The advantages of telescopic electrodes in needle electromyography

Alexander Kharibegashvili
Telavi State University Lecturer
Telavi District Hospital Neurologist

Abstract. In Needle EMG measuring motor unit (MU) territory for neuromuscular system evaluation is used. Painfulness and traumaticity of the examination are regarded as serious disadvantages of needle EMG.
The author offers a new needle electrode of telescopic construction, new methods and new parameters for evaluation of motor unit territory and neuromuscular system function.
The new electrode significantly reduces painfulness and traumaticity of tests, new parameters enable to identify (evaluate) the density of motor units and crossing of motor unit territories.
A significant reduction of painfulness and traumaticity of the examination will promote wide use of needle EMG possibly in pediatric patients as well. New methods and parameters enable better evaluation of functional state of motor units and neuromuscular system.

Keywords: electromyography, scanning electromiography, needle electrode, motor unit, painfulness, motor unit territory.

Measuring of motor unit (MU) territory is used in EMG (electromyography). This parameter is important for both, diagnostics of neuromuscular diseases as well as evaluation of the functional state of neuromuscular system.

Earlier, a pair of monopolar needle electrodes [1-4] (Fig. 1) or Buchthal's multielectrode [5-7] (Fig. 2) was used. In the first case the maximum distance between the electrode tips registering action potentials (APs) of motor units (MU) is determined, while in the latter case — maximum amount of sub-electrodes of the multielectrode recording synchronous potentials is determined. Low accuracy of test results and significant levels of pain are negative aspects of these methods.

Erik Stalberg et al have elaborated Macro Emg [8] and Scanning EMG [9] methods which may also be used to measure motor unit (MU) sizes.

When applying Macro EMG method the size of the motor unit (MU) may be identified (evaluated) indirectly according to the amplitude of the MUAP (motor unit action potential). This

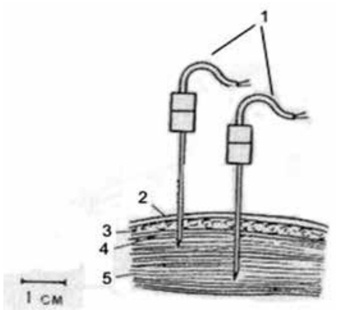

Figure 1 Measuring of motor unit territory with a pair of currently available monopolar needle electrodes

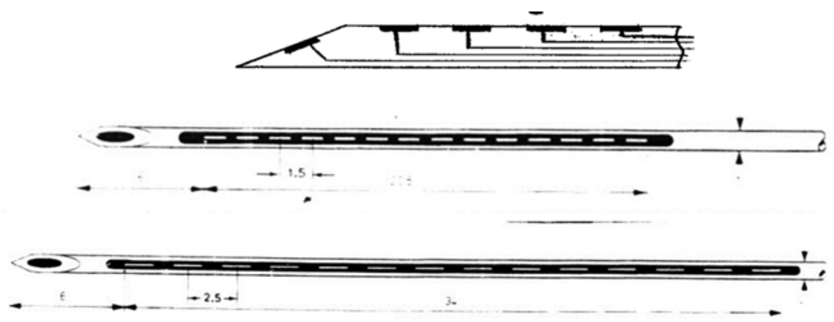

Figure 2 Different types of multielectrodes with different sizes of subelectrodes and distances between them

method is rather labor consuming and inaccurate as evaluation is made indirectly.

Scanning EMG method is based on scanning, i.e. a step-by-step, slow, gradual movement (insetion) of standard concentric needle electrode inside the muscle within the distribution zone of muscle fibers of the tested motor unit, collection of data on changes in action potential of the certain motor unit (MU) and development of relevant image on the display. Additionally, a SFEGM (single fiber emg) needle electrode, used as a trigger, is inserted in the muscle in order to register the APs from an individual fiber of the muscle, and to identify the MUAPs, being recorded by concentric needle electrode and belonging to the same MU from which APs are recorded with needle electrode for registration of the APs from an individual fiber. This method allows precise measurement of MU territories, however, painfulness and traumaticity derived from the necessity of slow and gradual insertion of the electrode in the muscle is very high.

These methods — Macro EMG and Scanning EMG are applied and advanced in modern electromyography [10-13].

We present telescopic bipolar and monopolar needle electrodes for which the patent on invention has been granted [14]. This electrode was previously reviewed in the International Neurological Journal [15]. The article presented now additionally discusses new methods using this electrode, as well as the possibility of widespread use of its simplified version in routine electromyography.

Operating principle of the proposed electrode is based on methods of scanning EMG — gradual withdrawal of the needle electrode from the muscle and recording synchronous APs of MUs provided by E. Stalbreg and L. Antoni [9].

Aim: Reduction of traumaticity and painfulness of EMG examination, improvements in evaluation of functional state of MUs and neuromuscular system, development of new parameters for evaluation of functional state of MUs.

