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REDUCING PAINFULNESS AND LABOR INTENSITY AND INCREASING ACCURACY OF TESTS IN NEEDLE ELECTROMYOGRAPHY

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Abstract

In Needle EMG measuring motor unit (MU) territory for neuromuscular system evaluation is used. Painfulness and traumaticity, labor intensity 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 labor intensity, painfulness and traumaticity of tests, new parameters enable to identify (evaluate) the density of motor units, crossing of motor unit territories and other characteristics of muscle. 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 electromyography, needle electrode, motor unit, painfulness, motor unit territory, labor intensity.

Introduction

Needle electromyography is one of the most adequate EMG methods providing the most complete information on the state of the peripheral neuromuscular system. The founder of the needle electromyography method is F. Buchthal. The method of needle electromyography is based on the study of motor units of skeletal muscles. Today needle electromyography (EMG) is an indispensable method of research not only in neurology, but also in rheumatology, endocrinology, dentistry, orthopedics and other areas of medicine.

Needle electromyography has a crucial role in diagnostics of neuromuscular diseases. Depending on the specific situation, electromyography of several muscles is performed. In some cases, the doctor examines the state of three muscles.

The difficulty of the needle EMG technique is that recording the potential of one motor unit (MU) is insufficient to judge the state of all muscle MUs; a sample of 20 motor units from their entire population is representative. The drawback of this research is that it is a painful, lengthy, traumatic procedure for the patient and a difficult and laborious one for the doctor. Routine electromyography takes 0.5-1.5 hours during which the electromyographist constantly moves the needle electrode to and forth in the muscle in order to obtain optimal location against the motor unit fibers. As a result, the procedure causes persistent pain to the patient and is labor-intensive for the physician.

Aim: Reduction of traumaticity and painfulness, labor intensity of EMG examination, improving the efficiency of measuring muscle motor unit territory and evaluation of functional state of MUs and neuromuscular system. Development of new parameters for evaluation of functional state of MUs.

Methods and Materials:

Study of the existing literature regarding the equipment and methods of needle electromyography, consideration of their positive and negative sides, introducing changes in the construction of needle electrodes, and EMG examination methods.

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, significant levels of pain and labor intensity 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).

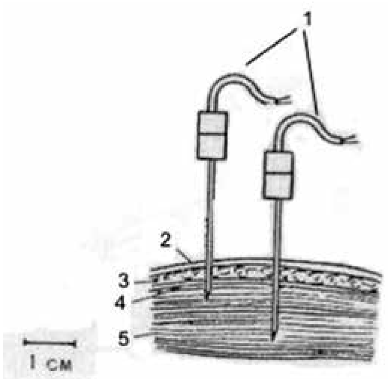

Figure 1 Measuring of motor unit territory with a pair of currently available needle electrodes

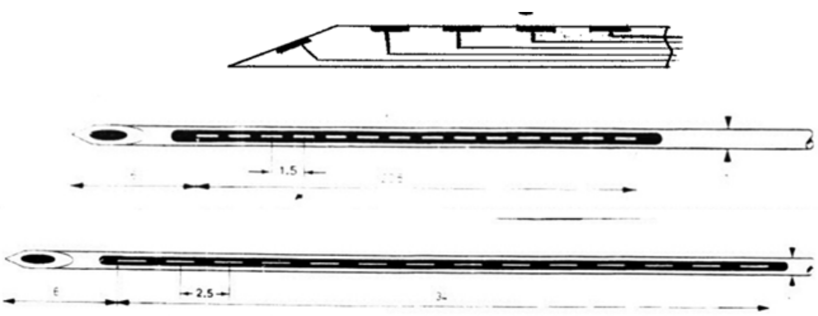

Figure 2 Different types of multielectrodes with different sizes of subelectrodes and distances between them

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This 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].

A new type of mono- and bipolar needle electrodes has been developed by us In Telavi State University, Georgia, Caucasus, – a telescopic electrode, acknowledged as an invention by the state. The telescopic bipolar needle electrode provided represents a hollow needle (cannula) 1 (Fig. 3 demonstrates the proposed needle electrode in assembled and dismantled condition), with a canal (longitudinal cutout) cut in it 2, a lath 3 with a scale 4 is fastened on the upper end of the hollow needle 1.

