Single Fiber EMG

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Single Fiber Electromyography

The technique of single fiber EMG (SFEMG) is mainly used to help with the diagnosis of myasthenia gravis when there is high clinical suspicion and other tests, including acetylcholine receptor, muscle specific tyrosine kinase (MuSK) antibodies and EMG with repetitive nerve stimulation have been negative.

This electrodiagnostic technique was developed in the 1960s by Erik Stalbërg and Jan Ekstedt with the purpose of obtaining action potentials from a single muscle fiber [1]. For optimal results with the single fiber EMG technique, a special concentric needle electrode with a small recording surface of 25 microns in diameter located 3 mm from the tip is used, so that it can selectively capture these action potentials from individual muscle fibers (see Figs. 11.1 and 11.2). The use of a high pass filter of 500 Hz when recording the action potentials further helps with the selectivity [3].

Acceptable action potentials are those with an amplitude of 200 microvolts or more.

More recently, monopolar and concentric needles have also been used to perform SFEMG, and reliable results can be obtained if the technique is done correctly by an experienced electromyographer. These needles have a lower cost and are disposable, eliminating the need to sterilize the needle electrode or to maintain the needle. It is recommended to increase the high pass filter to ~1000 Hz for better results. To the extent possible, a needle electrode with the smallest electrode surface should be used (e.g. 0.019 mm^2).

The single fiber EMG results can be obtained by using one of two techniques:

1. *Stimulation* SFEMG, in where individual motor fibers or motor axons can be activated using an intramuscular axonal stimulator in the form of a monopolar needle electrode positioned near the motor end-plate zone [1], which serves as the cathode, and a small surface electrode which serves as the anode.
2. *Voluntary activation* SFEMG, in which the patient voluntarily activates the muscle to be studied.

In either technique, the goal is to measure two parameters, the neuromuscular jitter and the presence of neuromuscular blocking.

Voluntary Activity SFEMG

As the patient does minimal contraction of the muscle to be examined, the SFEMG electrode is inserted into the muscle, preferably in the middle third of its length. The electrode is then placed in a

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N. Galvez-Jimenez et al. (eds.), *Electrodiagnostic Medicine*,
https://doi.org/10.1007/978-3-030-74997-2_11

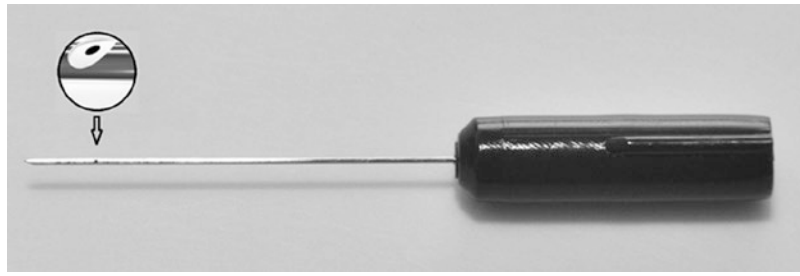


Fig. 11.1 Picture of a concentric single fiber electromyography (SFEMG) needle. Note the small recording surface (see inset) located 3 mm from the tip

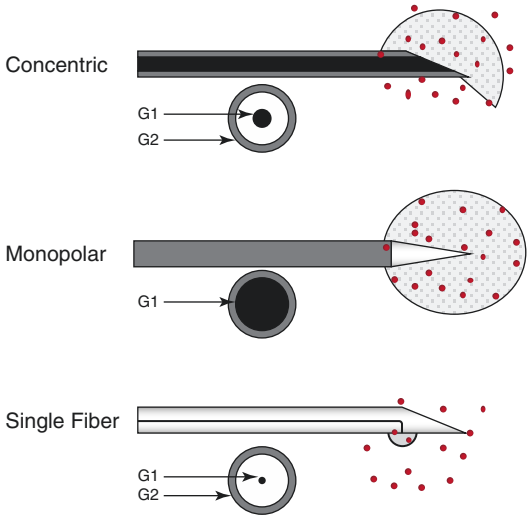


Fig. 11.2 Illustration showing the relatively small recording area (shaded) of the concentric single fiber electromyography (SFEMG) needle, compared to regular concentric and monopolar needle electrodes. G1, active recording site; G2, reference site. [Used with permission from [2]]

position where two (or at times more than two) time-locked action potentials from the same motor unit appear. Neuromuscular jitter is then recorded. The best recording is usually obtained from the superficial layer of the muscle and with minimal muscle contraction (firing frequency of the motor unit between 8 and 15 discharges per second) [4].