Methods: The aim is achieved by introducing changes in the construction of electrode and EMG examination methods.

Description of the Proposed Needle Electrode Construction

The telescopic bipolar needle electrode provided represents a hollow needle (cannula) 1 (Fig. 3 demonstrates the proposed needle electrode in assembled and dismantled condition),

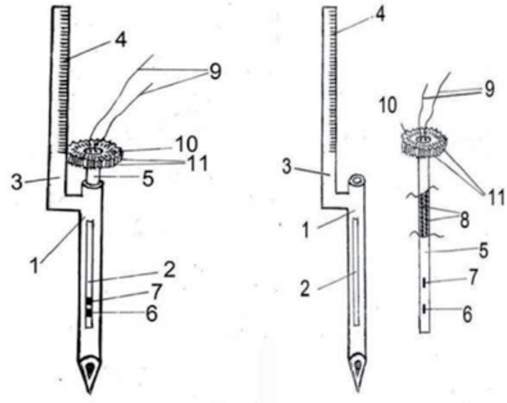

Figure 3 Proposed needle electrode in assembled and dismantled condition

with a canal cut in it 2, a lath 3 with a scale 4 is fastened on the upper end of the hollow needle 1. Dielectric movable rod 5 is placed in the hollow needle (cannula), two sub-electrodes 6 and 7 are fastened on the rod 5. Sub-electrodes 6 and 7 are connected with insulated electrical conductors- wires 8, which are located inside the dielectric rod 5. Conducting wires 8 emerge from the upper end of the dielectric rod 5 and connect with the wires 9. There is a cogwheel 10 with toothed edges 11 on the upper end of dielectric rod 5.

The proposed electrode may be executed in monopolar design (Fig. 4) and without the cogwheel and the lath (Fig. 5).

Description of the Operating Principle of the Proposed Telescopic Needle Electrodes and New Methods for Measuring Motor Unit Territories of Muscles

Before using the needle electrode, the dielectric rod 5 is placed in the hollow needle (cannula) 1. Then the needle electrode (hollow needle) 1 is inserted in the muscle and the dielectric rod 5 is gradually withdrawn from the hollow needle (while the hollow needle remains motionless in the muscle). Simultaneously electric activity of the muscle is recorded from the two sub-electrodes 6 and 7, emerging from the hollow needle 1 canal 2. While gradually removing the dielectric rod 5, if the sub-electrodes 6 and 7 are located within one MU, the electrical activity recorded by them (the sub-electrodes) will be synchronous. When the upper sub-electrode 7 crosses the MU border and sub-electrodes 6 and 7 happen to be on the opposite sides of the border (i.e. in different MUs) the electrical activity recorded by them will be asynchronous. The depth of the MUs border l_1 is identified according to the position of the cogwheel 10 as per the scale 4 given on the lath 3. When the lower sub-electrode 6 also crosses the border between the MUs and both electrodes are once again found within the border of a single MU, the electric activity recorded by them again becomes synchronous. Gradual removal of dielectric rod 5 from the hollow needle 1 continues (with the hollow needle remaining motionless) and desynchronization points of MUAPs are identified as MU borders in the muscle l_1, l_2, l_3 etc. Then the MU territories $l_2 — l_1$, $l_3 — l_2$ etc. are identified along the whole depth of the needle electrode.

In order to be fully convinced that both sub-electrodes of the bipolar electrode are inside the MU being tested, we may additionally insert the proposed electrode in monopolar design in the muscle. Electrical activities recorded by sub-electrodes of the bipolar electrode may be compared as per their synchronous or asynchronous nature not only against each other, but against electrical activities recorded by sub-electrode of the additionally inserted monopolar electrode in order to know that the electrical activities recorded by sub-electrodes of the bipolar electrode are from one and the same MU and not from the fibers of the other MU crossing the above MU. While electrical activity recorded by sub-electrodes of the bipolar electrode is synchronous with electric activity recorded by sub-electrode of additionally inserted monopolar electrode, sub-electrodes of the bipolar electrode are within the borders of the single MU. If when moving the bipolar electrode rod electric activity from one of the sub-electrodes of the bipolar electrode becomes asynchronous with electric activity recorded from other sub-electrode of the bipolar electrode and with the electric activity recorded by sub-electrode of the monopolar electrode this will indicate that the given sub-electrode has crossed the MU border.

In order to identify the MUs and the areas of their crossing we may employ two proposed electrodes in monopolar design. (Fig. 4). Using alternately dielectric rods of monopolar needle electrode together with the sub-electrodes are moved from one MU to another, identifying desynchronization points as MU borders depth l_1, l_2, l_3 etc., and identifying the MU sizes $l_2 — l_1$, $l_3 — l_2$, etc. as well as the size of the areas of their crossing.

