Concentric needle jitter on stimulated Orbicularis Oculi in 50 healthy subjects

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A B S T R A C T

Objectives: The aim of this study was to estimate the jitter parameters in healthy controls in stimulated Orbicularis Oculi (OOc) muscle using concentric needle electrode (CNE).

Methods: Fifty healthy subjects, 13 males and 37 females (21–56 years, mean age of 38 ± 9.2 years) were studied. The zygomatic branch of facial nerve was stimulated with a bar electrode. Jitter was expressed as the mean consecutive difference (MCD). Filter settings 1000 Hz–10 kHz.

Results: The mean MCD from individual studies (n = 50, Gaussian distribution) was 21.5 ± 1.99 μs (median = 21 μs), ranging from 17.8 to 26 μs (upper limit, 97.5%, 25.5 μs). The mean and median MCD from all potentials (n = 1500, non-Gaussian distribution) were 21.6 and 21 μs, ranging from 7.1 to 39 μs (upper limit, 97.5%, 33.4 μs).

Conclusions: Suggested practical limits in the OOc for mean MCD was 26 μs and for outliers 34 μs.

Significance: Stimulation jitter recordings with CNE could be used in practice but borderline findings should be judged with great caution until larger database obtained with uniform setting available.

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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, 1994; Sanders and Stålberg, 1996) to study the propagation velocity of individual muscle fibers, the distribution of muscle fibers within individual motor units, and the neuromuscular jitter (Stålberg and Sanders, 2009). A recent summary is given in Stålberg et al. (2010).

For jitter measurement, the SFEMG needle electrode has a small recording surface allowing for the recording of single fiber action potentials (SFAPs) from individual muscle fibers. Neuromuscular jitter represents the variation in time intervals between pairs of SFAPs in voluntarily activated technique (v-jitter) or the variation of many SFAPs may be very difficult to detect visually. We have found a practical limit to be 1 kHz high pass filter, rather than higher. This gives sufficient suppression of low frequencies, with still preserved signal shape so that presence of irregularities can be detected. As the signals obtained with CNE recording do not often represent a single fiber action potential, but rather a summation of many SFAPs, the term SFEMG will not be used instead of the SFEMG needle electrode.

To successfully use the CNE for the measurement of jitter, the low-frequency filter (high pass) should typically be raised from 500 to 1 kHz, to suppress activity from distant muscle fibers (Stålberg and Trontelj, 1994; Benatar et al., 2006; Farrugia et al., 2009; Stålberg and Sanders, 2009) instead of the SFEMG needle electrode.

Due to the increasing concern for the transmission of infections (Benatar et al., 2006; Sarrigiannis et al., 2006) an inexpensive disposable electrode is desirable for jitter analysis. In the past two decades attempts have been made to measure jitter by filtering the motor unit potential recorded with disposable monopolar (Clarke and Eisen, 1985; Wiechers, 1985), and, more recently, with concentric needle electrodes (CNE) (Benatar et al., 2006; Ertas et al., 2000; Kouyoumdjian and Stålberg, 2007, 2008a,b; Sarrigiannis et al., 2006; Farrugia et al., 2009; Stålberg and Sanders 2009)
The aim of this study was to study normal jitter parameters in the Orbicularis Oculis (OOc) muscle by using CNE in stimulation technique.

2. Methods

2.1. Subjects

Fifty healthy subjects recruited from Medical School (FAMERP, Brazil) employees were prospectively studied for jitter measurement using CNE in stimulated OOc. There were 13 men and 37 women with the mean age of 38 ± 9.2 years (range, 21–56). None of them were diagnosed with a neuromuscular disorder, an unrelated 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 studies, either portable Keypoint or KeypointNet electromyograph (Medtronic Skovlunde, Denmark) with a built-in jitter software was used for recording and analysis, using peak detection algorithm for time measurements. 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 or Alpine bioMed, Denmark). CNE measurement of jitter was done by the first author and the second author revised, when necessary, the digital recordings.

