Comparison between concentric needle EMG and macro EMG in patients with a history of polio

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Abstract

Objectives: Acute poliomyelitis causes degeneration of anterior horn cells, followed by denervation. Reinnervation and muscle fibre hypertrophy are mechanisms that compensate this loss of neurones. Concentric needle EMG (CNEMG) and macro EMG are two methods to assess the magnitude of initial involvement and the compensatory reinnervation. The aim of this study is to explore the difference between CNEMG and macro EMG describing the status of the motor unit in patients previously affected by polio.

Methods: Macro and concentric needle EMG investigations were performed in 261 muscles in 121 patients with a remote history of polio.

Results: CNEMG was abnormal in 211 muscles, macro EMG was abnormal in 246 muscles. The macro amplitude was 3–4 times 'more abnormal' than CNEMG amplitude relative to the reference values. CNEMG duration was less abnormal and showed only weak correlation with macro amplitudes. The most likely explanation for the difference in magnitude of deviation from reference values for CNEMG and macro EMG, is a more pronounced 'phase cancellation' between single fibre action potentials in CNEMG. This is supported by simulation studies reported here.

Conclusions: In conclusion macro EMG better reflects the size of the motor unit than the CNEMG. For detection of concomitant disorders, CNEMG is the method of choice. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Macro EMG; concentric needle EMG; poliomyelitis; reinnervation

1. Introduction

Acute poliomyelitis causes degeneration of groups of ventral horn cells, with subsequent acute denervation of muscle fibres in corresponding motor units. This is followed by reinnervation by the mechanism of collateral sprouting. The result may be a complete functional compensation or, in cases of pronounced acute denervation, an incomplete compensation. Muscle fibre hypertrophy is another type of compensatory phenomenon occurring in most of these cases. (Dalakas, 1988; Grimby et al., 1998) The clinical situation will thus show various degree of remaining weakness.

With normal ageing there is a physiologic progressive loss of ventral horn cells. Therefore in patients with old polio, a slow process of ageing-dependent denervation-reinnervation is superimposed, with a possible acceleration after decades (Grimby et al., 1998). In old polio there is a reduced number of ventral horn cells, each supporting a manifold increase in the number of muscle fibres compared to normal. Here, further loss of each ventral horn cell e.g. due to the ageing mechanisms, will cause denervation of a much higher number of muscle fibres than in the normal muscle because of previous reinnervation generating large motor units. The remaining reinnervated motor units will continuously become even larger (Grimby and Stålberg, 1994; Grimby et al., 1998).

One way to investigate the degree of involvement and reinnervation in a given muscle is by means of EMG techniques, aiming at the estimation of the average size of motor units and the description of the organization of muscle fibres in the motor unit (Cruz-Martinez et al., 1984; Trojan et al., 1991). Together with clinical information such as force and muscle atrophy, this will give an impression of the severity of the involvement and the dynamics of the process.

Usually, the EMG investigation is performed with concentric or monopolar needle electrodes. Amplitude, duration, area, shape, stability on repeated discharges and activity at full effort are parameters conventionally used to quantitate the EMG (Stålberg et al., 1996).

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From experience and experimental studies it is known that these parameters are indirect indicators of the number of muscle fibres and their concentration within the uptake area of the electrode. EMG may also assess the present activity of the denervation-reinnervation process.

Another method to assess the motor unit is the so-called macro EMG (Stålberg, 1980; Stålberg and Fawcett, 1982). This recording provides information from a larger area of the muscle than other needle EMG methods. The recorded signal is determined by most of the fibres in a motor unit and reflects number and size of muscle fibres in the entire motor unit. This method has been used in some studies of patients with old polio to follow the degree of reinnervation (Lange et al., 1989; Ivanyi et al., 1994).

The aim of the present study is to compare concentric needle EMG with macro EMG in muscles from patients with old polio with varying degrees of reinnervation. The first method is widely used for quantitative EMG analysis in routine. The second method requires a special electrode and analysis procedure. It is therefore of interest to know whether or not the methods differ in describing the status of the motor unit in the muscles of patients with a history of polio?

2. Methods

Most EMG recordings are performed on Keypoint EMG equipment (Medtronic Dantec, Copenhagen). In a few cases, Counterpoint (Dantec, Copenhagen) is used.

