EMG Waveforms

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CONTINUING MEDICAL EDUCATION

I have no relevant financial disclosures.

Slides and EMG waveform videos courtesy of Michele Arnold, MD

Objectives:

1. Be able to describe characteristics of different needle EMG waveforms
2. Recognize normal physiological findings on needle EMG.
3. Recognize pathological findings on needle EMG.
4. Review basic motor unit recruitment
5. Q&A Session – practice identifying EMG waveforms and videos.

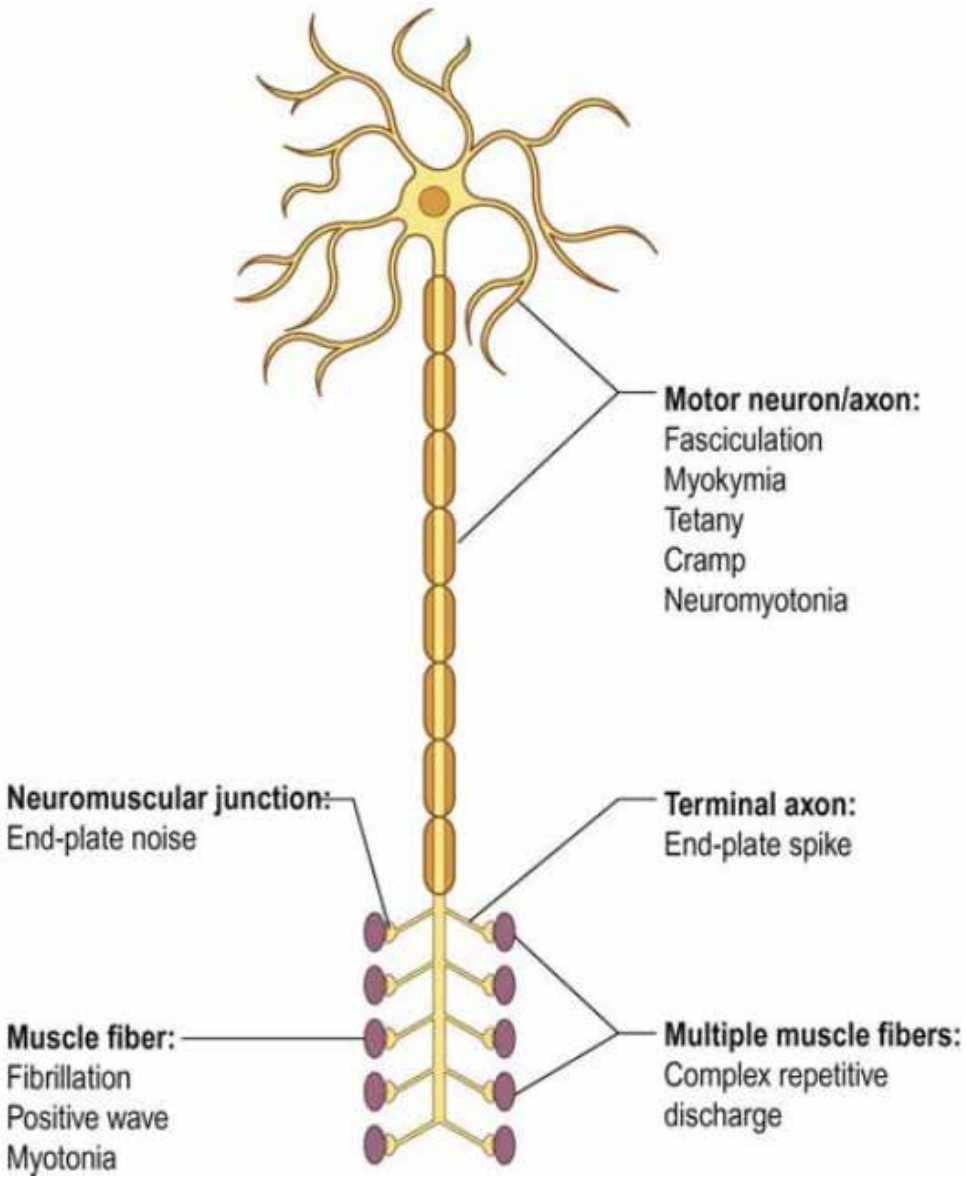
Waveform recognition – why should I care?

