Electromyography (EMG)  

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EMG - extracellular electrical activity recorded from muscle.

METHODS/DEFINITIONS:

- 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.
  - upward deflection indicates that active electrode is negative with respect to reference one.
  - 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).

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

- duration 2-15 msec.
- amplitude 200 µV - 3 mV.
- polyphasic 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 polyphasic potential (shown twice) – neuromyopathic potential.
  C. Short-duration, low-amplitude, polyphasic potential – myopathic potential.

Abnormal EMG

Evaluates:
1) insertional activity
2) spontaneous activity
3) voluntary activity.
Electromyography (EMG)

Prolonged insertion activity
a) acute denervation
b) active (usually inflammatory) myopathy

Abnormal spontaneous activity

- Fibrillation potential - biphasic (or triphasic) discharge with positive onset (except in endplate region).
  - amplitude up to 300 µV, short duration ≤ 5 msec, frequency ≤ 20 Hz.
  - usually fire rhythmically - reflect oscillations of resting membrane potential of muscle fibers.

- Positive sharp waves - initial positive* deflection → slow deflection in negative direction.
  - * traveling wave terminates at point of needle recording, so there is no upgoing negative phase.
  - found in association with fibrillation potentials.
  - amplitude up to 300 µV, duration ≥ 10 msec, frequency up to 100 Hz.

- Spontaneous fibrillation potentials + positive sharp waves:
  - 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.

- Myotonic discharges - spontaneous repetitive high-frequency trains of action potentials derived from single muscle fibers; decreasing amplitude and frequency.
  - *may arise at any site along motor axon or motoneuron body.

- Myotonia - myotonic disorders, acid maltase deficiency.
  - sound myographically like "dive bomber".

- EMG requires patient cooperation for full relaxation and maximal voluntary muscle contraction – EMG is less useful in pediatrics.
**Electromyography (EMG)**

Complex repetitive discharges - constant high frequency and amplitude; starts and stops abruptly and does not wax and wane (vs. myotonia) - sounds like "jack hammer".

- **etiology** - chronic partial denervation, certain muscular dysphonies or inflammatory muscle disorders.
- **arise in muscle itself** - initiated by fibrillating fiber that depolarizes adjacent fibers by ephaptic transmission.

**Myokymia** - spontaneous grouped pattern of firing of motor units (double, triple, or multiple discharges → period of silence → another grouped discharge).

- **etiology** - see p. Mov3 >>
- **arise in muscle itself** - initiated by fibrillating fiber that depolarizes adjacent fibers by ephaptic transmission.

**Myopathies** - number of muscle fibers in individual motor units; number of motor units is normal):
- myopathic potentials - duration & amplitude (i.e. recruitment density is normal, but envelope amplitude is reduced);
- pathognomonic finding of myopathy: full recruitment in weak, wasted muscle.

**Neuropathies** - number of motor units):
- **recruitment density** - decreased recruitment (reduced interference pattern); sometimes only one unit can be recruited by maximal effort, and this unit may fire faster than 40 Hz (discrete recruitment).
- **excess of small, short-duration potentials**.

**Diseases of neuromuscular transmission** (reduced safety factor for neuromuscular transmission → variation in number of muscle fibers firing with each discharge of unit):
- **motor unit action potentials** vary in amplitude & area;
- **excess of small, short-duration potentials**.
- **increased jitter** at single-fiber EMG. see below >>

**Neuropathic polyphasic potential** - indicative of muscle reinnervation. see p. PN7 >>

**Abnormalities of Motor Unit Action Potentials**

Needle electrodes record only from portion of motor unit, but change in amplitude and duration is diagnostic.

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

**Single-fiber EMG** - action potentials recorded from two or more muscle fibers belonging to same motor unit.

- **special electrode**.
- **temporal variability (jitter)** between two action potentials at consecutive discharges is measured.
- **jitter reflects** variation in neuromuscular transmission time in two motor endplates involved (i.e. variation in latency between nerve stimulus and resulting muscle action potentials).
normal jitter is 10-50 μsec.

- main clinical application - diseases of neuromuscular transmission - increased jitter, impulse blocking (failed muscle fiber activation).
- clinical muscle weakness correlates with impulse blocking
- normal single-fiber EMG rules out disorder of neuromuscular transmission!
- single-fiber EMG is more sensitive than repetitive nerve stimulation or determination of acetylcholine receptor antibody levels in diagnosing myasthenia gravis!

**EMG according to disorder**

**Denervation**
1) **INSERTIONAL ACTIVITY** - increased (e.g. bizarre high frequency discharges).
2) **SPONTANEOUS ACTIVITY** - tremors, fasciculations, complex repetitive discharges; increased polyphasic action potentials.
3) **VOLUNTARY ACTIVITY** - neuromuscular potentials (duration & amplitude); recruitment density.
4) **OTHER STUDIES** - prolonged "F response", lost H reflex. see p. D22 >>

**Myopathies**
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** - neuromuscular 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.

**Electromyography (EMG)**

Normal: Increased jitter:

- Normal EMG: All motor units activated.
- Increased jitter: Some motor units not activated, causing fibrillation of muscle fibers.

**Electromyographic features:**
- Fibrillations: Small, high-frequency potentials that are characteristic of denervation.
- Positive denervation potentials: Potentials that occur spontaneously in denervated muscle fibers.
- Myopathic potentials: Potentials that are larger in amplitude and duration than normal.
- Rapid recruitment: The ability of muscle fibers to generate high-frequency trains of action potentials.

**Electromyogram (EMG):**

- Submaximal contraction: Shows individual motor units without recruitment.
- Maximal contraction: Shows full recruitment pattern.
- Schematic representation of EMG findings in different conditions.

A, B. The normal electromyogram. Upper: Submaximal contraction. Note that the individual motor units have vary in amplitude. Lower: Maximal contraction. Note that the recruitment of action potentials is linear and continuous. 

### Normal EMG
- Free nerve fibers: Clear, distinct potentials with low noise level.
- Low polyphasic action potentials.

### Myopathy
- Insertional activity: Increased activity, bizarre, high-frequency discharges.
- Spontaneous activity: Fibrillations, positive sharp waves, fasciculations.
- Voluntary activity: Neuromuscular potentials, increased polyphasic potentials.
- Other studies: Prolonged "F response," lost H reflex.

### Myasthenia Gravis
- Increased jitter, impulse blocking.
- Normal single-fiber EMG rules out disorder of neuromuscular transmission.
- Single-fiber EMG is more sensitive than repetitive nerve stimulation or determination of acetylcholine receptor antibody levels.
Electromyography (EMG)

**Electromyogram in Hemiparesis**

- **Fibrillation potentials**
  - 100 μV
  - 50 ms

- **Positive sharp waves** (spike potentials)
  - 100 μV
  - 50 ms

- **Fasciculation potentials**
  - 55 μV
  - 50 ms

- **Giant unit**
  - 1 mV
  - 50 ms

C. The electromyogram is abnormal. From top to bottom: (1) Spontaneous fibrillation. This is an isolated fibrillation wave in the individual potentials measure no more than about 100 μV in amplitude and are of about 5 ms duration. (2) Positive sharp waves (spike potentials), also recorded from related testing muscles. The phenomenon is occasionally seen in denervated muscles. (3) Fasciculation potentials (spreading spontaneously) also recorded from related testing muscles in a patient with motor neuron disease. These potentials are biologically significant and are recorded from muscles that have suffered significant nerve damage. The initial amplitude of approximately 5 mV in amplitude occurring during voluntary activity, in a patient with motor neuron disease.