Qualitative analysis of the influence of concentric needle electrode components on motor unit potential

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In order to analyze the influence of Concentric needle electrode (CNE) components, 36 healthy volunteers were examined. MUAP parameters were analyzed after applying the manual method of extraction. The research was performed on the following muscles: m. vastus lateralis (MVL; depth of insertion were 0 cm/subfascial insertion and 1.5 centimetre (cm) perpendicularly (90^0) and obliquely (45^0) on muscle fibre direction, and temporal muscle (depth of insertion 0 cm/subfascial insertion and 1.5 cm rectangular (90^0) on muscle fibre direction or parallel on fossa temporalis) on either side. In contrast to monopole montages, the qualitative EMG analysis confirmed that EMG potential detected with CNE is not relevant enough to determine the precise location of muscle (end-plate, tendon); compared with that of the central core waveform, the MUAP shape recorded by CNE is usually different. It has also been confirmed that cannula, albeit in rare cases, might have a "contributing" instead of "diminishing" influence on CNE MUAP parameters, and this, in turn, might lead to a wrong interpretation or even pathological findings. In view of the contributing effects of CNE components we recommend a qualitative division of MUAPs of healthy persons.

Key words: Motor unit potentials, Concentric needle electrode.

Introduction

The muscular fibres of a single motor unit (MU) are distributed in the circular region of muscles stretching 5-7 mm in the upper extremities and 7-12 mm in the lower extremities (1). There is a somewhat higher density close to the centre of the region (2). The action potential of a motor unit (motor unit action potential MUAP, or motor unit potential MUP) reflects a summary of the activities of a certain number of muscle fibres of the MU during voluntary contraction. The first positive phase occurs when the impulse gets close to the recording electrode. The second negative phase occurs during depolarisation, while the third positive phase reflects repolarisation. The curve of detected

MUAPs in electromyographic (EMG) analysis consists of several components.

Amplitude is measured from the maximally positive to maximally negative deviation from MUAP. It is proportional to the number of activated musle fibres in the vicinity of the electrode. Lempe and Thile (1984) report the mean value of distance between the active muscle fibres and the electrode to be a more important factor than their respective diametre in regard to the MUAP amplitude (3). Potentially inactive fibres of other MUs can appear between those MU fibres which are dielectric and act as a filter, reducing the executive component of a single muscle fibre's potential (4, 5), exceeding 90% in only 200-500 μm (6).

Area: the surface of MUAP – reflects the values of duration and amplitude. There is evidence that 65% of MUAP area is built of 2 to 12 (on average 5) action potentials of muscle fibres (7).

Duration: denotes "deviation from", and "return to" the base line. It is also defined as the initial and final point of the slow component of MUAP. The greater the variations between the speed of conducting of the MU fibres, the longer the duration of MUAP. It is a reflection of the temporal and spatial summation of the electrical activities of MU muscle fibres (8). It is also the most reliable indicator of a pathological process (9, 10).

Number of phases: " number of crossings of the base line of MUAP plus one". MUAPs commonly have up to 4 phases, while those with 5 or more phases are the so-called polyphasic potentials. This depends on the synchronisation level between muscle fibre potentials in the vicinity of the electrode (11).

Turn implies a revision of polarity which does not cross the base line during the phase. When MUAP consists of more than 5 turns it is called "serrated" or "complex".

In neuromuscular diseases the MUAP configuration is disturbed. In neuropathological diseases the collateral reinnervation after the release of particular motor units increases the size of MU, resulting in the increase of the amplitude and duration of MUAP. The incidence of polyphasic MUAPs can increase. The most reliable criterion for *miopathy* is a shorter duration (11) along with a complete recruiting sample of lower amplitude, accompanied by the increase in the number of polyphasic MUAPs.

However, in MUAP analysis it is necessary to know the features of the recording electrodes. In order to record the biological electric activity it is necessary to have two electrodes. When both electrodes are placed close to the source of electric activity the mode of recording is determined to be bifocal or bipolar, but if one electrode is placed at a distance from the source, we have a monofocal or referential recording. Regardless of this, a certain amount of electrical activity of the tissue is recorded from both electrodes. In practical performance the *concentric (coaxial) needle electrode (CNE)* is composed of the central core which serves as the „active" electrode and of the outer part, cannula serving as a referential electrode. But the cannula itself is not entirely indifferent (12); its potential equals the mean value of tissue potential along the surface of the electrode (13). In a routine EMG analysis MUP is, in fact, the difference of potentials recorded either by the central core or cannula.

