

# **Neurophysiological assessment of movement disorders**

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## **NEUROPHYSIOLOGICAL ASSESSMENT OF MOVEMENT DISORDERS**

Neurophysiological investigations in movement disorders are objective methods to investigate and support clinical diagnosis of different abnormal movements, and to monitor their severity and the effects of treatment.

Many methods are available, most of them useful for research purposes, but often of limited clinical utility. All electrophysiological tests should be interpreted in conjunction with clinical features but neurophysiology may disclose information that it is not possible to obtain by clinical observation alone.

### **TREMOR**

Tremor is the movement disorder most subjected to neurophysiological study.

The type of tremor can be characterised on the basis of its frequency, pattern of muscle activation, and duration and amplitude of the muscle bursts.

The conditions favouring tremor (rest, postural, action), and the presence of associated neurological signs, are important to guide the electrophysiological diagnosis of tremor.

Tremor frequency is the most useful aspect: the upper limit of frequency of physiological or voluntary tremor in healthy subjects is 11 Hz. Tremor above this frequency is always pathological, and most commonly due to orthostatic tremor with a frequency of 13-18 Hz. Tremor at 5-7 Hz is seen in patients with Parkinson's disease (PD), essential tremor (ET) and tremor at >9 Hz in patients with enhanced physiological tremor (EPT). Low frequency tremor < 4Hz occurs in Holmes' tremor, dystonic tremor and cerebellar tremor. Tremor amplitude is of little value for diagnostic purposes.

Tremor can arise from different sources. It may be possible to separate central from peripheral tremor using external loading of the limb (500-1000g in the hand). Multichannel EMG recording and accelerometer data are extremely useful in assessing tremor frequency and characteristics. External loading typically reduces the tremor frequency in peripheral tremor (physiological tremor, EPT), but not in central tremor (PD, ET).

Physiological tremor and essential tremor may have the same frequency but the response to loading may help to differentiate between them. Essential tremor and parkinsonian tremor, both central tremors, are mainly differentiated on clinical grounds. Holmes' and cerebellar tremors both have a lower frequency and a central origin, and are usually easy to diagnose clinically.

Burst duration is useful mainly in identifying a cortical origin of tremor - rhythmic cortical myoclonus. Multichannel EMG recording may show a rostro-caudal pyramidal progression of the pattern of muscle recruitment, or rhythmic arrests of muscle tone as in negative cortical myoclonus or asterixis.

The pattern of muscle activation between agonist and antagonist muscles (synchronous versus alternating) is not very helpful in guiding the diagnosis.

Dystonic tremor is an irregular tremor below 7Hz. It is associated with dystonic postures in the affected extremity or elsewhere, is subject to position- and task-specific worsening, and increases with attempts to move the body part in the opposite direction to the dystonic pattern.

In psychogenic tremor, amplitude and frequency decrease during distraction (counting, tapping). Furthermore, tapping different frequencies with the unaffected hand "entrains" to the same frequency as that on the tremulous side. Tremor amplitude and frequency usually increase when adding a load to the affected limb. Muscle co-activation between agonist and antagonist muscles is often recorded (co-activation sign).

## **MYOCLONUS**

Myoclonus is classified according to its physiopathological basis as cortical, reticular or spinal

**Cortical myoclonus** is usually arrhythmic but can also be rhythmic (cortical tremor). It is characterised by jerks of short duration (<50 ms) involving many muscles and usually synchronously in agonists and antagonists.

EMG recording from an extremity can demonstrate spread of jerks from the proximal muscle to distal with velocity corresponding to that of alpha motor fibres.

In cortical myoclonus the EEG often shows multifocal or generalised spike and wave or multiple spike and wave which is usually time-locked to the muscle jerks.

However, in some cases the EEG does not show any time-locked abnormality.

EEG back-averaging can disclose myoclonus-related EEG activity that may not be recognised on the conventional polygraph. This technique can determine the precise time interval from the EEG activity to the myoclonus. It also identifies the scalp distribution of the myoclonus-related EEG activity based on simultaneous multichannel recordings.