The most used muscles for SFEMG include the orbicularis oculi, extensor digitorum communis and frontalis muscle.

The voluntary activation SFEMG technique requires more patient cooperation but is subject to less technical errors or misinterpretations.

With the needle in position, the neuromuscular jitter is obtained, which is described as the minimal variability in latencies that exist between the appearance of one action potential and a second one from a single motor unit (Fig. 11.3). One action potential triggers the display sweep, and the second (paired) action potential appears with slightly variable position for each discharge [4]. This variability exists due to the changes in the transmission time across the synaptic gap, or the time it takes for end-plate potentials at the neuromuscular junction to reach the action potentials threshold [1]. Once the SFEMG electrode is in position where these action potentials are present, with adequate amplitude, then a minimum of 50 discharges need to be recorded. This technique is repeated several times, until a total of 20 action potential pairs, from different areas of the muscle, can be obtained. This may require a total of 3–4 skin insertions (aiming to minimize the number of these).

The jitter is then expressed as the mean value of consecutive differences (MCD) of successive interpotential intervals (IPIs), represented in Fig. 11.4 below.

Many of the modern electromyography machines have the capability of calculating the MCD directly, though it is always advisable that the operator visually analyzes the signals that are being acquired to asses for poor triggering or disturbing activity from other motor units and quality of the signal.

When obtaining jitter measurement and action potentials, errors can occur if the electrode is moved in relation to the fiber and the amplitude of the action potential decreases, affecting the calculated jitter.

Normal Jitters Findings and Values with Voluntary Activation

The measurement of jitter varies from muscle to muscle and with age. As age increases, so does