The aim of this research was to confirm modes in which MUAP parameters, recorded by CNE, change in healthy persons, dependent on the activities of its components (the central core and the cannula).

Subjects and Methods

The research was conducted on 36 healthy volunteers of both sexes (21 or 58 % males), and average age of 33±11 years. The research was performed on the following muscles: m. vastus lateralis (MVL) and temporal muscle on either side. Depth of insertion were 0 centimeter (cm) or subfascial insertion, and 1.5 cm perpendicularly (90°), parallel (0°), and obliquely (45°) on muscle fibre direction for MVL, and 0 cm/subfascial insertion, and 1.5 cm rectangular (90°) to muscle fibre direction and parallel on the temporal fossa for temporal muscle. Subfascial insertions were detected by "insertional activity" and used as starting points for deeper (1.5 cm) insertions. The data collection of the MUPs was obtained manually – by applying the method of "averaging". The total number of MUPs collected for MVL was 52 for subfascial insertions and 50 for deeper (1.5 cm) insertions. The total number of MUPs collected for temporal muscle was 42 for subfascial insertions, and 40 for deeper insertions. Only characteristic MUPs, regardless of their incidence rate, depth of insertion, or kind of muscle were selected for analysis. As is well known, the MUP analysis itself is qualitative by nature, implying only quantitative MUP recordings without taking into account their incidence rate.

Simultaneously, on three separate channels we presented the potentials recorded between the diminishing surfaces of CNE, and separately, of the CNE recordings between the cannula and central core with the distant surface referential electrode placed on the skin above the patellae. MUPs were recorded during a looser, voluntary contraction while calculation of their average value was performed until the elimination of "artefacts". Respecting the criteria established by Stålberg et al. (1986) only MUPs were selected and analyzed with amplitudes over 50 μV (9) and a rise time of the initial positive to negative slope of less than 0.5 ms.

Medelec - Synergy EMNG apparatus was used in the present analysis. The filters were positioned at frequencies between 20 and 20.000 Hz. The MUP analysis was carried out with the enlargement of 20 μV/cm.

Results

The typical examples of triphasal MUPs obtained manually by the method of „averaging" – are presented in Figure 1. Activities of such MUPs are recorded by the central core. However, qualitative analysis showed a significant deviation of the MUP morphology from the „classical" triphasal ones. The highest activity of such MUPs is recorded by the central core. On the other hand, quantitative analysis showed significant deviations of MUP morphology from the „classical" triphasal ones. Although these features divide potentials roughly into several groups, each particular group may contain elements from the other groups apart from the dominant ones. The following MUP groups were detected:

I MUP which reflects realistically or fictionally the end-plate (EP) or tendon (figure 2 and 3);

II MUP with the amplitude recorded by CNE being higher than that recorded by the central core (figure 4)

- A. The central core is in the territory of MU, while the cannula contributes to the CNE amplitude.
- B. The central core is far from the MU, while the cannula, positioned in the territory of MU, contributes significantly to MUP

III MUP wherein both the cannula and the central core register different fibre populations (figure 5)

- A. The CNE potential is indented, while that of the central core is smooth, and vice versa
- B. A greater number of phases in the central core from MUP to CNE