Back-averaging analysis shows a positive-negative biphasic spike at the central electrode somatotopically representing the muscle from which the myoclonus is recorded. The initial positive precedes the onset of myoclonic EMG discharge in a hand muscle by approximately 20ms. The more distal the muscle the myoclonus is recorded from, the longer is the EEG-EMG time interval. Myoclonus-related discharge spreads through the motor cortex within one hemisphere, and also transcalsally to the homologous area of the contralateral motor cortex (10-15 ms). Unfortunately EEG back-averaging analysis is limited by muscle activity in the scalp and also in cases where the jerks are of high frequency, or are infrequent.

In subjects in whom myoclonic EMG bursts are of small amplitude, or repeated rhythmically at high frequency, frequency analysis has advantages over back-averaging. Frequency analysis of EMG-EMG and also EEG-EMG coherence can detect a pathologically exaggerated common drive in distal limb muscles, showing significant coherence in the physiological range (15-60Hz) but also, in some cases, at much higher frequencies.

Patients with cortical myoclonus may also show giant sensory evoked potentials; the initial components, a postcentral negative peak (N20) and a precentral positive peak (P20), are not enhanced; however, the subsequent components (P25, P30, N35) are 3-10 times as large as normal.

Long loop reflexes (C-reflexes) obtained by the motor subthreshold stimulation of the median nerve, recording from both thenar muscles, are also enhanced with a latency in the thenar muscle of around 45 ms, and 10 – 15 ms longer contralaterally due to the transcallosal transit time. Negative myoclonus is produced by a sudden (between 50 and 400 ms) interruption of a tonic muscle contraction, associated with an ictal discharge.

In Creutzfeldt-Jakob Disease (CJD), myoclonus is not stimulus-sensitive and occurs continuously and quasi-periodically in the resting condition every 600-1500 ms. There may be accompanying dystonic posturing. EMG bursts are similar to, or slightly longer than, those of classical cortical myoclonus. Periodic sharp discharges (PSDs) are usually associated with muscle jerks, but can occur independently. EEG spike-wave and EMG activity correlate loosely. On back-averaging, the negative spike-wave is much smaller than the PSD recorded with raw EEG. The time interval between EEG and jerks is 50-85ms (much longer than required for conduction through the pyramidal tract). Typical cortical reflex myoclonus may be seen in late stages of disease.

In subacute sclerotic panencephalitis (SSPE) sudden movements followed by a tonic phase (“hung up jerks”) can be related to periodic high amplitude EEG discharges occurring every 4-13 sec.

Essential myoclonus, myoclonus dystonia (except for SSPE), palatal and oculo-palatal myoclonus are characterised by EMG discharges lasting up to 400ms. In such cases the EMG does not show any specific EEG correlate

**Reticular, or brainstem, myoclonus** is characterised by generalised jerks with prominent involvement of proximal and flexor muscles. Jerks may be spontaneous or stimulus-induced, particularly with respect to sound.

Jerks originate from the brainstem reticular formation; (the first muscle to be activated is trapezius or sternomastoid); subsequently there is spread to the cranial and caudal muscles with different velocities of activation.

Myoclonic jerks may be associated with cortical spikes. However, the lack of correlation between the two suggests that spikes are projected to, but do not originate at, the cortex. Evoked potentials are not increased, but there may be an enhanced C-reflex.

The normal human startle response consists of a brief flexion response, most marked in the upper half of the body, elicited by unexpected auditory, and sometimes somesthetic, visual or vestibular stimuli. The nucleus reticularis pontis caudalis seems particularly important. Conduction of efferent impulses both upwards and downwards from the generator, possibly in the medial reticular formation, is slow. The shortest latencies are 20–50 ms for the orbicularis oculi muscle. In the quadriceps muscle the latencies of the responses are 100–150 ms. Electromyographic responses in the intrinsic hand and foot muscles are particularly delayed. However, the auditory startle reflex electromyographic latencies are rather variable. The constant reflex EMG activity in orbicularis oculi is the most important event in the normal auditory startle reflex. Considering the auditory blink reflex in orbicularis oculi as separated from the startle response, Brown found the earliest muscle recorded is the SCM with a latency of <100ms. The activity then spreads up the brainstem from the eleventh nerve to the fifth cranial nerve and down the spinal cord (reflex brainstem myoclonus) In physiological startle the stimulus-induced response tends to habituate, and disappears after 4-6 stimuli. Exaggerated startle responses are seen in hyperekplexia, in neuropsychiatric startle syndrome and in stimulus-induced epilepsy or other movement disorders such as stiff-person syndrome or tics.

