Video Article

Extraction of the EPP Component from the Surface EMG

Toshifumi Kumai[1]

[1]Graduate School of Oral Medicine, Matsumoto Dental University

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Abstract

A surface electromyogram (EMG), especially when recorded near the neuromuscular junction, is expected to contain the endplate potential (EPP) component which can be extracted with an appropriate signal filter. Two factors are important: the EMG must be recorded in monopolar fashion, and the recording must be done so the low frequency signal corresponding the EPP is not eliminated. This report explains how to extract the EPP component from the EMG of the masseter muscle in a human subject. The surface EMG is recorded from eight sites using traditional disc electrodes aligned along over the muscle, with equal inter-electrode distance from the zygomatic arch to the angle of mandible in response to quick gum clenching. A reference electrode is placed on the tip of the nose. The EPP component is extracted from the raw EMGs by applying a high-cut digital filter (2nd dimension Butterworth filter) with a range of 10-35 Hz. When the filter is set to 10 Hz, the extracted EPP wave deflects either negative or positive depending on the recording site. The difference in the polarity reflects the sink-source relation of the end plate current, with the site showing the most negative deflection corresponding to the neuromuscular junction. In the case of the masseter muscle, the neuromuscular junction is estimated to be located in the inferior portion close to the angle of mandible. The EPP component exhibits an interesting oscillation when the cut-off frequency of the high-cut digital filter is set to 30 Hz. The EPP oscillation indicates that muscle contraction is adjusted in an intermittent manner. Abnormal tremors accompanying various sorts of diseases may be substantially due to this EPP oscillation, which becomes slower and is difficult to cease.

Video Link

The video component of this article can be found at http://www.jove.com/video/1653/

Protocol

1. Preparation of EMG electrodes

1. Begin by preparing nine electrodes. Eight of them are used for recording signals from sites over the muscle, and one is a reference electrode.
2. After connecting the recording and reference electrodes to the amplifier, fill the discs with electric-conductance paste. Every type is OK, but a low fluid type is better.
3. Before attaching the electrodes to the skin, have the subject down firmly, and determine the approximate location of the masseter muscle on the face.
4. The superior tendon of the masseter muscle attaches to the zygomatic arch, and its inferior tendon to the angle of mandible.
5. Place the eight recording electrodes onto a long piece of adhesive tape in equal inter-electrode distance, and attach the array to the skin surface. The first recording electrode is placed on the zygomatic arch, and the last one on the angle of mandible.
6. Finally, attach the reference electrode to the tip of the nose.

2. EMG recording

1. To begin recording, first set the parameters of the multi-channel analogue amplifier (MEG6100). Set the gain to x 500, the low pass filter to 0.5 Hz, and the high pass filter to 10 kHz.
2. Connect the eight outputs of the analogue amplifier to an Analogue-Digital converter (PCI-MIO-16E-4). The digital signal is processed with LabView software with a sampling rate of 20kHz.
3. When everything is connected, record EMGs during quick chewing-gum clenching on the ipsilateral side.
4. The traces from the eight channels are presented on the LabView display immediately after the recording process has been completed.

3. EPP extraction and observation of its features

1. To extract the EPP component, first remove the action potential component from the raw EMGs using a high-cut digital filter (Butterworth filter).
2. Begin applying the filter with a cut-off frequency of 10 Hz. A slow wave that deflects in the positive or negative direction should appear. This wave corresponds to the EPP, and the difference in polarity reflects the sink-source relation of the end plate current.
3. When recording from the masseter muscle, the most negative deflection of the wave is expected in the trace from the most inferior recording site, and the polarity should shift around 3 sites away from that site.

4. The magnitude of the EPP component can be measured as a peak point of the deflection or an area during the deflection.
5. The polarity change of the EPP component can be determined by plotting the EPP wave from each channel against a reference channel that showed the most negative deflection.
6. Now by increasing the cut-off frequency, the slow wave will become oscillatory. The oscillation will increase with increasing cut-off frequency and will generally become obvious at a cut-off frequency of 30 Hz.
7. The phase of the wave will reverse across the trace in which the polarity of the 10Hz filtered EPP wave showed a reversal.
8. The phase shift of the oscillation can be checked with the same graphs that were applied to the 10Hz-filtered EPP wave.
9. From the interval between neighboring positive and/or negative peaks of the oscillation, we can get an approximation of the frequency of the oscillation

