosenfalk is commonly used; namely digital nerve orthodromic stimulation and the recording of sensing action potential with monopolar needle electrodes fixed on nerve, at the wrist, elbow, axilla, ankle, popliteal space, buttock. Sensory evoked potential latency is measured between the beginning of stimulus artifact and the peak of the first positive deflection of this potential.

MCQs (ONE CORRECT ANSWER)

1. Elementary electromyography is performed using:
   A. Needle electrodes inserted into the skin
   B. Skin electrodes applied to skin
   C. Needle electrodes placed into the muscle
   D. All these statements are correct

2. EMG resting recording has the following aspect:
   A. Isoelectric line
   B. Potential derived from a single motor unit
   C. Potential derived from adjacent motor units
   D. Potential derived from all motor units

3. Electromyography is used in:
   A. Work medicine
   B. Sports medicine
   C. Rehabilitation and physiotherapy
   D. All these statements are correct

4. The amplitude of electrical muscle action potentials depends on:
   A. Motor unit size
   B. Recording surface
   C. Contraction synchronization of muscle fibers
   D. A and B are true statements

5. The frequency of electrical muscle action potentials increases with:
   A. Motor unit size
   B. The degree of synchronization of muscle fibers
   C. Muscle contraction importance
   D. All these statements are false

6. Increased muscle contraction force:
   A. It can occur by adding spatial motor units
   B. It may be done through temporary summing of motor units
   C. Determine the increase in frequency and amplitude of EMG recording
   D. All these statements are correct

7. Central neuropathic EMG recording:
   A. It appears in pyramidal tract lesions
   B. It appears in peripheral motor nerve lesions
   C. It occurs in spinal motoneuron lesions
   D. A and C are true statements

8. EMG of peripheral neuropathy route:
   A. It appears in pyramidal tract lesions
   B. It appears in peripheral motor nerve lesions
   C. It occurs in spinal motoneuron lesions
   D. B and C are true statements

9. Normal value of nerve conduction velocity is:
   A. 35-55 m/s
   B. 45-65 m/s
   C. 25-35 m/s
   D. 30 -50 m/s

10. The factors that influence motor nerve conduction velocity (NCV) are:
   A. Peripheral temperature
   B. Perfusion of nerve trunks
   C. Patient's age
   D. All these statements are true

Answers: 1-C; 2-A; 3-D; 4-D; 5-C; 6-D; 7-D; 8-B; 9-B; 10-D.