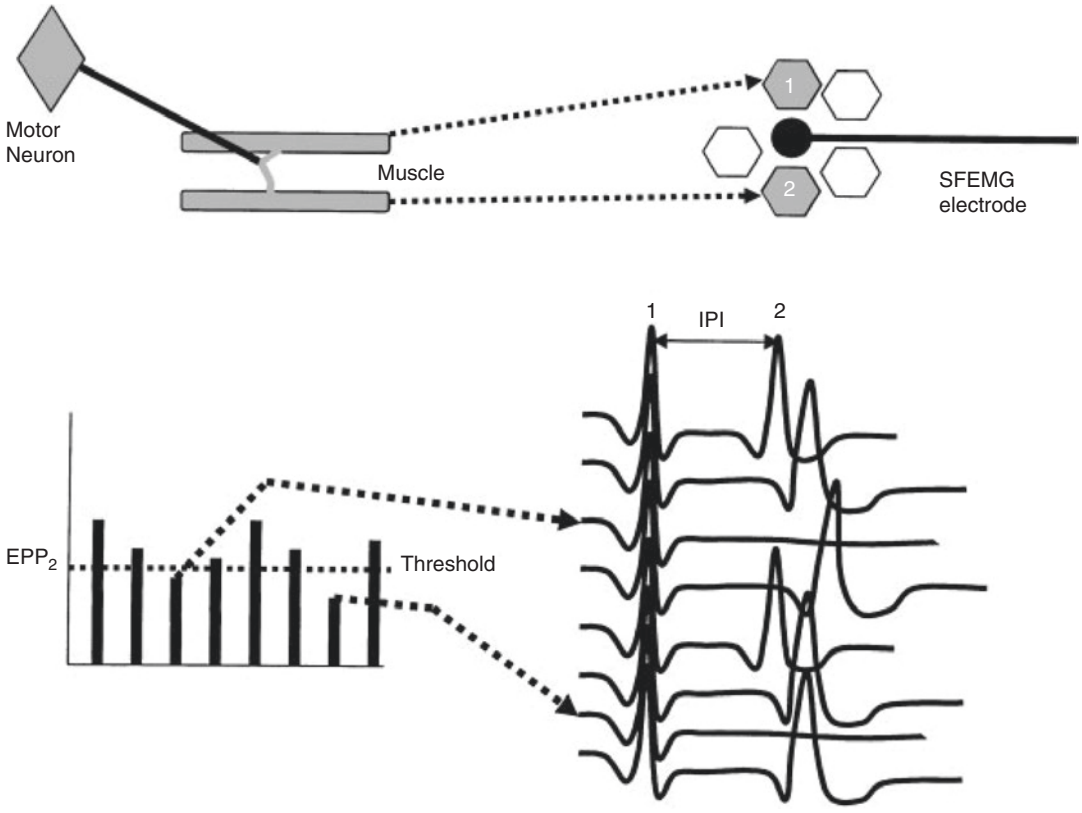
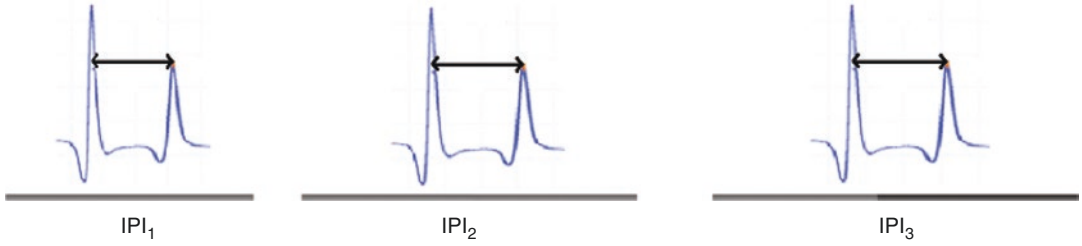


Fig. 11.3 Method of single fiber electromyography (SFEMG) with voluntary activation. The SFEMG needle is inserted into voluntarily activated muscle and is positioned so that recordings are obtained from two or more single muscle fibers belonging to the same motor unit. One single muscle fiber action potential serves as a time reference and the interpotential interval (IPI) is measured after consecutive discharges between the reference potential and subsequent time-locked potentials. In disorders of the neuromuscular junction, there may be marked variability of the IPI (abnormal jitter). If severe, neuromuscular transmission failure may occur in which the EPP amplitude fails to reach the threshold for action potential generation. This is demonstrated here by the absence of the second recorded fiber pair when the EPP in the second muscle fiber (EPP2) is subthreshold (dotted lines and arrows). [Used with permission from [5]]



$$MCD = \frac{[IPI_1 - IP1_2] + [IPI_2 - IPI_3] + \ldots [IPI_{n-1} - IPI_n]}{n-1}$$

IPI= interpotential interval
MCD=mean value of consecutive differences

Fig. 11.4 Representation of interpotential interval (IPI) and calculation of mean value of consecutive differences (MCD) in the determination of jitter

jitter in normal subjects. Normal jitter values range from 5 to 65 microseconds, and is different to each muscle. There exist predetermined reference jitter values for the most common muscles studied with the SFEMG technique.

The value of the interpotential interval (IPI) is important and it is recommended that this stays below 4 milliseconds, as erroneous high jitter values can be obtained from recordings with long IPI [1].

The results of jitter measurements in each muscle is presented as the mean or median value of the MCD values in all the pairs or endplates measured; the percentage of paired potentials in which blocking was present (given as percentage of blocking); and the percentage of pairs in which jitter exceeds the limit of normal for that particular muscle [3].

For a study to be considered abnormal the following must be present:

1. The mean (or median) jitter exceeds the upper limit of normal for the muscle; or
2. More than 10% of pairs have increased jitter (including blocking).