2.1. Concentric needle EMG

In this study, concentric needle EMG (CNEMG) electrodes are used. The standard concentric needle (CN) consists of a 150 μm diameter wire as the active recording element inside a cannula. The tip is ground to a 15-degree angle, producing an elliptical recording surface of the wire (150×580 μm), which has an area of 0.07 mm^2.

Analysis of spontaneous activity at rest is assessed visually. Motor unit potential (MUP) analysis is performed automatically with an inbuilt program called Multi MUP analysis (Stålberg et al., 1996). This is based on signal decomposition and averaging. Manual editing is performed when necessary. Usually around 20 different MUPs are obtained. This is typically carried out with 2–3 skin penetrations, at 3–5 different recording sites in each such penetration. At each recording site, 1–4 different MUPs are obtained. A minimum of 15 is required to be included in the study.

The results are expressed as mean values of various parameters, Z-scores, relative mean values normalised for age using a large control group and in terms of individual outliers (Stålberg and Fawcett, 1982; Bischoff et al., 1994). Stability of individual MUPs, the jiggle (Stålberg and Sonoo, 1994) is assessed visually and graded as stable, unstable and unstable with blocking. The interference pattern at strong voluntary contraction is either assessed with the inbuilt program or scored visually.

2.2. Macro EMG

The standard macro EMG method is applied (Stålberg and Fawcett, 1982). The recording electrode consists of a modified single fibre EMG (SFEMG) electrode with the cannula Teflon insulated except for the distal 15 mm. An SFEMG recording surface is exposed 7.5 mm from the tip. Recording is made on two channels. On the first, the SFEMG activity is displayed (using the cannula as reference), and used to identify the motor unit and to trigger an averaging procedure. The fibre density (FD) of the triggering single fibre electrode is recorded. Filter for this channel is 500–10 kHz. Jitter and blocking are assessed visually.

On the second channel, the activity from the cannula (using a remote surface electrode as reference) is averaged until a smooth baseline and a constant macro MUP is obtained. Filters on this channel are 5–10 kHz. The maximal peak to peak amplitude and the total area between the curve and the base-line during the total sweep time of 70 ms is measured from the averaged signal, the macro MUP.

The results are expressed as median values of individual amplitudes from at least 15 recordings. The relative macro amplitude is expressed as the obtained median value normalised for mean of median values from age matched controls (Stålberg and Fawcett, 1982). Fibre density is expressed as number of time locked spikes obtained on the SFEMG channel.

2.3. Simulation

Single fibre action potentials are simulated according to the line source model described elsewhere (Stålberg and Nandedkar, 1983). Motor units are simulated with various numbers of muscle fibres, ranging from 1 to 100/mm^2 for the entire motor unit using a constant motor unit territory of 6 mm in diameter. This corresponds to a range from sparse to moderately dense fibre packing. The fibres are scattered randomly in the territory. The fibre diameter is in the normal range 55 $\pm$ 6 (mean $\pm$ SD, range 30–70 μm) (Brooke and Engel, 1969). Parameters such as temporal dispersion of single fibre action potentials in a plane perpendicular to the fibre direction and distance dependent amplitudes (Nandedkar et al., 1984) of the single fibre action potentials are included in the model. The shape of these SFEMG action potentials are simulated as being recorded with a CNEMG electrode. They are summated to generate a MUP as recorded with a concentric needle electrode. The contribution of the cannula is also estimated and subtracted to simulate a CN-MUP. Similarly, the SFEMG action potentials are also given a shape obtained from a macro EMG electrode. The macro MUP shape is generated by the summation of the SFEMG action potentials, taking into account the physical extent of the

Table 1
Summary of the patient material[a]

	No. muscles	Age (mean ± SD)	Time since polio (mean ± SD)
BB	63	62.90 (8.97)	49.40 (9.55)
VL	93	57.19 (10.72)	48.11 (7.18)
TA	105	57.78 (11.19)	47.64 (8.19)

[a] BB, biceps brachii muscle; VL, vastus lateralis muscle; TA, tibialis anterior muscle.

electrode according to the model described elsewhere (Nandedkar and Stålberg, 1983).

In this comparison between the two methods, CN-MUPs and macro MUPs are simulated from the same simulated motor unit. The amplitudes of the generated MUPs are measured and correlated to number of activated muscle fibres.

3. Statistics

Linear regression is used for statistical analysis. All analysis is made with commercial available standard software (SPSS®, Chicago, IL).

The Pearson's correlation coefficient is used to study the interrelations between parameters.

The significance of correlation coefficients is two-tailed tested.