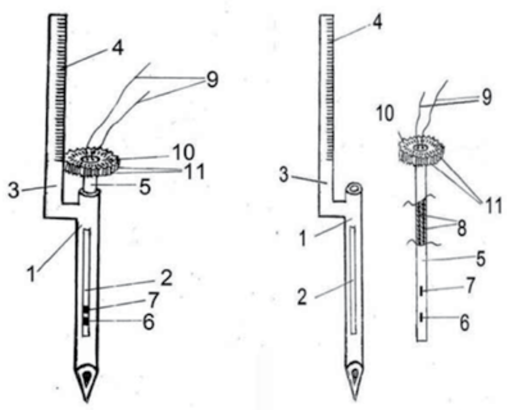

Figure 3 Proposed needle electrode in assembled and dismantled condition

Dielectric movable rod 5 is placed in the hollow needle (cannula) 1, 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 (longitudinal cutout) 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_2, l_3— l_2 etc. are identified along the whole depth of the needle electrode.

In order to be fully convinced that both subelectrodes 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 subelectrodes 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 subelectrode 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.

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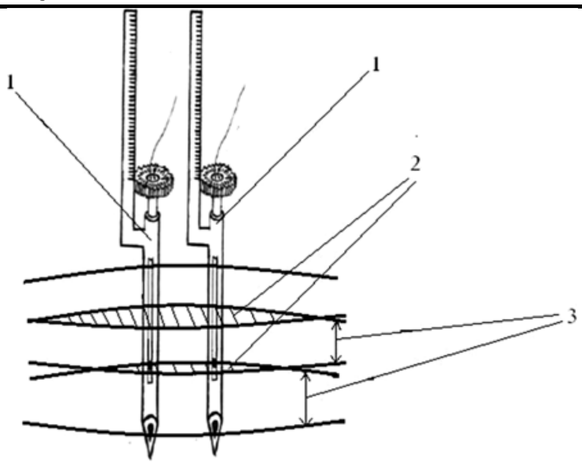


Figure 4 1 — Telescopic monopolar electrode with single sub-electrode, 2 — crossing areas of MUs, 3 — Motor units

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 depths 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.

Results

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.

The overlap of MUs can be determined in another way: divide the length of the segment L by the sum of the MU territories located on this segment L (the sum of the ME territories located on this segment L will be greater than L due to the overlap of MUs) and multiply by 100 (%). We suggest calling this - ,, total overlap"-TO.

TO=L/(l1 + l2 + l3 +...)x 100

Counting the number of preserved MUs may be important in the differential diagnosis of diseases, but its role in assessing the progression of the pathologic process is even more significant. Quantitative assessment of preserved MUs is now considered to be an important biomarker in evaluating the effectiveness of newly developed motor neuron disease treatment technologies. Therefore, over the last decades, electrophysiologic methods for estimating the number of DEs have been searched for, and today they are united under the common name MUNE (Motor Unit Number Estimation)[16]. It should be noted that the development of MUNE methods is complicated by the fact that today there are no alternative reliable methods for determining the true number of units.

We propose Motor Unit Number Estimation on the sertain segment L - MUNE-L, and on the certain square S - MUNE-S.

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 — k, we may be able to calculate the number of MUs — n. As when moving the sub-electrodes two borders are identified for each MU, the number of MUs on the given segment L will be n=k/2 (MUNE-L). If we count n MUs on the two sides -segment L of square n_1 and n_2 then the area S= L x L of the muscle will contain N= n_1 x n_2 number of motor units (Motor Unit Number Estimation on the certain square S - MUNE-S).

The author offers also a new parameter — MU-s density (MUSD), which equals to the ratio of the number of MUs on a certain segment L of a muscle n towards the L — segment length in centimeters MUD=n/ L.

In the existing literature, the measurement of motor unit potential (MUP) density [17] has been proposed.

MUP density is determined by the ratio of area to amplitude and is the most sensitive indicator of myopathic disorders (density reduction), because MUP amplitude indirectly characterizes the density of muscle fibers adjacent to the electrode and is measured from the point of positive peak to the point of negative peak.

Additionally, we propose to measure muscle density.The muscle density (MD) is equal to the sum (S) of the amplitudes (A) of the MUs on a segment L divided by the length of that segment SA/L. Since the MUs territories overlap, the muscle density (MD) will be greater than the MUP density and will reflect the density of muscle fibers of all MUs in a given muscle segment 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.