**Spinal Myoclonus** Two different patterns of spinal myoclonus are recognised: propriospinal myoclonus and segmental myoclonus. Myoclonus is most often positive, but negative myoclonus may also occur.

Propriospinal myoclonus is characterised by arrhythmic sequences or runs of axial jerks producing flexion or extension of the trunk. Bursts of muscle activity vary from 50ms to 4s. EMG jerks arise from abdominal or cervical spinal segments and slowly spread rostrally and caudally at <10 m/s. Cranial muscles are not involved, with the exception of the neck. It can be stimulus-sensitive.

Segmental myoclonus is described as regular or irregular repetitive jerks, involving a group of muscles innervated by 1 or 2 spinal segments.

## **DYSTONIA**

Many neurophysiological abnormalities have been found in patients with dystonia, but these are only partially useful for diagnostic purposes in individual patients. Impaired reciprocal inhibition of forearm flexor muscles at intermediate and long latency, reduced cortical silent period duration, and short- and long-interval intracortical inhibition have been seen in different studies in dystonic patients. More sophisticated analyses of EMG discharges consider EMG-EMG coherence. This may disclose the character of the descending discharges responsible for the abnormal muscle activity in dystonia. An abnormal 4 to 7 Hz drive is seen in dystonic muscles in patients with the DYT1 gene mutation, idiopathic torticollis and myoclonus dystonia. In the arms there is evidence of an abnormal corticomuscular drive in the 15 to 30 Hz band leading to co-contraction between antagonistic muscles, with the exception of writer's cramp where a discrete peak in EMG-EMG coherence may be seen at 11 to 12 Hz.

## **RIGIDITY**

### **Stiff Person Syndrome**

This is characterised by axial rigidity at rest involving mainly trunk and proximal lower limb muscles. Exteroceptive stimuli may evoke a sudden exacerbation of rigidity (reflex spasm).

A crucial finding is the presence of continuous motor unit activity in the paraspinal muscles that persists even when trying to relax. EMG electrical silence cannot be obtained. The rigidity and continuous motor unit activity lessen or even disappear during sleep and after spinal or general anaesthesia, indicating a central source.

Exteroceptive or musculocutaneous reflexes are enhanced, habituate poorly, and spread as reflex spasms into muscles normally not involved in the reflex. These findings point to enhanced spinal interneuronal excitability, due to defects either within spinal interneuronal networks at a segmental level or their descending control. Polysynaptic reflexes are characteristically exaggerated in both upper and lower limbs as well as the axial (paraspinal) muscles. These responses begin with one or several myoclonic jerks at short intervals (50-70ms) that are synchronous in antagonistic muscle pairs and are followed by prolonged tonic muscle activation (observed clinically as spasm). This pattern appears to be characteristic of stiff person syndrome. Patients with stiff limb syndrome present continuous motor units at rest at least in one limb. Spasms tend to involve repetitive grouped discharges of motor units.

## **CONCLUSION**

The pathophysiology of movement disorders is an active research field. However, many currently available tests have limited clinical application. Distinction between dystonia of psychogenic origin and organic movement disorders continues to present diagnostic challenges, and we need better criteria to differentiate types of tremor.

Shibasaki H, Hallett M. Electrophysiological study of myoclonus. *Muscle & Nerve* 2005. Feb; 31 (2):157-74

Deuschl G. Neurophysiology tests for the assessment of tremor. *Adv Neurol.* 1999; 80: 57-65

Brown P. Neurophysiology of the startle syndrome and Hyperekplexia. *Adv Neurol* 2002; 89:153-159

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