Concentric needle single fiber electromyography: Comparative jitter on voluntary-activated and stimulated *Extensor Digitorum Communis*

João Aris Kouyoumdjian, Erik V. Stålberg

*Faculdade de Medicina de São José do Rio Preto (FAMERP), São Paulo, Brazil*

Department of Neurological Sciences, Neuromuscular Investigation Laboratory, R. Luiz Antônio Silveira 1661, 15025-020 São José do Rio Preto, SP, Brazil

Department of Clinical Neurophysiology, University Hospital, Uppsala, Sweden

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Abstract

Objective: To compare the jitter values in voluntarily activated (v-CNE) and stimulated (s-CNE) techniques for *Extensor Digitorum Communis* muscle using a disposable concentric needle electrode (CNE). Quantifying jitter using a CNE in conjunction with a stimulated technique has not been reported previously.

Methods: Forty-one normal subjects were studied, 15 male and 26 female with a mean age of 34.1 ± 10.7 years (19–55). The jitter values were expressed as the mean consecutive difference (MCD) of 20 analyzed potential pairs using v-CNE and 30 isolated potentials using s-CNE.

Results: The mean MCD (n = 41) was 23.0 ± 2.8 μs for v-CNE and 18.2 ± 2.2 μs for s-CNE. The mean jitter of all recorded potentials was 22.9 ± 6.7 μs for v-CNE (n = 820) and 18.3 ± 5.2 μs for s-CNE (n = 1230). Upper limits for the 18th (v-CNE) and 27th highest (s-CNE) MCD were 38.9 and 30 μs, respectively (95% confidence limit). The jitter decrease in s-CNE compared to v-CNE was 1:0.79.

Conclusions: Our findings of the jitter values using CNE were similar to other published reports using the voluntarily activated technique; however, these are the first described for the stimulated technique using CNE.

Significance: The present study confirms that CNE can be used for the stimulated jitter acquisition and measurement, although certain precautions must be taken regarding signal quality, e.g., observing minimal summation.

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Keywords: Single fiber electromyography; Jitter; Concentric needle electrode; *Extensor Digitorum Communis*

1. Introduction

Single fiber electromyography (SFEMG) was developed in the early 1960s by Erik Stålberg and Jan Ekstedt in Sweden (Ekstedt, 1964; Stålberg and Trontelj, 1994a; Sanders and Stålberg, 1996). For jitter measurement, the special SFEMG needle electrode has a small recording surface (25 μm in diameter) which is exposed at a port on the side of the electrode (3 mm from the tip), allowing for the recording of single fiber action potentials (SFAP) from individual muscle fibers. Neuromuscular jitter, together with intermittent impulse blocking, is the most useful SFEMG parameter for the electrodiagnosis of neuromuscular transmission. It represents the variation in time intervals between pairs of SFAPs in voluntarily activated-SFEMG (v-SFEMG) or the time measured between axonal microstimulation and SFAPs in stimulated-SFEMG (s-SFEMG). Voluntarily activated-SFEMG represents the combined jitter in two SFAP end-plates, whereas s-SFEMG represents the jitter of just one SFAP end-plate.

The special SFEMG electrode is expensive and, after sterilization, reused many times. Due to the increasing concern for the transmission of infections (Benatar et al., 2006; Sarrigiannis et al., 2006), an inexpensive disposable electrode is desirable. Due to this demand, the use of
disposable concentric needle electrodes (CNE) in the measurement of jitter is under investigation (Ertas et al., 2000; Benatar et al., 2006; Sarrigiannis et al., 2006; Kouyoumdjian and Stålberg, 2007). To successfully use the CNE for the measurement of jitter, the low-frequency filter should typically be raised from 500 Hz to 1 or 2 kHz, to suppress the activity from distant muscle fibers (Benatar et al., 2006; Sarrigiannis et al., 2006). With the increasing suppression of low frequencies, the signals become small and spiky, related to the rise time of the components. Individual shape characteristics of slow wave components, indicating the summation of many single fiber action potentials, cannot be detected. Therefore, too much filtering is disadvantageous. We have found a practical limit to be 1 kHz high pass filter, rather than higher. As the signals obtained with CNE recording do not always represent a single fiber action potential, but rather a summation of many, the term SFEMG will not be used for these recordings. Earlier, the term “jiggle” has been introduced to describe the variability in a motor unit potential obtained with a CNE (Stålberg and Sonoo, 1994) and is still a possible nomenclature. To avoid confusion at this moment, the term “jitter recording with CNE” has been used.