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

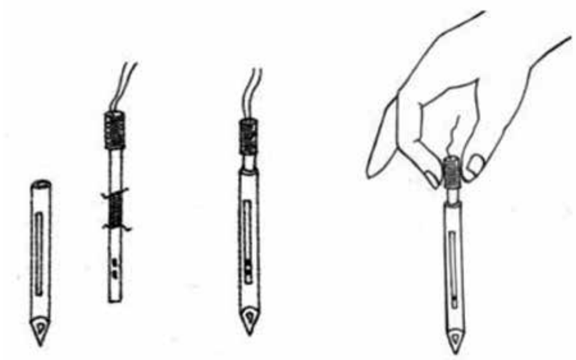
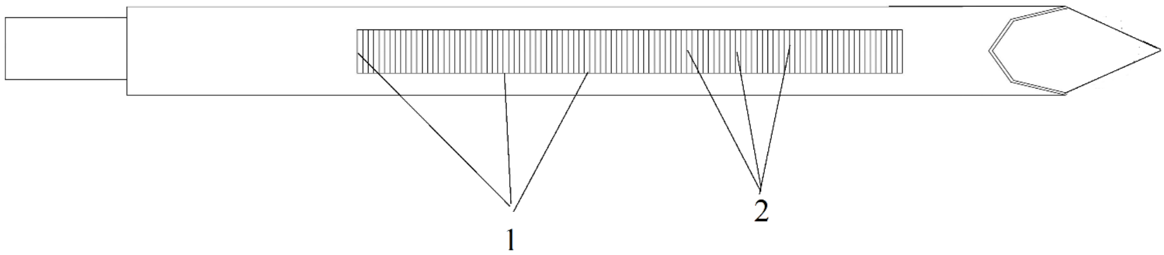
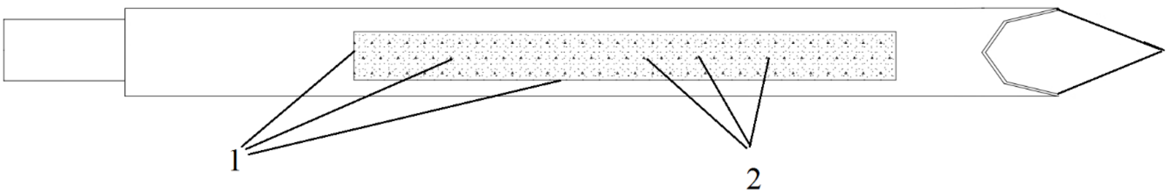


Figure 5 Proposed needle electrode for routine electromiography tests in assembled and dismantled condition

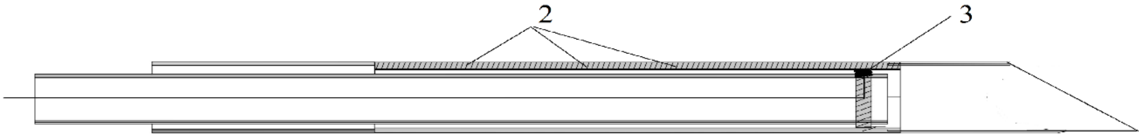
With the development and cheapening of the technology, a dielectric plate, curved with the same radius as the cannula wall - as an extension of the cannula wall - can be fixed in the longitudinal cutout of the cannula wall (Fig. 6).
In the dielectric plate there will be fixed vertically placed and insulated from each other thin wires - metal threads, or metal strips, one end of which will end on the outer side of the cannula wall and touch the muscles, and the other - on the inner side of the cannula wall and touch the contact surface of the dielectric rod protrusion.



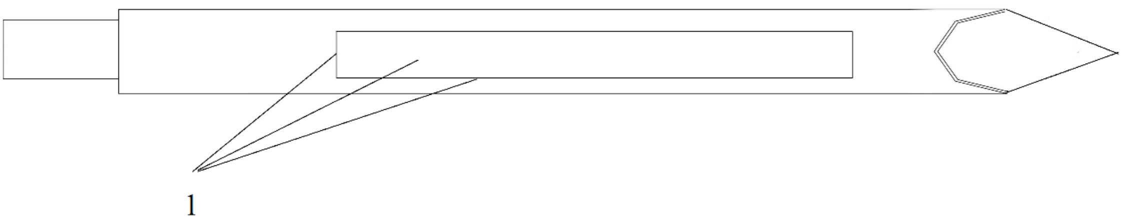
a) 1 – dielectric plate, fixed in the longitudinal cutout of needle electrode, 2 –insulated metal strips



b) 1 – dielectric plate, 2 –insulated metal wires



c) sectional side view, 2 - insulated strips or wires in dielectric plate 3 - dielectric rod protrusion with contact surface



d) above view, 1 - electrically anisotropic plate

Fig. 6 Needle electrode with plate in the canal – longitudinal cutout

a) above view of needle electrode, dielectric plate with insulated metal strips, b) above view of needle electrode, dielectric plate with insulated metal wires, c) sectional side view of needle

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electrode, dielectric plate with insulated wires or strips d) above view of needle electrode, needle electrode with electrically anisotropic plate in the canal (longitudinal cutout)

A protrusion is created on the dielectric rod with a platform on which a contact surface is applied, which in turn is connected to a conductor located inside the dielectric rod. The contact surface is in movable contact with the inner wall of the dielectric plate with wires vertically located in it. The larger the contact surface of the dielectric rod protrusion, the more wires or strips will come into contact with it (the protrusion) and the electrical signals from a larger area of the muscle will be collected and recorded on the electromyograph. If a material with sufficient electrical anisotropy is created, an electrically anisotropic plate can be installed in the longitudinal cut of the needle electrode, which will conduct electric current only in the vertical direction.