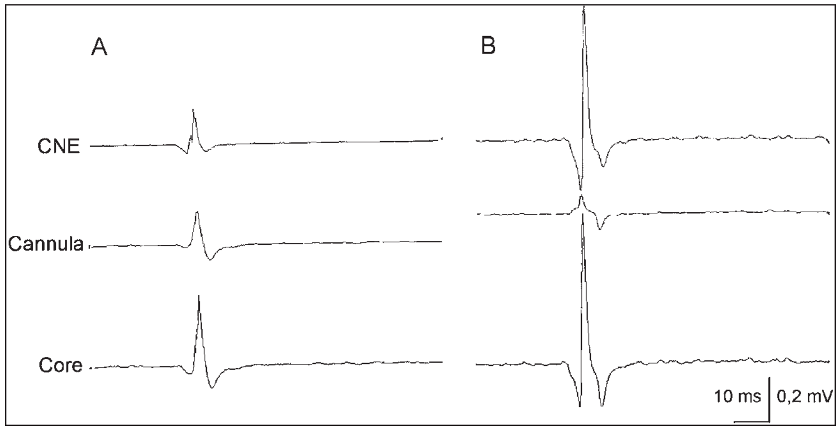

Figure 1 Examples of MUP obtained manually – by method of averaging
– From top to bottom: potential recorded with CNE by a cannula and central core MVL, insertion 90^0, depth1.5 cm.

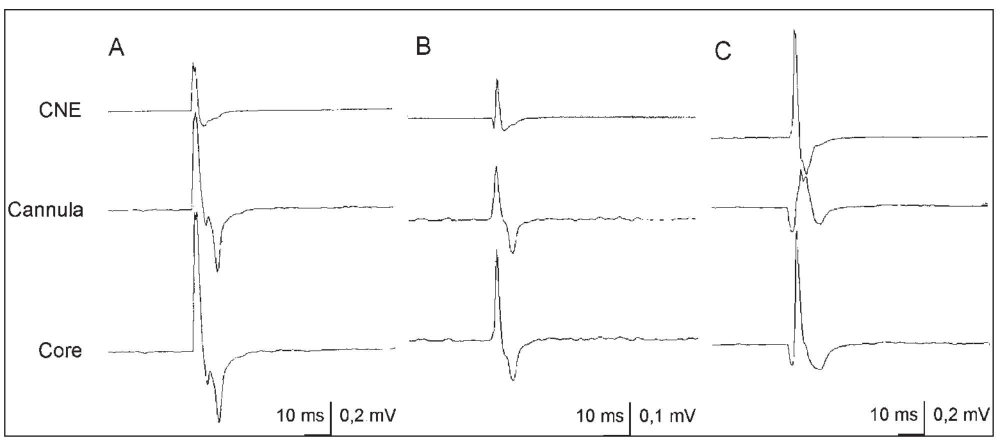

Figure 2 MUPs which reflect really or fictitiously end-plate (EP)
A. Region of EP. Classical example of bipolarl (-+) waveform on all channels. MVL, subfascial insertion. B. Region of EP, but diminishing of the cannula (channel 2) from central core (channel 3) gives 3 phases on CNE. MVL, subfascial insertion. C. Impression of EP on CNE because of diminishing of the cannula (channell 2) from central core (channel 3). MVL, insertion 45°, depth1.5 cm.

