You Make the Call!!
Mastering EMG Waveform Recognition
Basic

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Learning Objectives

After this session, you should be able to:

• Recognize basic firing patterns of EMG waveforms
• Identify and understand the significance of spontaneous EMG waveforms
• Determine how the changes in MUPs help identify the type and length of disease process
Recording and analyzing the electrical activity of the muscle fibers in motor units in the muscle

Unique combination of knowledge and skill
50 yo with an unusual sensation in his skin (Tibialis anterior)

What is the waveform?
End plate spike
Fibrillation potential
Fasciculation potential
Voluntary motor unit potential
Origin of EMG Potentials

**Single Muscle Fibers**

- **Single Fibers**
  - End plate spikes
  - Fibrillation potentials
  - Myotonic discharges

**Groups of Fibers (different motor units)**

- Insertion activity
- CRDs

**Groups of Fibers (same motor unit)**

- Fasciculation potentials
- Myokymic discharges
- Neuromyotonic discharges

**Voluntary MUPs**
FORM OF THE ACTION POTENTIAL OF A CONDUCTED IMPULSE
RECORDED MONOPOLARLY AT VARIOUS POSITIONS IN A
VOLUME CONDUCTOR — LORENTE DE NO EXPERIMENT—
2 skills needed.

PATTERN RECOGNITION
Identifying Waveforms
Categorize by pattern

SEMI-QUANTITATION
MUP Assessment
Recruitment, Size, Stability
Pattern Recognition of EMG Waveforms

Listen
Firing pattern
“Sounds like . . . .”

Look
Configuration

Name
Fib, Endplate, etc.

Compare

Motor unit potential
Fibrillation potentials
Complex repetitive discharge
Myotonic discharges
End plate spikes
Myokymic discharges
Firing Patterns of EMG Potentials

Regular: linear change (fibrillation potential)

Regular: no change (complex repetitive discharge)

Regular: exponential change, wax/wane (myotonic)

Irregular: (random change) (end plate spike)

Semi-Rhythmic: (motor unit potential)

Bursts: – Regular or semi-rhythmic (myokymic)
You Make the Call
What is the pattern of firing?

**Irregular:** (random change) (end plate spike)

**Regular:** linear change (fibrillation potential)

**Semi-Rhythmic:** (motor unit potential)
Endplate Activity

Endplate spikes

- Biphasic - initial negativity

Endplate noise

Firing pattern: irregular, rapid

Miniature end plate potentials
Firing pattern: irregular, rapid

Irregular Pattern

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\end{array} \]
Fibrillation Potentials

Action potentials of individual muscle fibers in the absence of innervation

FIRING PATTERN: Regular
Fibrillation Potentials

Spike form

Positive wave form

**Regular: steady change** *(fibrillation potential) *(0.5-15 Hz)*
Potentials recorded from a single muscle fiber by two electrodes along the fiber

(The potentials are initiated by movement of electrode #1)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Side</th>
<th>Ins Act</th>
<th>Sport Fib</th>
<th>Sport Fasc</th>
<th>MUP Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abductor digiti minimi (pedis)</td>
<td>R</td>
<td>INC</td>
<td>+++</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Gastrocnemius (medial head)</td>
<td>R</td>
<td>INC</td>
<td>+</td>
<td>0</td>
<td>NL</td>
</tr>
<tr>
<td>Abductor hallucis</td>
<td>R</td>
<td>INC</td>
<td>++</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>First dorsal interosseous (pedis)</td>
<td>R</td>
<td>INC</td>
<td>+++</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Fibrillation Potentials
Associated Disorders

**Neurogenic**
- Anterior horn cell disorders – e.g. ALS
- Radiculopathies – “active”
- Mononeuropathies – “severe”
- Axonal peripheral neuropathies

**Myopathic**
- Inflammatory (e.g. polymyositis, IBM)
- Toxic myopathies (e.g. statin, hydroxychloroquine)
- Muscular dystrophies
- Metabolic (e.g. acid maltase)

**Severe NMJ disorders**
- Myasthenia gravis (severe)
- LEMS
- Botulism

Requires MUP assessment to establish diagnosis!
78 year old with leg pain

How would you interpret this study?
Subacute, active L5 radiculopathy
Chronic (old), active L5 radiculopathy
Chronic (old), inactive L5 radiculopathy

Fibrillation potentials in Radiculopathies
Don’t always = “active”
Grading Fibrillation Potentials

Reflects number of denervated fibers:

1+ - Persistent single trains
2+ - Moderate numbers
3+ - Many in all areas
4+ - Completely fill baseline
Fibrillation Potentials in Myopathies

May be:
- Low amplitude (tiny)
- Very slow firing (<1 Hz)
- In superficial layers (esp dermatomyositis)
- Complex (split fibers)

Pay Attention!
Listen Carefully!
Slow needle movements
With pauses!
Myotonic Discharges

Regular: exponential change, wax/wane (myotonic)
Myotonic Discharges
Associated Disorders

**Myopathic (Prominent)**
- Myotonic dystrophy (DM1/DM2)
- Myotonia congenita
- Paramyotonia congenita
- Hyperkalemic periodic paralysis

**Myopathic (Infrequent)**
- Polymyositis
- Acid maltase deficiency
- Drug-induced myotonia (statins, colchicine)

**Neurogenic (Rare)**
- Axonal peripheral neuropathies
- Severe, old neurogenic disorders
Fasciculation Potentials

Origin - AHC, axon, nerve terminal

FIRING PATTERN
- Single, random, irregular
- 1 - 100 per minute

FORM
- No standard configuration
- Often distant
Complex Repetitive Discharges

- Fast or slow (3 – 40 Hz)
- **Configuration**: (3-10 spikes, stable or unstable)