The results is considered significant when $P < 0.05$.

4. Patient material

One hundred and twenty one patients with old polio referred to the department for EMG investigations were included. Inclusion criteria for a patient to be included were: a history of acute polio >20 years ago and no other major neurological disorders. Two patients were excluded, one patient suffering from L5 radiculopathy and one patient with HMSN 1. The inclusion criteria for muscles to be included in the study was that quantitative analysis had been made with data from at least 15 MUPs with both techniques. Results from the following muscles were included in this study; biceps brachii (BB), vastus lateralis (VL) and tibialis anterior (TA). All three muscles have not been studied in all patients. Result from each muscle has been treated separately.

Data about patients is summarised in Table 1.

All patients gave their informed consent and the study was accepted by the ethic committee of the hospital.

5. Results

The concentric needle EMG showed classic neurogenic findings in some muscles in all patients but not necessarily in those included in this study, supporting the history of earlier polio. Fibrillation potentials were present in a small proportion of the muscles investigated. The general conclusion of the entire investigation is summarised in Table 2.

Of the 3 muscles studied here, CNEMG showed most

Table 2
CNEMG, macro EMG and FD results for muscles studied[a]

	BB	VL	TA	Total
CNEMG				
No. muscles studied	63	93	105	261
No. of abn EMG (conclusion)	37	79	95	211
No. of abn EMG ampl	37	78	95	210
Rel ampl; mean, range of 2SD[b]	2.02 0.58–7.04	3.79 1.06—13.59	3.32 1.17–9.40	
No. of abn EMG dur	19	28	53	100
Rel dur; mean, range of 2SD[b]	1.16 0.64–2.07	1.33 0.88–2.02	1.24 0.88–1.75	
Macro EMG				
No. muscles studied	63	93	105	261
No. abn macro ampl	49	87	87	223
Rel ampl; mean, range of 2SD[b]	3.56 0.79—15.98	6.38 1.31–31.00	3.84 0.81–18.25	
FD				
No. abn (total)	58	72	87	217
No. abn FD/ normal macro MUP ampl	12/14	3/6	8/18	

[a] For CNEMG 'abn (conclusion)' means that at least one of the MUP parameters amplitude or duration is outside 2 SD of age matched reference values, or that the pattern at full effort shows a definite loss of motor units. For all other parameters, 'abn' indicates values outside 2SD healthy controls, normalised for age. For macro MUPs, the mean of all relative median values is given.

[b] Because of skew distribution, the values are calculated after log transformation. The results in the table are give after linear transformation of the calculated values.
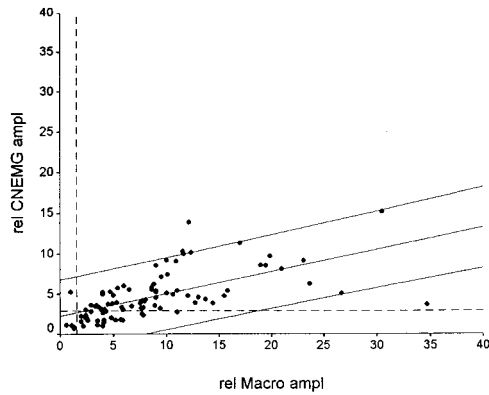
Fig. 1. Plot of relative (rel) CNEMG amplitude (ampl) versus relative (rel) macro EMG amplitude (ampl) in vastus lateralis muscle. The slope of the regression line is 0.274 ($r^2 = 0.40$). The upper normal limits (2 SD) for the 2 parameters are indicated with hatched lines. Note the higher number of abnormal macro EMG findings when CNEMG was normal, than the opposite.

pronounced changes in VL and least in BB, corresponding to the clinical involvement. The reduction in interference pattern was generally related to the severity of MUP changes.

Macro EMG showed increased amplitudes in 223 out of 261 muscles. The fibre density was generally increased when the macro amplitude was increased. In 29 cases the FD was indicated normal, when the macro amplitude was increased. In these cases, the FD has not always been quantitated properly but the SFEMG recording was only used to produce a trigger signal for the macro recording. These 'false negative' results have not been used for any further conclusion. However, FD was also normal in 15 of the muscles with normal macro EMG amplitude (Table 2). Here special attention was paid to the accuracy of FD measurements. In 11 of those also CNEMG was normal in the same muscle. In 38 muscles with normal macro amplitude findings, FD was abnormal in 23.