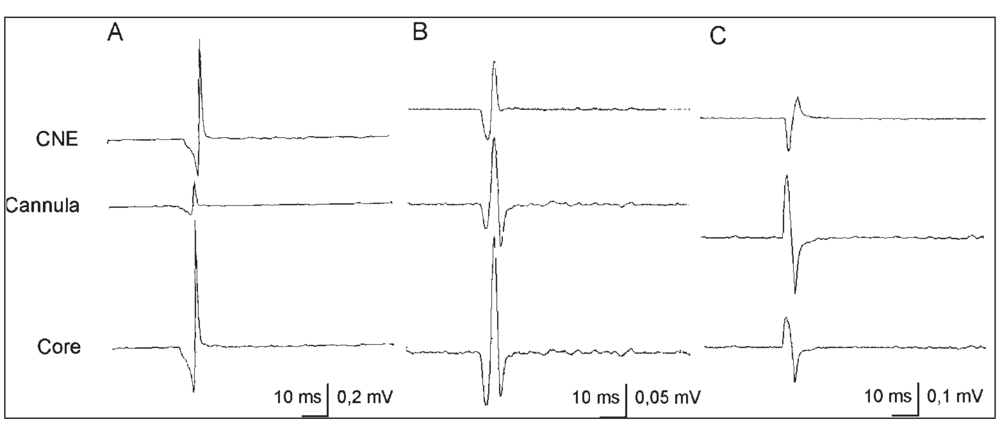

Figure 3 MUPs which reflect the tendon really or falsely
A. Region of tendon. Classical example of bipolar (+-) waveform on all channels. MVL, insertion 90°, depth1.5 cm. B. Impression of tendon on CNE because of diminishing of cannula's final positivity (channel 2) from central core (channel 3); shorter duration. MVL, insertion 90°, depth1.5 cm. C. Dominant contribution of cannula whose MUP (channel 2) is bigger than MUP of central core (channel 3). Region of EP (visible on channels 2 and 3), but diminishing of cannula from central core provides a false tendon shape on CNE with +-phase. Temporal muscle, insertion 90°, depth 1.5 cm.

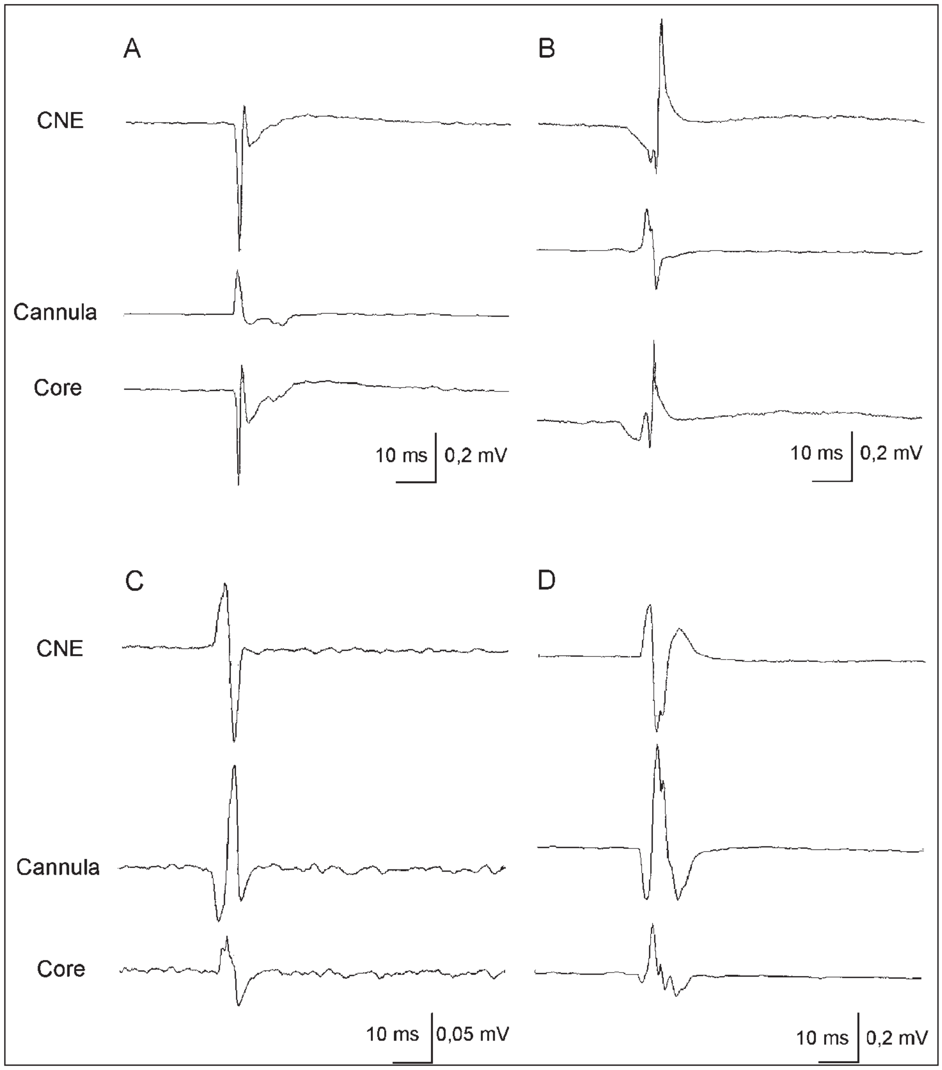

Figure 4 MUP whose amplitude recorded with CNE is larger than that recorded with central core
A, B. Central core is in MU territory with a cannula contributing to CNE amplitude. MVL, insertion 90°, depth1.5 cm. C, D. Central core is located far from MU while the cannula, located in MU's territory, contributes dominantly to MUP. MVL, insertion 90°, depth1.5 cm.