The aim of this study was to compare the normal jitter parameters in the Extensor Digitorum Communis (EDC) muscle by using CNE in both voluntarily activated and stimulated techniques in the same subject.

2. Methods

2.1. Subjects

Forty-one normal subjects were prospectively studied for jitter measurement using CNE in voluntarily activated and stimulated EDC. There were 15 men and 26 women with the mean age of 34.1 ± 10.7 years (19–55). None of them were diagnosed with a neuromuscular disorder, other influential medical condition, or were taking medication that reasonably could have interfered with the study, e.g., calcium blockers (Ozkul, 2007).

2.2. Recording

For all the studies, a portable Keypoint electromyograph (Medtronic Skovlunde, Denmark) with build in jitter software was used for recording and analysis. CNE measurement of jitter was done by the first author and the second author revised, if necessary, the digital recordings. The recordings were performed using a CNE with a diameter of 0.30 mm and a recording area of 0.019 mm² (this CNE is the smallest or “facial needle”; Medtronic, Denmark).

2.3. Voluntary technique (v-CNE)

For jitter measurement was done through the insertion of a CNE into the muscle near the end-plate zone. A recording of 2 or more time locked signals from the same motor unit was performed during voluntary contraction of the EDC muscle. A maximum of 3 separate needle insertions into the EDC was performed, with a few different recording sites of various depths into the muscle at each skin insertion. The jitter values of 20 different recordings were calculated for each subject. For jitter analysis, both the examiner and the Keypoint software selected only individual potentials (spikes) with minimal summation of many SFAPs, i.e., with a distinct and dominating spike of short rise time without notches and a well-defined peak. The spike components used for the analysis were required to have a clear separation with no or minimal “merging” of one signal on the other. Nonetheless, the triggering potential was often a compound signal composed of more than one spike, while the other signal (occurring after or occasionally before the trigger) was sharper and with constant shape at consecutive discharges. The measurements were made between software extrapolated negative peaks of the signals. The time spent to obtain 20 acceptable recordings is similar to that for SFEMG: 30–40 min for less experienced and 20 min for the experienced investigator for one muscle.

2.4. Stimulated technique (s-CNE)

For jitter measurement was performed by intramuscular axonal stimulation delivered by a disposable monopolar needle electrode, 15 mm × 0.35 mm, 28 G (Medtronic, Denmark) inserted near the motor end-plate zone, between proximal and middle third of EDC. A disposable scalp needle electrode, 10 mm × 0.30 mm, 30 G (Medtronic, Denmark), was used as the anode and inserted subcutaneously about 2 cm away from the cathode. Stimulation was delivered at 10 Hz; the stimulus was delivered as rectangular pulses of 0.04 ms duration and the intensity was adjusted to produce a slight twitch of the muscle. In general, this could be achieved at about 2–6 mA. The CNE, as described for v-CNE, was inserted into the twitching portion of the muscle and positioned to record clearly defined spike components. For each spike component accepted for the analysis, care was taken to avoid subliminal stimulation that can cause intermittent blocking and high jitter. The jitter was measured between stimulus and spike when a further increase in stimulus intensity no longer decreased the jitter for the components to be studied according to standard methods (Trontelj and Stålberg, 1992). The CNE was moved to several sites in the muscle alternating with the readjustments of the simulating electrode in order to get different spike components; in all the cases, 30 different spikes were measured in each subject. The time spent for this technique was about 20–30 min. Both the techniques were well tolerated.

For each jitter analysis, a minimum of 50 and an ideal 100 consecutive traces were recorded. Filter setting was 1–10 kHz. The mean value of MCD and the mean sorted-data difference (MSD) (Stålberg and Trontelj, 1994b) were calculated. If the MCD/MSD ratio was...
greater than 1.25, the MSD value was used instead of MCD value as the jitter value in v-SFEMG. The Keypoint software also calculated the mean interpotential interval (MIPI). Fiber density was not considered in CNE studies.

2.5. Ethics

The study was approved by the Faculdade de Medicina de São José do Rio Preto Ethic Committee and informed consent was obtained from each subject.