Combination of results: there was a significant ($P < 0.01$) correlation between the changes in CNEMG and macro EMG (Figs. 1 and 2). Table 3 shows the results of the regression analysis.

In general, the relative change was much more pronounced in macro EMG.

Macro was more often abnormal than CNEMG.

A summary of the results comparing the final conclusion from CNEMG and macro EMG is given in Table 4.

In the 28 cases with normal CNEMG amplitude but abnormal macro amplitude, the FD was abnormal in 19 cases, but normal in 9.

5.1. Simulation

Only amplitudes were studied (Figs. 3–5). The slope of the regression lines for the correlation between CNEMG relative amplitude and number of fibres was 0.0019 ($P < 0.001$, $r^2 = 0.88$).

The slope for the regression line for correlation between macro relative amplitude and number of fibres was 0.0053 ($P < 0.001$, $r^2 = 0.995$). The slope for the regression line for correlation between CNEMG relative amplitude and macro relative amplitude was 0.36 ($P < 0.001$, $r^2 = 0.88$) (Fig. 5). This slope was somewhat larger than that obtained in the actual recordings from patients which was 0.26, 0.27 and 0.27 for biceps, vastus lateralis and tibialis anterior muscles, respectively.

6. Discussion

EMG in patients with old polio show typical signs of loss of motor units and of reinnervation. This is due to the initial acute attack to the neurones followed by reinnervation. In addition, there is an ongoing process with reinnervation probably due to age related changes (Grimby et al., 1998). In the case of reinnervation by the mechanism of collateral sprouting, a surviving motor unit seems to innervate only those denervated muscle fibres that are situated within its
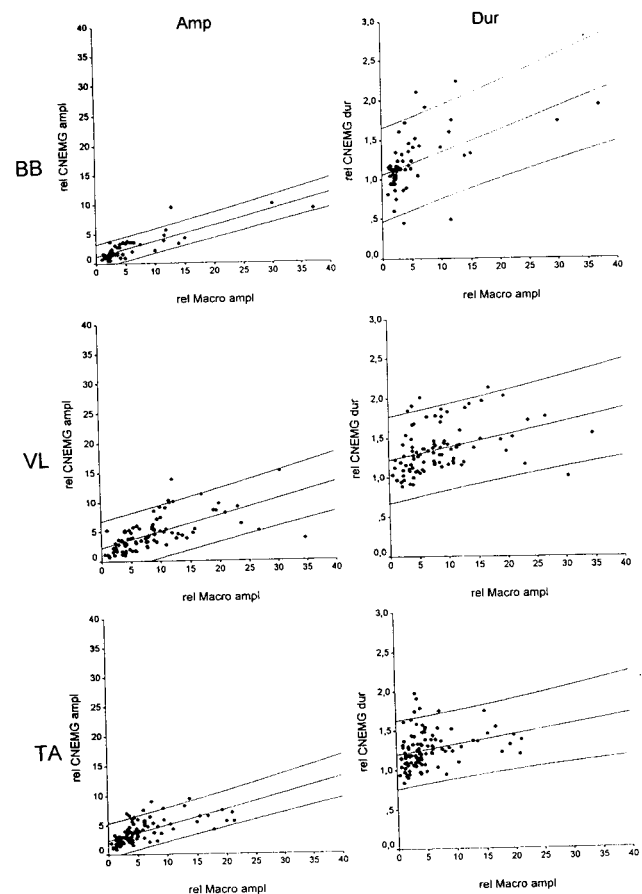

Fig. 2. Regression analysis of relative (rel) CNEMG amplitude (ampl) versus relative (rel) macro amplitude (ampl) and relative (rel) CNEMG duration (dur) versus relative (rel) macro amplitude (ampl) respectively for the 3 muscles. Note the general greater scatter and the higher relative changes for macro amplitudes. There is a better correlation between CNEMG amplitude and macro amplitude than between CNEMG duration and macro amplitude. Values are given in Table 3.