In general, when blocking is present jitter values should already be abnormally increased. In MG gravis for example, blocking occurs during voluntary activation once jitter values exceed 80–100 μs.

A jitter value of 5 μS or less can be seen in some cases of myopathies and rarely with voluntary activation in normal muscle, this probably representing recording from split muscle fibers activated by a single NMJ. These values should not be counted for assessment of the neuromuscular transmission [3].

It is best to calculate mean MCD from individual muscles with data of jitter values less than 150 μs, as this can significantly increase mean jitter value, even if all other endplate potentials of this muscle show normal jitter values. Increase jitter, with or without blocking, can occasionally occur in one of 20 pairs in normal muscle [4].

Overall for reliable results, SFEMG must be performed by an electromyographer knowledgeable in the technique of data collection and analysis. Most patients cooperate well with this study and report relatively little discomfort. The SFEMG needle must be in good condition, with a sharp tip that prevents more than minimal muscle fiber damage.

Conditions that could limit SFEMG study include patients with limb tremor, in which the use of a facial muscle is generally preferred. Another challenging patient subgroup includes sedated patients, uncooperative patients or children under 8 or infants, in which the use *stimulated* SFEMG is then preferred. A decrease in intramuscular temperature below 35 °C can increase the jitter in normal muscle, so such low temperatures such be avoided.

SFEMG in Myasthenia Gravis

In patients with myasthenia gravis, the following in a tested muscle may be found:

1. Endplates with normal jitter values.
2. Endplates with jitter values above the normal range without impulse blocking.
3. Endplates with increase jitter and intermittent impulse blocking.

Jitter is found to be increased in most patients with myasthenia gravis, and this finding is more pronounced when weak muscles are tested but can also be found in muscles that do not show clinical weakness. A SFEMG tracing showing marked jitter in a clinically affected muscle is shown in Fig. 11.5 below. Jitter is abnormal in

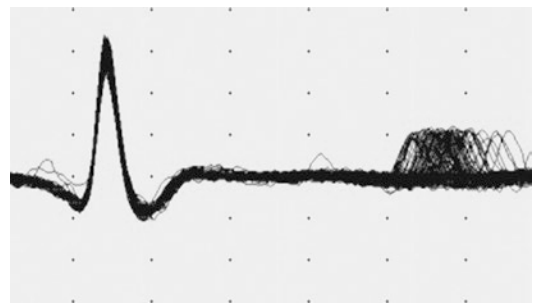


Fig. 11.5 Single fiber electromyography (SFEMG) with high jitter in the frontalis muscle, 1 kHz high-pass filtering, 200 μV/D, 0.5 ms/D. [Used with permission from [6]]

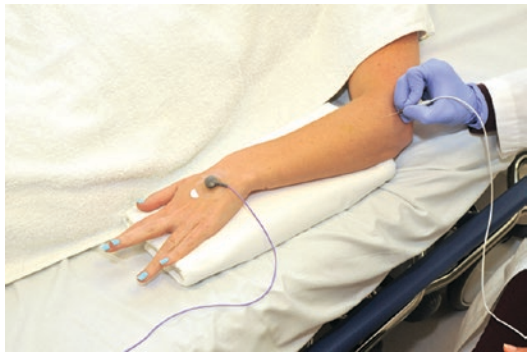


Fig. 11.6 Single fiber electromyography (SFEMG) technique recording from the extensor digitorum (communis) muscle. This is done by having the patient extend the middle finger only while the needle is inserted parallel to the muscle fibers

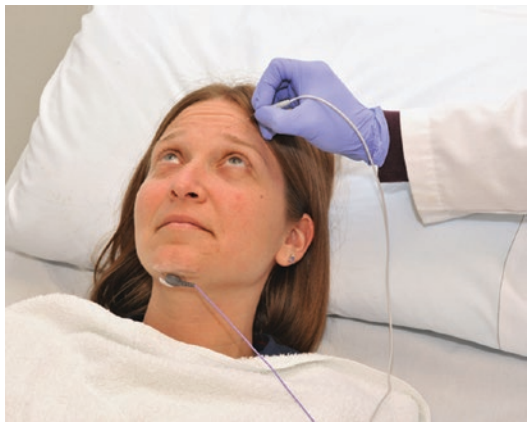


Fig. 11.7 Single fiber electromyography (SFEMG) technique recording from the frontalis muscle. This is done by having the patient gently elevate eyebrows while the needle is inserted parallel to the muscle fibers

~85% of patients with ocular MG, and in up to ~95–99% of patients with generalized MG.