4. EMG recording results

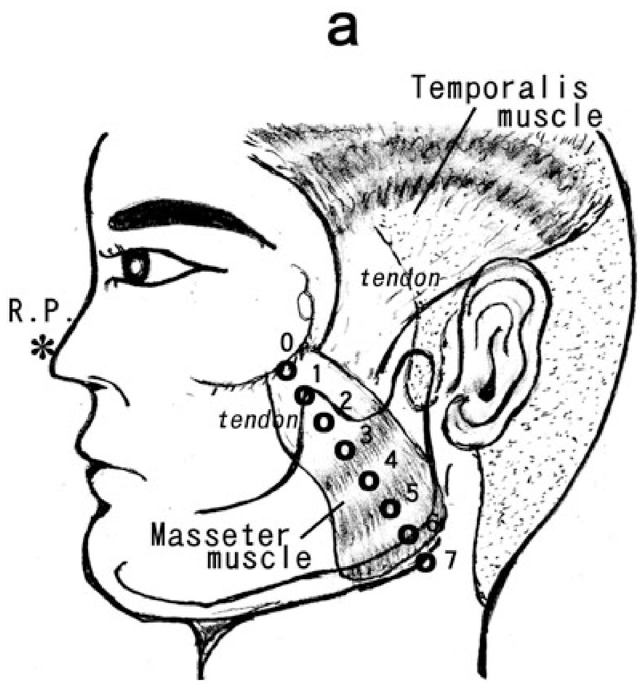

Figure 1a: Shown here is a schematic of the eight sites along the masseter muscle that were recorded from.

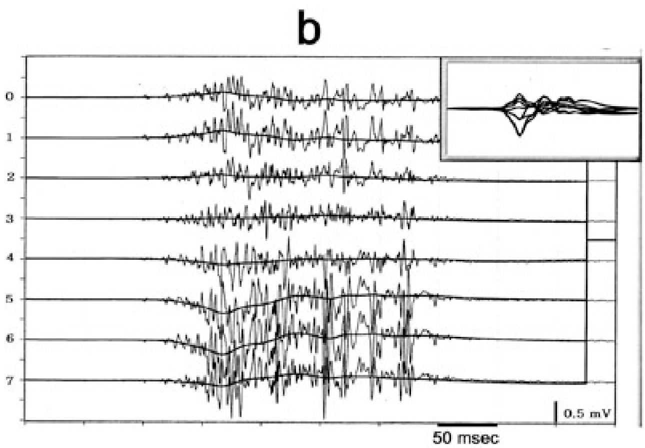

Figure 1b: We see a sample of the monopolar EMGs recorded simultaneously from the sites over the masseter muscle in response to quick gum clenching on the ipsilateral side. The EPP component was extracted using a high-cut digital filter with a cut-off frequency of 10Hz, which is superimposed on each raw EMG. In this trial, the most negative deflection was observed in traces-5 and -6 and the polarity changed across trace-3.

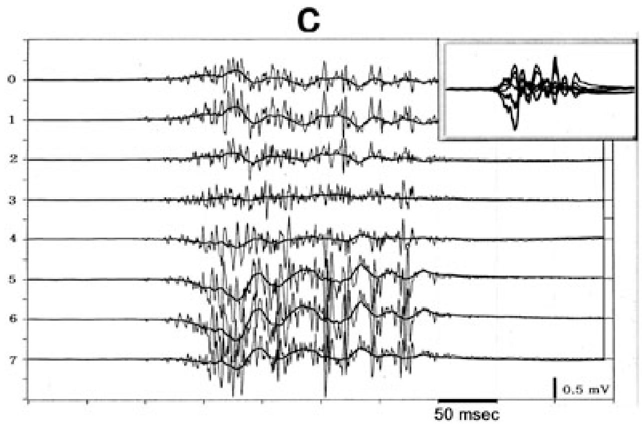

Figure 1c: When the cut-off frequency of the high-cut digital filter was set to 30Hz, the slow wave exhibited an oscillation. Its phase also shifted across trace 3, where the polarity of the 10Hz-filtered EPP wave changed. The interval between neighboring positive peaks of the oscillation was measured. In this subject, the average inter-peak interval was 31.7 ± 6.5 msec over 16 recordings.

Discussion

1. As the negative potential is considered to be formed by a flow-in of the endplate current, and the positive deflection, by its flow-out [1,2,3,4], the trace showing the most negative deflection must correspond to the site locating the neuromuscular junction [5]. Figure 1b indicates the neuromuscular junction of the masseter muscle locate in its inferior portion close to the angle of mandible, which is approximately the same as results obtained by another method utilizing the conduction manner of the motor unit action potential [6,7].
2. The masseter muscle has an anatomically characteristic conformation: its superior tendon is very long, and its inferior tendon, quite short [8]. The polarity of the EPP component (and the phase of its oscillation) tended to shift across the portion where muscle fibers are estimated to shift to the tendon. This suggests that most of the synaptic current would flow out from the tendon.
3. The EPP oscillation is considered to originate substantially from rhythmic group discharges of α-motor neurons, and indicates that muscle contraction is adjusted in an intermittent manner. Although such a discharge pattern could be built up in the higher central nervous system [9], it is also probable that it originates from a suppressive feed-back action of the Golgi tendon organs on α-motor neuron activity set by γ-motor neuron innervating the muscle spindle.
4. Various types of abnormal tremors are known in humans. The tremors occur involuntarily with a frequency of about 5-10 Hz. Although these frequencies are slower than the frequency of the EPP oscillation observed in this examination, the abnormal tremors must be caused substantially by this EPP oscillation, which becomes slower and is difficult to cease.

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