Table 3
Regression analysis of indicated parameters[a]

	Rel CN ampl slope[b]	r^2	Rel CN dur slope[b]	r^2
Rel macro ampl BB	0.26**	0.55[c]	0.029**	0.21[c]
Rel macro ampl VL	0.27**	0.40	0.017**	0.14
Rel macro ampl TA	0.27**	0.42	0.013*	0.070

[a] Slope and r^2 values are given.
[b] Significance: *$P < 0.01$, **$P < 0.001$.
[c] No extreme values.

original territory (Kugelberg et al., 1970; Stålberg and Dios-zeghy, 1991). Therefore, in a given motor unit, only a part of its territory may be involved in reinnervation. During a continued process of denervation-reinnervation, this random involvement will be transferred and exaggerated to the next cycle of denervation/reinnervation. If an axon is finally innervating all fibers in one area, fascicle, after preceding reinnervation (large grouping with no overlapping fibers in a given area), these fibers can not be reinnervated in case this motor unit becomes denervated (Kugelberg et al., 1970; Ryniewicz et al., 1990; Stålberg, 1990). This will lead to areas of grouped atrophy and an over all loss of muscle fibers. These mechanisms lead to variation of fibre density within a given motor unit. This is related to the clinically defined so called post polio syndrome (Halstead and Rossi, 1987).

It is often of importance to assess the dynamics of the reinnervation process. This can be done with EMG methods. Since the different EMG electrodes reflect different uptake area, the result will be influenced by this uneven fibre distribution to a different degree. The optimal choice of EMG method is therefore dependent on the information that is requested at each moment.

The FD-parameter obtained with SFEMG will show a great variation in the recorded number of muscle fibres at different sites in a muscle with reinnervation, since its exploring radius is about 300 μm. It is very sensitive in detecting early signs of abnormal fibre distribution in the motor unit but does not give information about the over all size of a motor unit. With CNEMG, a larger area of the motor unit is reflected, estimated to be about 2.5 mm for the duration parameter and 0.5 mm for the amplitude in the normal motor unit (Nandedkar et al., 1985) but somewhat more in reinnervation. This uptake area should be compared with the normal motor unit territory of 5–10 mm (Stålberg and Dioszeghy, 1991). The uptake area of the CNEMG electrode is relatively small due to a number of reasons, some of which are the following. First, the closest muscle fibres generate the highest amplitudes, which can be relatively truly reproduced only with small electrodes such as SFEMG electrodes. For larger electrodes the great difference between close and distant fibres is attenuated for technical reasons (Gath and Stålberg, 1976). The concentric needle electrode, is in these terms relatively small. Second,

the cannula is used as the reference electrode. This records from the entire motor unit and relatively more of the slow wave components from distant electrical fields, defining the duration in the CNEMG. In CNEMG the cannula signal is subtracted from the core signal. The duration value is therefore shortened. In the extreme case, the cannula signal will record a significant amplitude from groups of fibres, a signal that actually is the same as the macro EMG signal (Fig. 6). When this is subtracted from the core signal, the MUP amplitude is reduced. Finally, the algorithm for estimating the duration is on purpose set to truncate the slow initial and terminal part of the MUP at the ends, representing distant activity. By this truncation, activity from distant fibres is attenuated more than activity from close fibres, and so the recording selectivity is increased.

The macro EMG gives a global view of the motor unit for two reasons. First, the physical length of the electrode (15 mm), when inserted perpendicularly to the fibre direction, covers the entire diameter of an average sized motor unit, which allows a larger number of muscle fibres to be close to
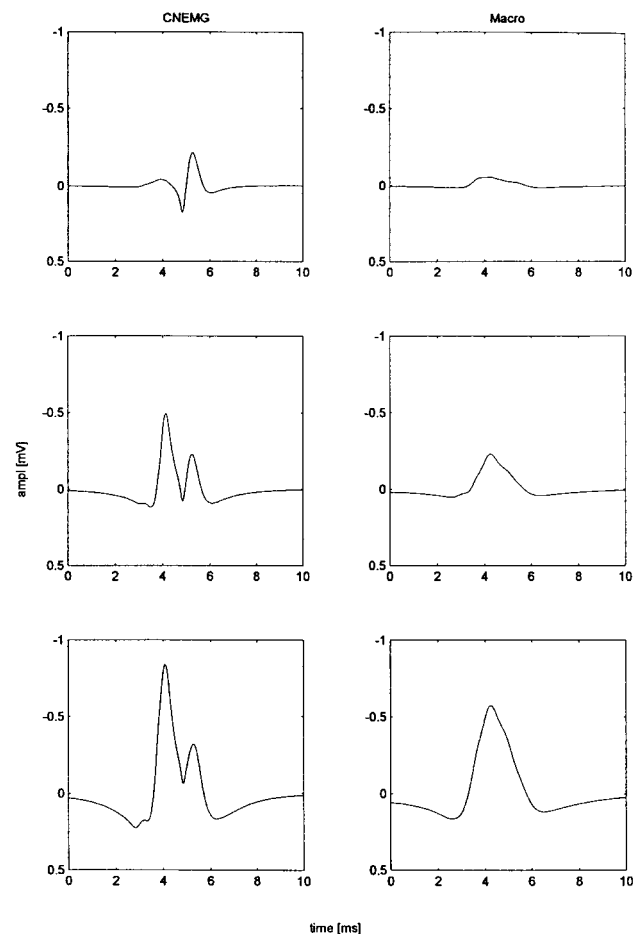