To reduce the complexity of electromyography examination, we propose to connect a hollow needle and a dielectric rod to a microscrew (Fig. 7).

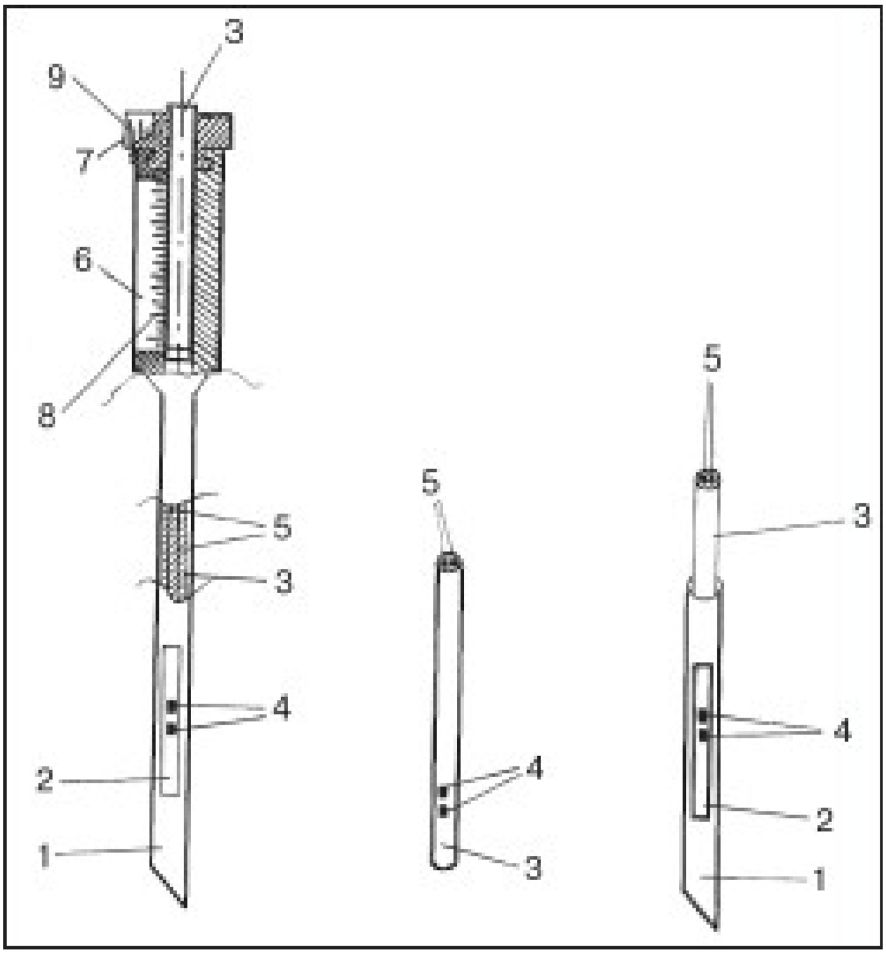

Fig. 7 6 - moving mechanism case, 7 – nut, scale 8 of case 6, scale 9 of nut 7

On the dielectric rod 3 thread is created, and a nut 7 is put on the rod, scales 8 and 9 are applied to the movement mechanism case 6 and on the nut 7. When the nut 7 is fully turned, the mark on the rod (it is not shown on the figure) moves one scale division on the case scale. That is, the divisions on the nut 7 scale 9 are subdivisions of the scale 8 on the case 6. On the dielectric rod are affixed one (monopolar electrode) or two microelectrodes (bipolaar electrode).

In modern electromyographs, selection and analysis of MU-s potentials are performed automatically. Computer analysis of MU-s allows to estimate density, size index, stability index, and regularity. The electromyographist merely inserts and moves the needle electrode in the muscle to achieve an optimal location near the motor unit (MU) fibers.

If we connect the micro screw of the proposed electrode to a micromotor and a computer, the electromyographist only has to insert the needle electrode into the muscle, the rest - the movement of the dielectric rod with the microelectrode and the analysis of the electromyogram will be performed automatically by the computer.

Discussion

The New parameters offered by the author — Relative crossing area (RCA), Motor unit density (MUD), muscle density (MD), total overlap -TO 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.

Connecting a needle electrode to a microscrew, micromotor and computer makes the EMG test fully automated and significantly reduces labor intensity.

With this device, 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

MUSD — motor unit's density

MD - muscle density

TO - total overlap

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