Discussion

The first MUP group consists of MUPs which really or falsely reflect the end-plate (group IA, figure 2) or tendon (group IB, figure 3). The typical MUP lacks the initial positive component after CNE insertion in the EP region (figure 2A) and as a result, the bipolar (-+) MUP remains on all channels (cannula 2, central core 3). However, after insertion into the EP region, it is possible to record three phases with CNE due to the differing arrival times of the main negative peak of MUP on the cannula or central core and of the „diminishing" of the cannula from the central core (figure 2B). A false impression of end-plate on the CNE because of the „diminishing" of the initial positive component along the cannula from the central core is also a possibility (figure 2C).

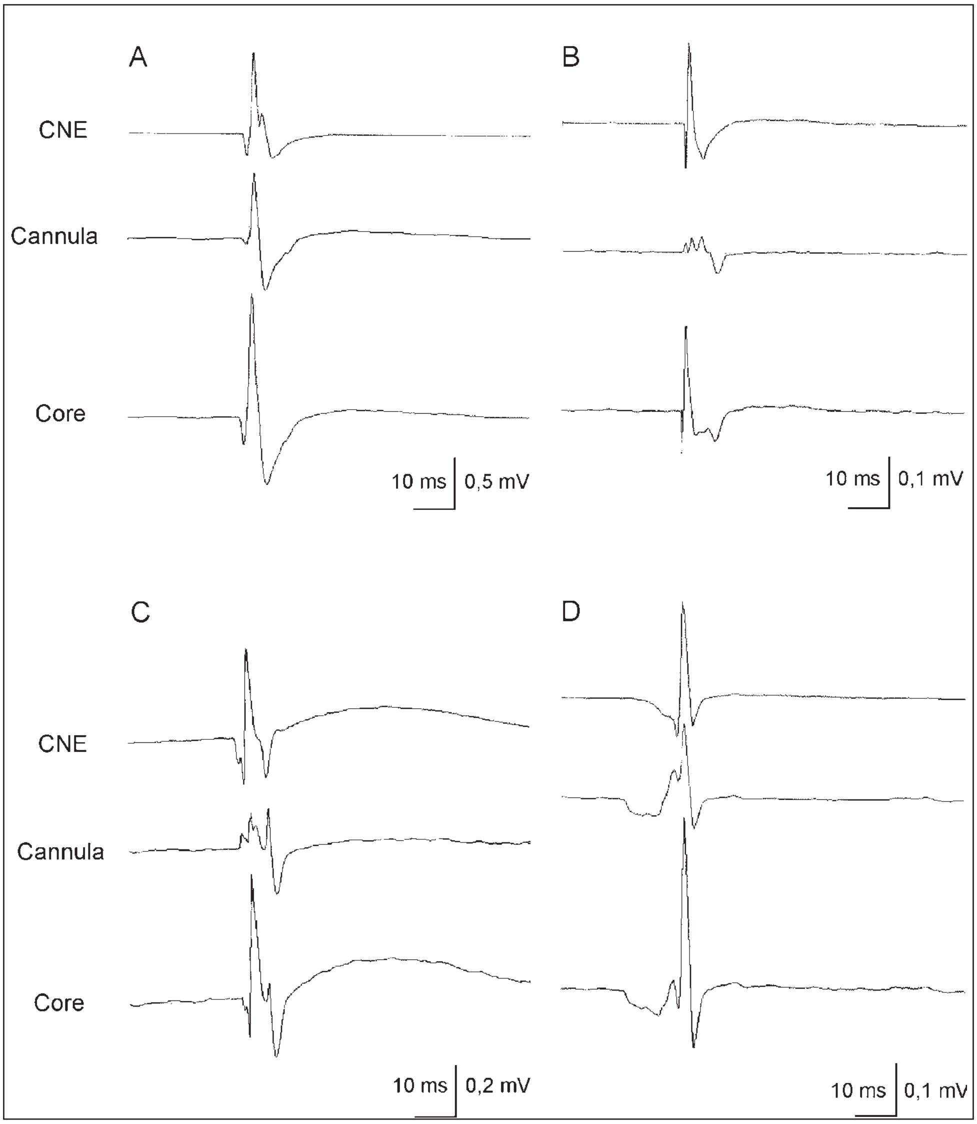

Figure 5 MUPs wherein the cannula and central core detect various fibre populations. Potential of CNE is serrated while that of the core is smooth, and vice versa, A. Various fibre populations are detected by the cannula (channel 2) and central cores (channel 3). The result is a serrated but triphasal potential of CNE (channel 1). MVL, subfascial insertion. B. Central core (channel 3) and cannula (channel 2) detect their own fibre population. Fractions of cannula (like macro- EMG). MVL, subfascial insertion. C. A bigger number of phases on central core from MUP on CNE. Central cores (channel 3) and cannula (channel 2) register different fractions. Polyphase of potential registered by central core (channel 3), but diminishing of fractions provides CNE's potential (channel 1) which has three phases. MVL, insertion 90°, depth1.5 cm. C. One fraction of MU is detected in the same manner by both electrodes (cannula on Channel 2, and central cores on channel 3), and that is being diminished on CNE (channel 1), and as a result (instead of several phases or serrations smooth potential emerges on CNE). MVL, subfascial insertion.

A classical example of a bipolar (+-) waveform upon the CNE insertion in the region of the tendon is recorded on all channels (figure 3A). However, there is a possibility of a false „impression" of the tendon on the CNE because of the „diminishing" final positivity of MUP which is gathered thanks to the cannula from the central core MUP (channel 3) so that the CNE MUP is of a shorter duration (figure 3B).

The finding in figure 3C is very interesting. In this case the CNE is inserted in the region of the end-plate (which is visible on channels 2 and 3 where initial positivity of the MUP is missing), but the „diminishing“ of the cannula MUP from the central core MUP gives a shape of the tendon on the CNE with a +- phase. Here, it is obvious that the contribution of the cannula is significant to MUP of a higher amplitude in relation to MUP of the central core, positioned farther from the MU than the cannula (and as such, it has a smaller MUP amplitude),. The cannula's negativity provides the initial positivity for the CNE while its positivity provides the final negativity for the CNE. Taking into consideration the fact that such potentials shorten the duration of MUP on the CNE, it is possible to obtain not only a false picture of the location but also to come to a false judgment of a myopathic process in certain circumstances.