The muscle to be tested should be selected depending on patients' symptoms, and it is preferable to select an unequivocally symptomatic muscle in order to increase the probability of finding abnormal jitter. We prefer the extensor digitorum (communis) (Fig. 11.6) in patients with generalized myasthenia gravis, and the frontalis (Fig. 11.7) or orbicularis oculus (Fig. 11.8) in patients with primarily ocular symptoms with or without generalized weakness.

The extensor digitorum is mostly tested first, and preferable in patients with limb or with bulbar

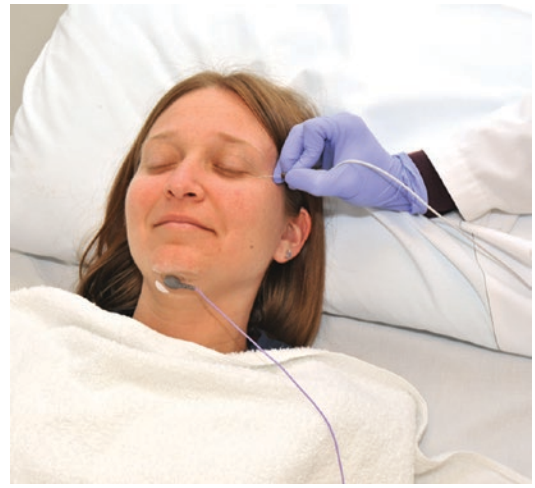


Fig. 11.8 Single fiber electromyography (SFEMG) technique recording from the orbicularis oculus muscle. This is done by having the patient close the eyes, minimally squeezing the eyelids shut. The needle is inserted parallel to the muscle fibers, directed away from the eyelid margin

muscle weakness. This muscle can be abnormal in about 85% of patients with MG during their initial electrodiagnostic assessment. This muscle is preferred due to being relatively easy to activate, with minimal patient discomfort and ease of finding pairs of action potentials. With the patient elevating the middle finger minimally, the needle is inserted parallel to the axis of the muscle fibers.

With respect to firing rate and jitter values, the jitter is most likely to be increased when the firing rate is rapid in an endplate pair, compared to when it is firing slowly.

We prefer patients discontinue the use of cholinesterase inhibitors, when clinically safe, at least 12 hours before the study. This may be more useful in patients with ocular MG or in those with minimal limb weakness as jitter can become abnormal only when these medications are discontinued. In other patients, jitter values can still be increase even when they continue to take the cholinesterase inhibitors.

If SFEMG is done in a clinically weak muscle, and jitter is normal, then the diagnosis is almost surely not MG.

In MG, jitter may not be present during initial recording of muscle activation, and measurement may need to be made for several minutes for jitter

to become abnormal. This does not occur in healthy muscle, as jitter remains stable even with prolonged activation.

Jitter values do not generally correlate well with disease severity, but these values could potentially be used to monitor patients with MG, in which jitter becomes abnormal over time indicating a possible clinical exacerbation.

Abnormally increased jitter does not only occur in MG and can also be found in Lambert Eaton myasthenic syndrome (LEMS), polyneuropathies or motor neuron disorders. Therefore, it is very important to do nerve conduction studies (including repetitive nerve stimulation) and routine EMG in patients prior to SFEM, in order to exclude these diagnoses. In cases of LEMS, the jitter will be increased out of proportion to the severity of muscle weakness, and impulse blocking is commonly found. In polyneuropathies, the jitter can be increased during reinnervation, and later normalizes or reduces.

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