2.3. Stimulation technique

The zygomatic branch of facial nerve was stimulated with a bar electrode (percutaneous), about 2–3 cm from the canthus (Fig. 1). Frequency stimulation was set at 10 Hz, the stimulus was delivered as rectangular pulses of 0.10 ms duration and the intensity was adjusted to produce a slight visible twitch of the Orbicularis Oculi muscle. In general this could be achieved at about 5–7 mA. The CNE was inserted about 1 cm lateral to the canthus and positioned to record clearly defined spike components. For each spike component accepted for analysis, care was taken to avoid subliminal stimulation that can cause high jitter and intermittent blocking. For each spike that was measured, we always made sure a supramaximal stimulus, by just increasing the stimulus intensity a little. 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 spike may represent a SFAP, or be a summation of two or more potentials. To be accepted for measurements the ASFAPs should have a fast rising phase without notches or shoulders and have a well defined peak. The shape should be constant at consecutive discharges, best seen when 5–10 traces are superimposed and inspected with high sweep speed, e.g., 0.5 ms/div. The negative going deflection part of the signals should be parallel on superimposed traces. Some examples of acceptable and not acceptable potentials are shown in Fig. 2.

The CNE was moved to several sites in the OOc muscle from 1 cm lateral to the canthus, alternating with readjustments of the stimulating electrode in order to get different ASFAPs; in all cases 30 different spikes were measured in each subject. The time spent for each study was about 30–40 min.

Jitter for each study was expressed as the mean of mean consecutive difference (MCD) in 30 analyzed potentials. For each jitter analysis, a minimum of 50 and ideally 100 consecutive traces were recorded. Filter setting was 1–10 kHz. The Keypoint software also calculated the mean peak latency.

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

The mean of the 50 mean MCD (s-jitter) values in each subject was $21.5 \pm 1.99$ µs ranging from 17.8 to 26 µs; median was 21 µs; the distribution was Gaussian (Anderson–Darling, $p$-value = 0.119). The upper 97.5% confidence limit was 25.5 µs. The mean of all 1500 ASFAPs MCD (s-jitter) values was $21.6 \pm 6.03$ µs ranging from 7.1 to 39 µs; median was 21 µs; the distribution was non-Gaussian (Anderson–Darling, $p$-value < 0.005). The upper 97.5% confidence limit was 33.4 µs. The results are shown in Figs. 3 and 4. The mean value of the latency to ASFAPs (measured to peak) was $4694 \pm 895$ µs ranging from 3322 to 7273 µs. For the individual recordings, ranging from 1.5 to 14.1 ms, there is no significant correlation between jitter and latency ($R^2 = 0.015$) (Fig. 5).

4. Discussion

For SFEMG, reference jitter values for various muscles have been collected in individual laboratories and in a multicenter

![Jitter from stimulated Orbicularis Oculi with CNE](image)

Fig. 3. Gaussian distribution of the mean consecutive difference (MCD-jitter) values in 50 healthy subjects. The 97.5% upper limit was calculated as 25.5 µs (+2SD). CNE = concentric needle electrode. AD = Anderson–Darling normality test.
study. For CNE jitter, a few laboratories have reported reference values. The present study has measured the jitter values obtained after facial zygomatic branch stimulation in the OOC muscle. Often, the spikes obtained with CNE are not obtained from single muscle fibers (Stålberg and Daube, 2003; Stålberg and Sanders, 2009) but represent summation of more than one SFAP. Therefore, separate normative data should be collected for CNE recordings, as already done for SFEMG recordings. A few studies which have compared jitter values from SFEMG and from CNE in healthy controls and patients with myasthenia gravis reported a good correlation between the results (Ertas et al., 2000; Benatar et al., 2006; Sarrigiannis et al., 2006).

The reference values using ordinary SFEMG electrode for v-jitter the OOC have already been established in the literature (Gilchrist et al., 1992). For the age group below 60 years, the mean MCD is 30 μs and 95% upper normal limit is 37.3 μs for the mean of 20 MCD values. The reference values using SFEMG electrode for s-jitter in the OOC were studied by Trontelj et al. (1988), Valls-Canals et al. (2003) and Ertas et al. (1998); the last one also compared the values between SFEMG and CNE electrodes in the same subject. All results from those studies are shown in Table 1.

In our previous studies from CNE for v-jitter in EDC and OOC (Kouyoumdjian and Stålberg, 2007, 2008a,b) the values were always somewhat lower than the SFEMG jitter. The lower v-jitter values with CNE was attributed to the possibility that more than one SFAP constitute at least one of the components in the analysis, usually the triggering one. In our studies of OOC we found v-jitter CNE mean MCD to be 24.7 μs and s-jitter CNE to be 21.5 μs. The s-jitter should theoretical be reduced by \( \sqrt{2} \) from the v-jitter since only one motor end-plate is involved. In our data, the difference is less. Furthermore, the CNE s-jitter is somewhat higher than the SFEMG s-jitter, 12.6–16.3 μs from others. Therefore our s-jitter values are somewhat higher than expected.