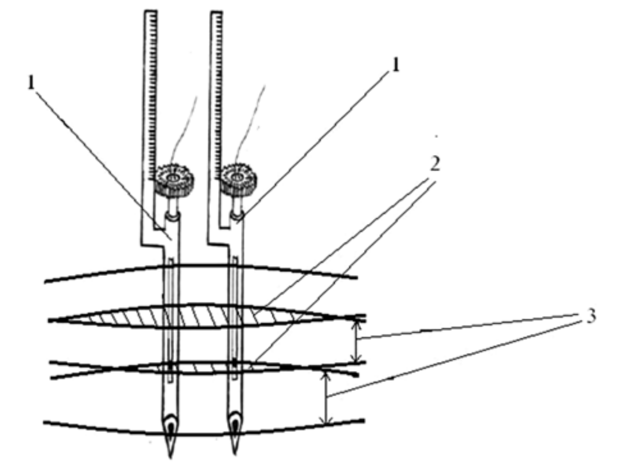

Figure 4 1 — Telescopic monopolar electrode with single sub-electrode, 2 — crossing areas of MUs, 3 — Motor units

Resalts

EMG examination with currently available needle electrodes requires manipulations with these electrodes, frequent movement of the electrodes forwards and backwards resulting in significant increase of pain and traumaticity.

In EMG examination with the proposed telescopic bipolar and monopolar needle electrodes, only the dielectric rod 5 placed in the hollow needle is moved, the hollow needle remains motionless in the muscle. This dramatically reduces painfulness and traumatic nature of the examination.

MU territories S as well as areas of their crossing Sca can be measured using these methods. 20 MU territories, 20 crossing areas of MU territories can be measured and average values S (av) and Sca (av) identified. After that, relative crossing area is identified RCA=Sca (av) / S (av) x 100%, the author offers this parameter to estimate the intensity of MU crossing.

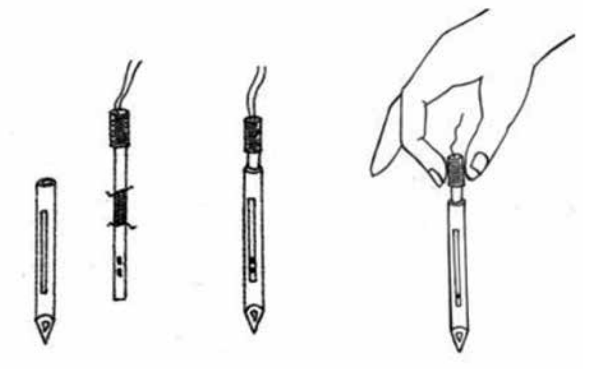

Figure 5 Proposed needle electrode for routine electromiography tests in assembled and dismantled condition

In addition, by using bipolar telescopic electrode or two of the proposed monopolar telescopic electrodes we may define the number of MUs at a certain depth of a muscle — segment L. If we move the bipolar electrode rod together with the sub-electrodes along a certain segment of a muscle and calculate the borders of MUs on this segment — n, we may be able to calculate the number of MUs — K. As when moving the sub-electrodes two borders are identified for each MU, the number of MUs on the given segment L will be $K=\frac{n}{2}$. The author offers a new parameter — MU density (MUD), which equals to the ratio of the number of MUs on a certain segment L of a muscle K towards the L — segment length in centimeters $MUD=\frac{K}{L}$.

We may consider that three-dimensional bioelectric activity localization method, used in electroencephalography, may also be used in future in electromyography along with 14 subelectrode multielectrode or surface electrodes for localization of MUs and their borders.

Discussion

The New parameters offered by the author — Relative crossing area (RCA) and Motor unit density (MUD) enables us to better evaluate the functional state of neuromuscular apparatus and motor unit.

Significant decrease of pain and traumaticity of the examination gives us basis to consider the use of the proposed electrodes in routine EMG. The employment of the proposed electrode in routine tests is of crucial importance as the majority of patients dread of pain and needle puncture.

For routine EMG tests the proposed electrode may be of a simpler construction without the toothed cogwheel and the lath (Fig. 5).

The patient will only feel the pain when inserting the electrode in the muscle. If the needle electrode is inserted in the muscle quickly, the pain will be reduced to the minimum. During the examination, instead of having to move the needle electrode for an hour or more in order to receive a high-quality recording, only the dielectric rod inserted in the cannula is moved in case of the proposed project, while the cannula itself remains motionless in the muscle. As a result, the patient does not experience pain during the examination process.

And this moment — sharp decrease of pain and trauma — perhaps will allow us to employ the EMG testing with needle electrodes in pediatric patients.

Abbreviations:

SFEMG — single fiber emg
EMG — electromyography
AP — action potentials
MU — motor units
MUAP — motor unit action potential
RCA — relative crossing area
MUD — motor unit's density

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