The following MUP group (group II) displays an amplitude recorded with CNE higher than that recorded by the central core (figure 4).The figure 4A displays the MUP with the obvious difference of the observed fractions of the core located in the MU territory (a higher amplitude) in relation to the cannula. Negativity of MUP on the cannula within the MP, lacking the initial positivity, appears at the similar time as the initial positivity of the MUP onto the central core, and consequently, thanks to this „addition“ contributes to an increase in amplitude of the MUP's initial positive phase on the CNE. The negativity of the MUP collected from the central core remains relatively unchanged in relation to the CNE. The final result is that the CNE has a higher MUP amplitude than the central core (group II A). In the case of the „contributing“ influence of the cannula, the pattern on CNE might be falsely diagnosed as neuropathic.

Similar findings were recorded in the next example (figure 4B). The cannula MUP contributes to the MUP amplitude on the CNE so that the potential is of a higher amplitude than that on the central core whose MUP is still of a higher amplitude in relation to cannula, and thus it is „closer“ to the MU's territory. Here, the first negative phase of the MUP recorded by the central core is annulled.

In both examples the central core is located in the MU's territory while the cannula contributes to the amplitude of the concentric needle electrode potential (group IIA).

The MUPs follow recorded with the central core located far from the motor unit (group IIB) while the cannula, located in the motor unit's territory, contributes by and large to the motor unit's potential (figure 4C and 4D). Figure 4C displays the bipolar (-+) MUP recorded with CNE which, in fact, reflects the region of the end-plate. The peak of the central core is far from the MU so that the MUP, collected there, is of an amplitude lower than that of the cannula, but at the same time is bipolar (-+). The classical triphasal MUP of the cannula prevails since it is closer to the MU's territory, and this is obvious from its higher amplitude in relation to central core's MUP. Because of the initial positivity of the cannula which is "added" to the initial negativity of the central core the first-negative phase occurs on the CNE of a higher amplitude than the negative phase of the MUP on the central core. On account of the main negative phase of the cannula MUP the final positive phase on the CNE occurs. Here erasure occurs of the identical, final positive phases of MUPs of both the central core and cannula. The CNE displays MP of the end-plate with two fractions (-+). Regarding MUP in the IIB group there is a larger number of phases of motor unit potentials of the central core than of the CNE.