**Regular**: fixed intervals (abrupt onset, cessation, change)

- Fast or slow (3 – 40 Hz)
- **Configuration**: (3-10 spikes, stable or unstable)
Complex Repetitive Discharge

Ephaptic transmission from neighboring muscle fibers
Myokymic Discharges

Site of Initiation

Recurrent BURSTS (Regular or Irregular)
Doublets, triplets, multiplets
Firing rate within burst (5-150 Hz)*
# Myokymia

## Etiologies

<table>
<thead>
<tr>
<th>Focal</th>
<th>Radiation (cranial, plexus, single nerve)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brainstem (multiple sclerosis, glioma, syringobulbia)</td>
</tr>
<tr>
<td></td>
<td>Mononeuropathy (CTS), radiculopathy (isolated muscles)</td>
</tr>
<tr>
<td></td>
<td>ALS (5% pts, more in cranial muscles)*</td>
</tr>
<tr>
<td>Generalized</td>
<td>Isaacs’ syndrome (VGKC)</td>
</tr>
<tr>
<td></td>
<td>Polyradiculopathy (AIDP, CIDP)</td>
</tr>
<tr>
<td></td>
<td>Episodic ataxia type 1 (VGKC α-subunit gene KCNA1 mutation)</td>
</tr>
<tr>
<td></td>
<td>Rattlesnake envenomation</td>
</tr>
</tbody>
</table>

Voluntary Motor Unit Potentials

**Semi-Rhythmic** (5-40 Hz) – Limited (10%) variation

Sound: “ataxic clock”
Normal Motor Unit Potential
Recording multiple (5-15) muscle fiber action potentials
When assessing MUPs, questions to answer . . .

- Normal or Abnormal?
- Neurogenic Myopathic NMJ?
- Severity?
- If neurogenic: Acute Subacute Chronic?
Temporal Course of MUP Changes
Acute Neurogenic Injury

- Normal
- Reduced Recruitment
- Unstable Turns
- Polyphasic, Long duration
- Long duration

- Normal
- 1 minute
- 1-2 months
- 2-6 months
- > 6 months
Normal MUP Recruitment
Reduced Recruitment
MUP Firing Rate is **TOO FAST**

Single MUs firing >20 Hz is abnormal*

Assessing Recruitment

**Recruitment Frequency**

- Firing rate of 1\textsuperscript{st} MUP when 2\textsuperscript{nd} MUP begins to fire.
- NL < 11 Hz (exceptions: triceps, wrist/finger extensors, cranial muscles)

**Recruitment Ratio**

- Ratio of firing rate of fastest firing MUP to # of MUP firing at any one time
- Most limb muscles ratio < 5
  - 15 Hz: 3 MUP
  - 20 Hz: 4 MUP
“Poor Activation”

MUP1

MUP2

Force

MUP Firing Rate

Effort
Pain
Central Disorder
Stroke
Myelopathy

Mild

(Strong)

Force
Rapid (Early) Recruitment Assessment is **Effort-Dependent**!

Recruitment frequency and ratio are **normal**

Multiple MUP with minimal effort ("all or none pattern")

"... activation of >3 MUs with minimal effort or barely perceptible muscle contraction has been called early recruitment."*

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**Diagram: Firing Rate (Hz)**

- MUP1
- MUP2
- MUP3
- MUP4

**Force**

- Mild

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Motor Unit Potential Stability
Blocking of Muscle Fibers
MUP Stability (Sound)

Stable

Unstable
Polyphasic MUP
Neurogenic - Asynchronous Firing

Phase = Baseline crossings + 1

Polyphasic MUP = 5 or more phases
<15% of MUPs in muscle
Polyphasic MUP
Myopathy
Muscle Fiber Contributions to MUP

Motor Unit Territory (5-10 mm)

Amplitude (0.5 mm)

Duration (2.5 mm)
MUP Size Parameters

- **Duration (ms)**
  - Time distribution of fibers

- **Amplitude (uV)**
  - Fiber density near needle tip

- **Area (uVms)**
  - Fiber density in larger pickup region

- **Thickness** (Area/Ampitude)

- **Size Index** \[2 \times \log_{10} (\text{Amp}) + \frac{\text{Area}}{\text{Amp}}\]
### MUP Upper and Lower Limits of Duration (msec, age 20)
(from Buchthal 1955)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI</td>
<td>8.0 - 12.2</td>
</tr>
<tr>
<td>Deltoid</td>
<td>8.2 - 12.2</td>
</tr>
<tr>
<td>Triceps</td>
<td>9.3 - 13.9</td>
</tr>
<tr>
<td>Biceps</td>
<td>8.0 - 12.0</td>
</tr>
<tr>
<td>Anterior tibial</td>
<td>9.8 - 14.8</td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>8.2 - 12.2</td>
</tr>
<tr>
<td>Medial gastroc.</td>
<td>7.5 - 11.3</td>
</tr>
<tr>
<td>Opponens</td>
<td>7.3 - 10.9</td>
</tr>
<tr>
<td>Peroneus longus</td>
<td>7.8 - 11.8</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>9.6 - 14.4</td>
</tr>
<tr>
<td>Cervical PSP</td>
<td>8.6 - 12.8</td>
</tr>
</tbody>
</table>
Normal Duration MUP (8-12 ms)
Long Duration MUP (>12-14\* ms)
2 MUPs, Similar Duration (15 ms)
MUP with Satellite Spike
Learning Points

• Assess firing pattern of potential to determine the type of discharge
• Morphology of different waveforms can be similar
• Recruitment and MUP morphologies help determine temporal course