Fig. 3. Simulation studies. Simulated motor unit potentials recorded with a CNEMG electrode and with a macro electrode respectively, are summated. Examples of simulated signals using 3, 10 and 30 fibres/mm², respectively. Note the relative greater increase in amplitude for macro EMG compared with CNEMG.

Table 4
Summary of findings in CNEMG (amplitude and duration) and macro EMG amplitude

	No. muscles	Both normal	CNEMG n/macro abn	CNEMG abn/macro n	Both abn
CNEMG ampl/macro amplitude					
BB	63	11	15	3	34
VL	93	4	11	2	76
TA	105	8	2	10	85
CNEMG duration/macro amplitude					
BB	63	14	30	0	19
VL	93	6	59	0	28
TA	105	14	38	4	49

the electrode than is the case when using smaller electrodes (Fig. 7). Second, the large electrode surface suppresses the contribution of the closest action potentials, and favours the relative influence of slow wave components and so includes distant fibres. Finally the reference electrode is remote from the muscle and does not record any significant signal of the motor unit.

Regarding the obtained results in this study, it is thus easy to understand why the parameters of CNEMG and macro EMG are different in absolute values, e.g. amplitude, area or duration. It is also easy to understand that the variation within a muscle should be much more pronounced when a selective method was used compared to a more global recording, shown elsewhere (Stålberg and Fawcett, 1982). It is however somewhat difficult to understand why the relative average deviation from normal values is different for the different techniques. The more selective CNEMG could record from an area with high concentration of fibres, with higher amplitudes than the true mean for the motor unit, or from areas with local loss of fibres, giving low value. The

average value obtained from many recording sites should still be representative for the motor unit. In this study the macro recording is the most 'abnormal' for a given patient in terms of relative amplitude, with a factor of 3–4 times higher increase in mean values in a muscle. In other words, in the numerical description, the CNEMG seems to indicate a less severe abnormality than the macro EMG. In this study there are some borderline cases, some detected with only macro EMG parameters, fewer with only CNEMG parameters. This fact, related to the diagnostic sensitivity of the methods, is not focussed on in this study, but rather how the results reflect the size of the motor unit and degree of severity.

The reason for the difference in relative changes with pathology, between CNEMG and macro EMG will be briefly discussed. Could it be a sampling problem? Does the CN favour small signals or the macro EMG large? If the largest signals in general were very unstable, the automatic computer system for analysis of the CNEMG signal should have difficulties in detecting required minimal number of discharges (5) of sufficient similarity to allow them to be accepted by the computer system. This is not the case since visual inspection of every recording has
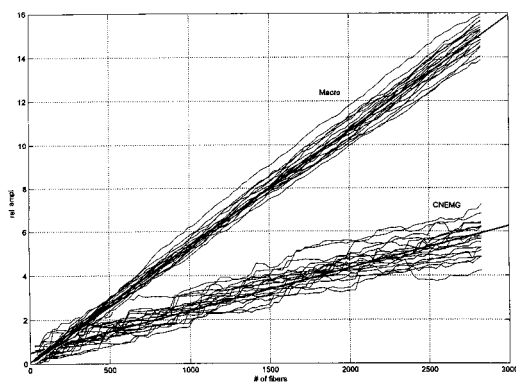

