# Electromyography (EMG)

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**EMG:** extracellular electrical activity recorded from muscle

## METHODOLOGY

- **Spontaneous electrical activity** and individual motor units cannot be seen with **SURFACE ELECTRODES**.
- **NEEDLE ELECTRODE** placed within muscle:
  - a) **Monopolar needle electrode**
  - b) **Concentric needle electrode** (most popular) - fine silver (or platinum) wire, insulated except at its tip, that is contained within pointed steel shaft - potential difference between outer shaft and inner wire is recorded.

- **Potentials** are amplified → evaluated visually (on oscilloscope screen) and **aurally** (over loudspeaker).
- **Motor unit pathology** can be localized to nerve*, muscle, or neuromuscular junction. *EMG also permits lesion to be localized to spinal cord, nerve roots, plexuses, or peripheral nerves – by topographic pattern of affected muscles.

**Usefulness of EMG:**

1. Support of diagnosis (e.g. myopathy vs. neuropathy)
   - N.B. specific etiologic diagnoses cannot be made!
2. Confirming clinical phenotype of muscle involvement established on neurologic examination (i.e. confirming muscle weakness in individual muscles)
3. Guiding muscle biopsy

## Normal EMG

- Needle electrode is inserted → brief burst of activity for ≤ 2-3 seconds → no spontaneous activity*.
  - *except in endplate region - endplate "noise" (nonpropagated miniature endplate potentials generated by spontaneous Acch release).

1. Slight voluntary contraction is initiated → few motor units are activated - fire irregularly at low rate.
2. Increasing effort → fire more rapidly; at certain firing rate, additional units are recruited.
3. Maximal effort → so many units are recruited that individual potentials cannot be distinguished – "complete interference pattern".
   - Normal recruitment pattern on maximal effort is dense with no breaks in baseline; amplitude of envelope (excluding single high-amplitude spikes) is 2-4 mV (using concentric needle with standard recording area 0.07 mm²).

## Abnormal EMG

**Evaluate:**

1. Insertional activity
2. Spontaneous activity

### Normal extracellularly recorded individual motor unit action potentials are bhiphasic or triphasic.

- Duration: 2-15 msec.
- Amplitude: 200 µV - 3 mV.
- Polysynaptic potentials (> 4 phases) are nonspecific findings:
  - Occur in both neurogenic and myogenic disease;
  - Also are found in small numbers (10-15%) in all normal muscles.

- **A. Normal triphasic potential.**
- **B. Long-duration, high amplitude polysynaptic potential (shown twice) – neurogenic potential.**
- **C. Short-duration, low-amplitude, polysynaptic potential – myopathic potential.**

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*Source: *Practical Neurology* (5th ed.) by Scott, R., & Williams, D., 2014.*
3) voluntary activity:
   a) motor unit form (individual action potentials - amplitude, duration, number of phases) - during minimal volitional activity.
   b) density of motor units (recruitment pattern) - during maximal volitional activity.

- EMG requires patient cooperation for full relaxation and maximal voluntary muscle contraction -- EMG is less useful in pediatrics.

**Prolonged Insertion Activity**

- acute denervation
- active (usually inflammatory) myopathy

**Abnormal Spontaneous Activity**

- Denervated muscle fibers discharge spontaneously!
  - fibrillation potentials and positive sharp waves.

**Fibrillation Potential** - biphasic (or triphasic) discharge with positive onset (except in endplate region).
- represents action potential generated in **single muscle fiber** (so cannot be detected by clinical examination)
- amplitude up to 300 µV, short duration ≤ 5 msec, frequency ≤ 20 Hz.
- usually fire rhythmically - reflect oscillations of resting membrane potential of muscle fibers.
- **etiology** - increased muscle irritability:
  1) denervated muscle: may not appear even for 3-4 weeks after acute neuropathic lesion.
     - found earlier in proximal muscles (in distal muscles may appear only after 4-6 weeks).
     - once present, persist indefinitely unless reinnervation occurs or muscle completely degenerates so that no viable tissue remains.
  2) occasionally in some active myogenic disorders (inflammatory, muscular dystrophies, muscle trauma, certain metabolic disorders [e.g. acid maltase deficiency]).

**Positive Sharp Waves** - initial positive* deflection → slow deflection in negative direction.
- found in association with fibrillation potentials.
- amplitude up to 300 µV, duration ≥ 10 msec, frequency up to 100 Hz.

**Fasciculation Potential** - spontaneous activation of **all muscle fibers in motor unit**
- indistinguishable from normal motor unit action potentials!
- amplitude & duration greater than fibrillation potential.
- sudden dull thump over loudspeaker.
- **etiology** - disease of anterior horn cells*, very occasionally certain myopathic disorders (e.g. thyrotoxicosis), sometimes as isolated phenomenon without pathological significance (benign fasciculations).
- may arise at any site along motor axon or motoneuron body.

**Myotonic discharges** - spontaneous repetitive high-frequency trains of action potentials derived from **single muscle fiber**; decreasing amplitude and frequency.
- **etiology** - myotonic disorders, acid maltase deficiency.
- sound myographically like "dive bomber".
Diseases of neuromuscular transmission

- reduced safety factor for neuromuscular transmission → increased number is indicative of muscle reinnervation
  - single-fiber EMG is more sensitive than repetitive nerve stimulation or determination of acetylcholine receptor antibody levels in diagnosing myasthenia gravis!

Contracture (involuntary, sustained muscle contraction in phosphorylase deficiency) - electrical silence.
**Myopathy**

1) **INSERTIONAL ACTIVITY** - increased (e.g. bizarre high frequency discharges).
2) **SPONTANEOUS ACTIVITY** - complex polyphasic motor unit potentials; some myopathies (e.g. polymyositis, muscular dystrophies) may show fibrillations, positive sharp waves.
3) **VOLUNTARY ACTIVITY** - myopathic potentials (duration & amplitude); rapid recruitment.

**Neuromuscular junction disorders**

1) abnormal repetitive motor nerve stimulation results. see p. D22 >>
2) increased jitter, blockings on single fiber EMG.

**Myotonia**

- SPONTANEOUS hyperexcitability: repetitive high-frequency trains of action potentials; wax and wane in amplitude and frequency.

![Electromyographic features. A. Fibrillations consist of spontaneous depolarization of single muscle fibers that have been denervated. They appear as short duration di- or triphasic potentials. B. Positive denervation potentials. C. Myopathic motor units.](image)

![A. The normal electromyogram. Upper: Submaximal contraction. Note that the individual motor units have size between 1.5 and 2 mv in amplitude and are of approximately 5 to 7 msec duration. Lower: During maximal contraction there is a full "interference pattern". The spikes of greater amplitude represent action potentials derived from motor units lying relatively close to the recording electrode, whereas those of lower amplitude are derived from motor units located farther away.](image)
Electromyography (EMG)

C. The electromyogram in observation. From top to bottom: (1) Spontaneous fibrillation. This is a condition in which firing rates for the individual potentials increase so slow that all spikes in amplitude and are of about 4 Hz in duration. (2) Positive sharp wave (spike potentials), also recorded from relaxed muscles. The phenomenon is occasionally seen in otherwise normal muscles. (3) Complex repetitive potentials (fibrillation potentials). Also described as “fibrillation potentials arising spontaneously,” these are potentials generated within muscles in patients with various movement disorders. These potentials are histologically normal. They occur in a patient with motor neuron disease. (4) Fibrillation potentials occurring during voluntary activity in a patient with motor neuron disease.