Which are possible explanations for this difference? One reason may be our larger material. The other reason may be our more strict criterion for accepted signals than in earlier SFEMG studies,
Thus less risk of including signals with summation, a factor that reduces the numerical jitter. It should be noted that also in SFEMG s-jitter, there is also a possibility of summation, and great care must be taken regarding signal quality.

Yet another reasons may be technical such as those discussed below.

4.1. Stimulus pulse

In this study we have used surface stimulation with 0.10 ms duration of pulses, in contrast to 0.04 ms suggested for intramuscular stimulation (Trontelj and Stålberg, 1992; Stålberg et al., 2010). The short duration of 0.04 ms is recommended to bias stimulation towards nerve rather than muscle. This is not the issue in a technique where we stimulate outside the muscle. We used 0.10 ms since then 5–7 mA was a sufficient stimulus strength compared to much more for shorter stimulus durations.

4.2. Jitter at the point of stimulation

The other technical point is whether percutaneous stimulation may add jitter at the point of stimulation. In all recordings we ascertained that the stimulation strength was supramaximal, i.e., further increase in stimulus strength did not further decrease the jitter, generated at the stimulus site. We therefore do not believe that stimulus jitter is significant. Furthermore, in a few cases, we initially compared the jitter values for percutaneous and near needle stimulation, and no difference was detected (Kouyoumdjian and Stålberg, 2009). Proper surface stimulation decreases the numerical jitter. It should be noted that also in SFEMG s-jitter, there is also a possibility of summation, and great care must be taken regarding signal quality.

4.3. Method for jitter measurement

Another technical factor is the technique of measurements. We have used peak detection rather than amplitude level for the time markers. In separate tests when the peak detection method was introduced no difference was seen between methods for amplitude level or peak detection when “clean” signals were studied (Stålberg, unpublished). With riding signals, jitter value is erroneously introduced no difference was seen between methods for amplitude level or peak detection when “clean” signals were studied (Stålberg, unpublished). With riding signals, jitter value is erroneously high for the amplitude level trigger method (Stålberg and Sanders, 2009), thus our values should sometimes be lower than from other studies, which is not the case (see Table 1 for time measurement method).

The other somewhat unexpected finding in this study is the smaller than expected difference between v-jitter and s-jitter in the CNE studies. This has no explanation at present.

Earlier study (Gilchrist et al., 1992) has no mention to gender difference for this muscle, and therefore we accept the imbalance in gender in this pooled material. Other neurophysiological parameters such as motor unit potential values, nerve conduction and F-wave latencies do not show significant gender differences. In this study we did not find a significant effect of age on jitter. One reason may be the restricted age span of 21–56 years. The other is the fact that very small age changes are seen in this muscle also in other material (Gilchrist et al., 1992) as well as for conventional EMG parameters. Furthermore we found a very weak correlation between latency and jitter that can be neglected when it comes to describing normality. A weak correlation was reported by Trontelj et al. (1988) studying latencies up to 16.5 ms. Therefore age or latency is not included in the calculations of reference limits. In spite of that, further studies are necessary for CNE jitter reference in subjects above 60 years.

It should be remembered that percutaneous stimulation in the face may evoke a blink reflex (Stålberg et al., 2010). This is unlikely to occur in this study with the weak stimulation lateral to the eye compared to stimulation of the supraorbital nerve. The blink reflex has a large jitter, and R1, the shortest of the responses, is normally seen with a latency of more than 12 ms. None of our recordings were R1 of the blink reflex. Only seven out of 1500 recordings had a latency >12 ms (Fig. 5), and none had a jitter in the range of a blink reflex. A practical advice is to discard recordings with a latency >12 ms.

In conclusion, CNE is an acceptable alternative to SFEMG to acquire spike components, ASFAPs, after percutaneous branch stimulation. This study defines reference limits obtained from 50 healthy subjects. For MCD we suggest an upper limit (about 2SD) of 26 μS and for individual recordings 34 μS. Still, a certain level of caution must be maintained before a study using CNE is declared abnormal in other material has to be collected in a multicenter effort.

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