3. Results

The mean jitter (±standard deviation) was analyzed according to a previously used method, i.e., a calculation of the mean MCD of 20 recordings for v-CNE and 30 isolated potentials for s-CNE (Stålberg and Trontelj, 1994a,b). There was no correlation to age in this material (p > 0.5). There were no recordings with impulse blocking.

3.1. Voluntary-CNE jitter

The mean of the 41 mean v-CNE MCD values in each subject was 23.0 ± 2.8 μs ranging from 17 to 29 μs. The upper 95% confidence limit was 28.6 μs. In all the cases MCD was used. The so-called outlier limit, 18th highest value out of 20 recordings for each subject (up to 10% of the values may be outside the limit, and the study is still considered normal) was 30.3 ± 4.3 μs. The upper 95% confidence limit was 38.9 μs. The mean value of MIPI values was 794 ± 185 μs ranging from 530 to 1412 μs.

3.2. Stimulated-CNE jitter

The mean of the 41 mean s-CNE MCD values in each subject was 18.2 ± 2.2 μs ranging from 15 to 25 μs. The upper 95% confidence limit was 22.6 μs. The outlier value (27th highest value, i.e., with 10% of the highest values outside this limit, the study is considered normal), was 24.0 ± 3.0 μs. The upper 95% confidence limit was 30.0 μs. The mean value of MIPI values was 4912 ± 1098 μs ranging from 2913 to 7610 μs.

3.3. Comparison between v-CNE and s-CNE jitter values

The mean value of jitter in all individual recordings was 22.9 ± 6.7 μs for v-CNE (820 records) and 18.3 ± 5.2 μs for s-CNE (1230 records), being 20.1% (p < 0.01) lower than that for v-CNE. Calculations of difference within each subject between mean MCD for v-CNE and s-CNE showed that s-CNE value was 20.9% (p < 0.01) lower than the corresponding value for v-CNE. These values may change somewhat, when a larger material is collected. Both parametric (paired t test) and non-parametric (Mann-Whitney test) comparison between v-CNE and s-CNE MCD showed a p value < 0.0001, considered extremely significant. Linear regression analysis shows an extremely significant correlation between v-CNE and s-CNE mean MCD (p value < 0.0001 and r² = 0.5030). Linear regression analysis shows an extremely significant correlation between v-CNE MCD of the 18th highest value and s-CNE MCD of the 27th highest value (p value = 0.0010 and r² = 0.2461). The upper limit of the 27th highest value for s-CNE and the upper limit of the 18th highest value for v-CNE (95% confidence limit) are shown in Fig. 1A and B, respectively. Linear regression plots of the mean jitter for both the techniques are shown in Fig. 2.

4. Discussion

Clinically, the jitter measurement is the most sensitive electrophysiological test for diagnosing myasthenia gravis (MG) (Ertaş et al., 2000; Sanders, 2002; Benatar et al., 2006; Sarrigiannis et al., 2006) and has become an integral part of the evaluation for this disorder. The reference values are important for correct interpretation of results.

This is our second study on normative jitter measurements using CNE. In the first study (Kouyoumdjian and Stålberg, 2007), the v-CNE of the EDC muscle was analyzed in 50 subjects. The present study compares the jitter values obtained with voluntarily activated and stimulated
CNE in the EDC muscle. The use of a CNE electrode is important since this electrode is disposable and inexpensive; thus, no electrode maintenance is necessary, resulting in the elimination of recording quality deterioration. Often, the spikes obtained with CNE are not obtained from single muscle fibers (Stålberg and Daube, 2003). Therefore, separate normative data should be collected for CNE recordings, as already done for SFEMG recordings. A few studies have reported good correlation between jitter values from SFEMG and from CNE in healthy controls and patients with MG (Ertaş et al., 2000; Benatar et al., 2006; Sarrigiannis et al., 2006).