In the next example (figure 4D) it is obvious that the peak of the central core is located far from the centre of the MU's territory, and as a result, MUP of a lower amplitude has been recorded. The MUP of the cannula prevails because it is located within the territory of the MU. On account of the initial positivity of the cannula MUP the first-negative phase on the CNE MUP occurs. In this example there is no erasure of the final positive phase of the central core (being smaller) and the cannula (being larger), resulting in the final, negative deviation on the CNE. As a result the CNE displays three unusual fractions (-+-).

There follow MUPs (group III) wherein the cannula and the central core register different fibre populations (figure 5)

In the IIIA group the potential of the concentric needle electrode is indented while that of the central core is smooth, and vice versa (figure 5A). The MUP of different fibre populations detected by the cannula and central core is displayed. The result of the "diminishing" of the main negativity of the cannula MUP in relation to that of the central core is an indented, but nevertheless, triphasal (+-+) MUP on the CNE.

Also, in the next example (figure 5B), the central core and cannula register different fibre populations. At this, fractions of the cannula MUP have the same shape as those in the macro EMG. The final positivity of the central core is indented, but thanks to the „diminishing" of fractions of the cannula MUP there follows a relatively smooth final positivity of MUP recorded with CNE.

In the next example (figure 5C) the central core and cannula also register different fractions of MU. In this case we can observe the polyphasal MUP registered by the central core. „Diminishing" of fractions results in MUP with three phases on the CNE.

In the next example (figure 5D) both electrodes (the cannula and the central core) register one fraction (initial positivity) of MU in the same mode which, in turn, is „diminished", resulting in a smooth, shorter MUP recorded with CNE instead of several phases or indentations.

A larger number of phases or turns in CNE bipolar montages is sometimes a result of the „greater influence" of individual components (cannula, central core), which does not necessarily reflect temporal dispersion since, for example, the classical and „smooth" triphasal MUPs in the central core and cannula arriving at different times may yield, due to „diminishing", four or more phases of MUP recorded with CNE. Nevertheless, qualitative analysis has also shown the reverse possibility – sometimes the effect of temporal dispersion and poliphasy in the central core and cannula is erased, and as a result, MUP recorded with CNE has fewer phases.

Dumitru et al. (14) report the initially negative deflexion for the two illustrative MUPs recorded with a central core-cannula montage. Deflexion occurs because of the potential recorded by the cannula in the cannula-surface montage which is greater in relation to the potential recorded by the central core. By so-called "differential amplification" a comparatively greater initial positive deflexion recorded by the cannula is transformed, and consequently, that negativity is „diminished" with the initially positive deflexion of the central core, resulting in the residual negative potential which is the onset of MUP (12). We have also observed similar phenomena of „diminishing" in our study.

In the case of the cannula recording a relatively higher potential in relation to that of the central core, especially in relation to the initial and final segments of MUP, it is understandable that the central core-cannula potential will display the same duration as the central core-surface electrode potential. By contrast, if the cannula and central core detect a similar onset and end of MUP, the final duration of MUP will depend on the dominant signal in any temporal location with the possibility of constructing MUP of a shorter duration for the central core-cannula montage (12, 13, 14).

Conclusion

The qualitative analysis has confirmed that it is not possible to determine the precise location of muscle (end-plate, tendon) on the basis of EMG findings with CNE as is the case with monopolar montages, but also that the shape of the CNE MUP is usually different from that of the central core. At the same time, it has been confirmed that cannula can occasionally have a „contributing" rather than a „diminishing" influence on CNE MUP parameters (amplitude, duration, number of phases) which, under certain circumstances, may lead to the wrong interpretation of EMG findings.

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