Fig. 4. Simulation studies. Plot of relative amplitude (rel ampl) versus number of fibres for CNEMG and macro EMG. The number of fibres is continuously increased from 1 to 100 fibres/mm^2 corresponding to a total of 28–2827 fibres within a territory of 6 mm diameter. Only 20% of the MUs are shown for the sake of clarity. Regression line for all motor units is shown (full lines). The obtained summated signal increases in amplitude, more so for the macro simulation. Slope of regression line is 0.0019 (r^2 = 0.88) for CNEMG and 0.0053 (r^2 = 0.99) for macro EMG. Note the greater variation in amplitude increase with the addition of muscle fibres in CNEMG than in macro EMG simulations.
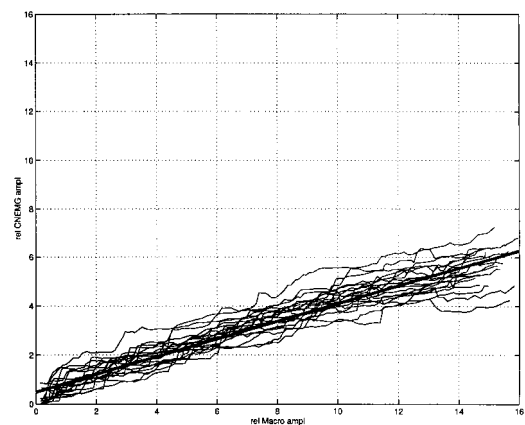

Fig. 5. Simulation studies. Plot of relative (rel) CNEMG amplitude (ampl) versus relative (rel) macro amplitude (ampl). Slope of regression line is 0.36 (r^2 = 0.88, $P < 0.001$). Only 20% of the MUs are shown for the sake of clarity. Regression line for all motor units is shown (full line).
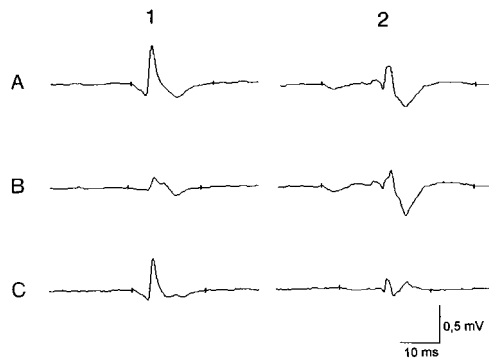
Fig. 6. Two examples of recordings (1–2). In (A) and (B), a remote reference has been used. (A) represents the signals from the central core (like a monopolar recording), (B) represents activity from the cannula (corresponding to the macro EMG), and (C) the difference between (A) and (B) (corresponding to CNEMG MUP). Note, the lack of correlation between (B) and (C).

never given the impression of a systematic methodological loss of large signals. Another possibility would be that recordings, although made at the same occasion and in the same part of the muscle, would be performed with different degrees of activation in patients compared to controls. With strong activation, larger motor units are recruited (at least in normal subjects). This should probably not influence the CNEMG signal (Ertas et al., 1995) since the amplitude is mainly independent on total motor unit size. However it will influence the macro signal, becoming larger with increasing force. In the investigations, the degree of activation has always been slight or moderate, in all cases less than 20% of maximal contraction. The same instructions have been given to the patient as were used for the reference material. The firing rhythm and frequency is similar for controls and patients with both types of recordings when tested with different low degree of activation. There is no general impression that higher threshold motor units were activated in polio patients. Also fatigue could induce recruitment of high threshold units. However, CNEMG is usually made after the macro EMG study, and usually at least 15 min have passed before the same muscle was investigated with the other EMG technique.

The most likely explanation for the difference between CN and macro EMG results is the technical difference between the two recording techniques. The CNEMG summates single fibre action potentials obtained by its central core. The single fibre action potentials, recorded with the CN electrode are very short positive-negative going spikes with a duration of the order of 200 μs. Individual single fibre action potentials must therefore arrive at the electrode within a time window of this magnitude in order to add effectively. With slight time shift, a phase cancellation occurs and the sum may even be smaller than the individual components. With many single fibre action potentials, as is the case in the pathological motor unit in

polio, there is a certain likelihood for summation to an increased signal in relation to the number of individual components. However, a significant phase cancellation still takes place. Furthermore, in CN MUPs a jiggle in individual MUPs will reduce the maximal MUP amplitude when many repetitive discharges are averaged, an inherent feature of the analysis process.

The macro MUP on the other hand represents the summation of a large number of signals with much longer rise times, with asymmetric long positive phases and a somewhat shorter negative phase, due to the effects of the large recording surface. This reduces the degree of phase cancellation and the result is therefore more truly related to the number of contributing single fibre action potentials.