The normal jitter values for v-SFEMG in the EDC have already been established in the literature (Gilchrist, 1992; Bromberg and Scott, 1994; AAEM Quality Assurance Committee, 2001a,b). For the age group below 60 years, the 95% upper normal limit is 37.3 μs for the mean of 20 MCD values and 54.4 μs as an outlier limit for individual recordings (10% of the recordings beyond this limit is acceptable). In a previous study using CNE, we reported a mean MCD (n = 50) of 24.2 ± 2.8 μs (95% confidence upper limit, 29.8 μs). The present study shows similar values (23.0 ± 2.8 μs, 95% confidence upper limit 28.6 μs). Further, the present values (22.9 ± 6.7 μs; n = 820 pairs) for mean jitter did not differ from our previous study values of 24.07 ± 7.30 μs (n = 1000 pairs). Additionally, these results reflected a study in 10 normal subjects (23.3 ± 8.0 μs, n = 200 pairs) from Ertaş et al. (2000), but varied slightly from the values of 30.6 ± 9.2 μs (n = 453 pairs) by Sarrigiannis et al. (2006) in 20 normal subjects. The age dependent jitter values found in SFEMG could not be evaluated in our data because of the small number of subjects.

The normal jitter values for s-SFEMG EDC suggested a 95% upper normal limit of 25.0 μs for the mean of 20–30 MCD values and 40.0 μs as outlier limit for the age group of 15–39 years (Trontelj and Stålberg, 1992). Our results using CNE revealed a mean jitter value of 18.2 ± 2.2 μs, with an upper limit of 22.6 μs in 41 studies. The outlier limit (10% limit for individual data) was 24.0 ± 3.0 μs with an upper limit of normality of 30 μs (95%).

Lower jitter found in CNE studies can be attributed to the possibility of more than one SFAP constituting at least one of the components in the analysis, usually the triggering one. Thus, the resultant summation diminishes the jitter.

We present lower jitter values for s-CNE than for v-CNE, with a difference of 20.7% for mean MCD and a 20.1% reduction for a pooled material of individual recordings. This difference was less than that found in SFEMG, previously described as 33% for mean MCD and 26.5% for individual motor end-plates (Trontelj et al., 1986; Trontelj and Stålberg, 1992). The reason for lower jitter values in stimulated techniques compared to voluntarily activated techniques is that only single end-plates are studied during stimulation techniques, whereas in the voluntary recording the jitter from two motor end-plates are summated. The theoretically expected jitter in the stimulated technique should be 30% less (factor $\sqrt{2}$) than in the voluntarily activated technique (Trontelj et al., 1986; Trontelj and Stålberg, 1992; Sanders and Stålberg, 1996). The reason for the deviation from the expected difference between the voluntarily activated and stimulated techniques in the CNE recordings is unknown.

Data comparison shows that the largest difference between the SFEMG and CNE measurements of jitter is found for the voluntarily activated technique, most likely due to the rationale discussed above. However, in s-CNE individual components, particularly with long latency, may be separated from the summation pattern, resulting in more accurate values. Although the present data seem to indicate that the main difference in the recordings from the two electrodes is found in the v-CNE, the opposite can also be envisioned. For example, with stimulation many axons are often stimulated, and there is even a larger risk of summation than in the situation of voluntary activation, where individual motor units can be separated because of their various shapes and asynchronous discharging. Thus, s-CNE may be even more prone to artifacts than stimulated SFEMG and special caution must be taken to obtain only few and very spiky signals in the s-CNE recording.

It seems that the jitter obtained from CNE is smaller than in SFEMG, and the variation between laboratories in reported jitter values is greater compared to multicenter SFEMG studies, albeit the reports in the literature are sparse. The limits of normality for jitter using CNE are not sufficiently established, and we suggest that a practical value for the upper limit for MCD would be 30 μs for v-CNE and 25 μs for s-CNE. Corresponding values for outlier limits would be 42 μs for v-CNE and 35 μs for s-CNE.

In conclusion, CNE not only increases the safety and decreases the costs, but can also be used to acquire spike components, mainly composed of SFAP both at voluntary activation and after intramuscular axonal microstimulation. We report a jitter reduction varying from 20.1% to 21.3% in s-CNE when compared to v-CNE, which is less than that for a similar comparison in SFEMG recordings.
This difference most likely reflects some difficulties due to the summation of SFAPs, giving a lower MCD value than SFEMG, particularly during voluntary activation. A certain level of caution must be maintained before a study using CNE is declared abnormal or normal in situations of borderline jitter values until a better definition of acceptable recording quality has been developed, and larger reference material has been collected.

References


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