This hypothesis is supported by the simulation experiments. The signals obtained from the same motor units summate much more effectively in macro EMG than in CNEMG seen in the simulations performed in this study. The slope for macro EMG is almost 3 times steeper than that for CNEMG with respect to the regression between signal
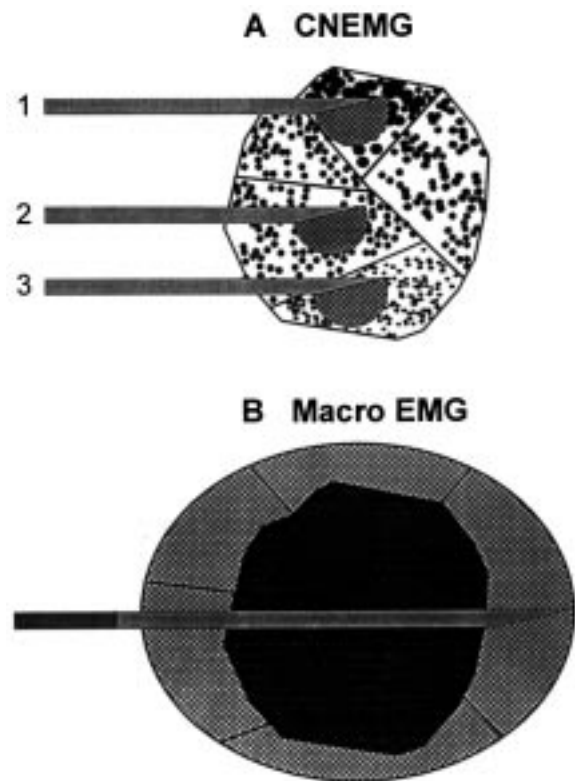

Fig. 7. Schematic representation of one motor unit with its fibers represented in 5 fascicles. The motor unit is abnormal, with an uneven fiber distribution due to collateral sprouting, as in polio. (A) shows the CNEMG, B the macro EMG. The CNEMG electrode has a very restricted uptake area (mesh pattern) compared to the macro electrode that records activity from an area exceeding the entire motor unit. Depending on the position of the CNEMG electrode, it may record from abnormally dense area (1), from a relatively normal area (2) or from an area with atrophic fibres (3). The macro electrode records the over all signal from the entire area.

amplitude and number of component fibres. The difference between CNEMG simulation and macro EMG simulation is clearly in the direction of the findings in the patients, although the numerical difference is somewhat less in simulations. The slope of the regression line macro amplitude versus CN amplitude is 0.36 in simulations and 0.26–0.27 in patients. There is no obvious explanation for this difference from obtained values other than shortcomings in the exact setting of all parameters in the simulation.

Duration for macro signal is dependent, not only on number of muscle fibres in the motor unit but anatomy of the end plate zone (Stålberg and Dioszeghy, 1991). Therefore, no comparison has been performed between macro and CN duration. However, CN duration, supposed to be greatly dependent on number of muscle fibres in the uptake area of the electrode, could be used for comparison with macro amplitudes. Still, the CN parameter changes less with pathology than the macro amplitude. It should be remembered that the CNEMG technique is using the cannula as reference, (similar to the macro electrode). This seems to cancel much of the expected increase in duration. This factor in addition to the phase cancellation contributes to the discrepancies.

CN parameters thus change less than macro amplitude for a given relative increase in number of muscle fibres in a reinnervated motor unit and vary much more within the motor units. Therefore, this parameter can not by itself accurately be used to estimate the motor unit size or to give an indirect indication of number of remaining neurones. Macro EMG is superior in this respect.

However, CNEMG still has a place in the examination of polio patients and is in some of these respects superior to macro EMG. In general indications for EMG in these patients are:

- diagnosis,
- detection of concomitant disorders,
- assessment of degree of involvement.

For the two first indications, CNEMG may be sufficient. Only in 39 out of 246 muscles was CNEMG normal when FD or macro amplitude revealed abnormalities. It is superior in finding concomitant disorders, e.g. root lesion where fibrillation and other spontaneous activity is better seen in the CNEMG. It can also detect myopathic disorders as cause of the weakness more accurately than the macro EMG.

CNEMG also has the advantage over macro EMG in that it gives an indication of the activity of the denervation-reinnervation process by the jiggle parameter. However the SFEMG recording in the macro electrode, gives even more detailed information about the transmission in peripheral nerve twigs and end plates.

For the quantitative assessment of degree of involvement, macro EMG is superior. This information is useful in the evaluation of the over all status of the muscle, its relation to weakness and in relation to training and in monitoring changes over time.

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