- Clinical care
- ABPMR Certification Parts I and II
- Maintenance of certification
- American Board of Electrodiagnostic Medicine:
  - Knowledge-based questions
  - Questions involving pictorial interpretation
  - Questions involving surface anatomy or video waveform recognition
- Neuromuscular Medicine subspecialty board (ABPMR, ABPN)

Waveform – audio characteristics

Miniature End Plate Potentials (MEPPs)	Endplate Spikes (EPS)	Fibrillation Potentials (fibs) + PSWs	Fasciculation Potentials
Cassette tape hiss seashell murmur	Fat sputtering in a pan “Ouch!”	tick + dull thud; crackling cellophane, rain on a tin roof	Random, abrupt pop(s) or snap(s), popcorn
Complex Repetitive Discharges (CRDs)	**Myotonic Potentials**	**Myokymic Potentials**	**Neuro-myotonia**
Idling motorcycle; continuous DRONE; mechanical	Dive bomber	Marching soldiers, sputtering motor boat; BURSTS	Indy 500 racecar, decrescendo ‘pinging’

Source of waveform generation



How "local" is the waveform?

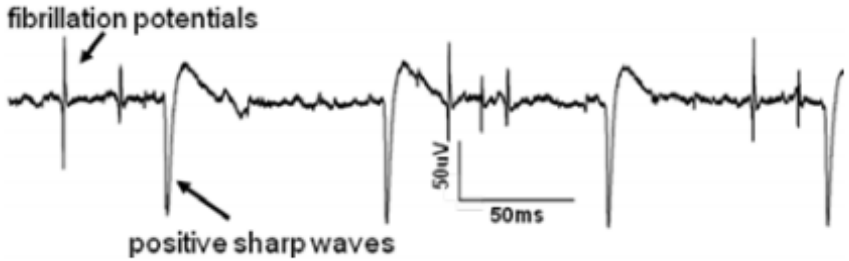
Axon/Motor neuron

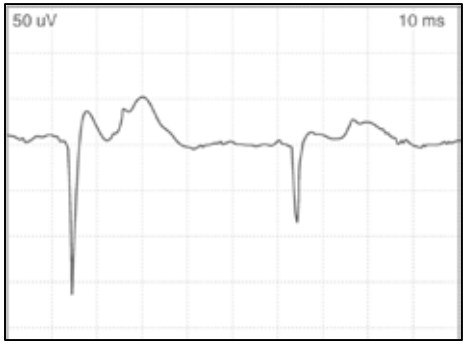
Firing spontaneously (individual)	Firing spontaneously (in bursts)
Fasciculation potentials	Myokymic discharges
Neurotomyotonic discharges	Synkinesis
Myoclonus	Tremor
Dystonia	Hemifacial spasm
Stiff-person syndrome	

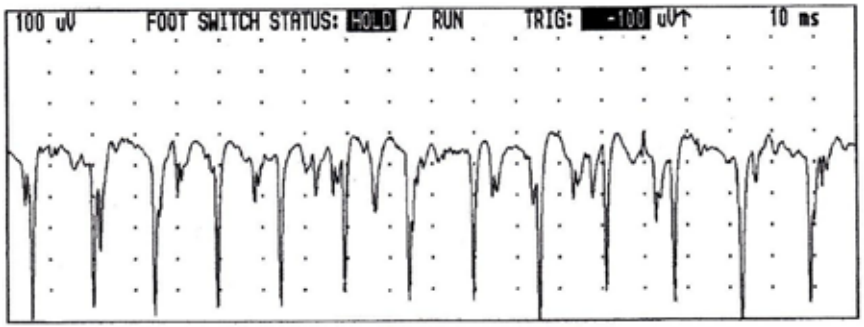
Single fibers

Firing alone	Firing in groups (adjacent fibers)
Endplate spikes	Insertional activity
Fibrillation Potentials	CRDs
Myotonic Discharges	

Positive sharp waves (PSWs)



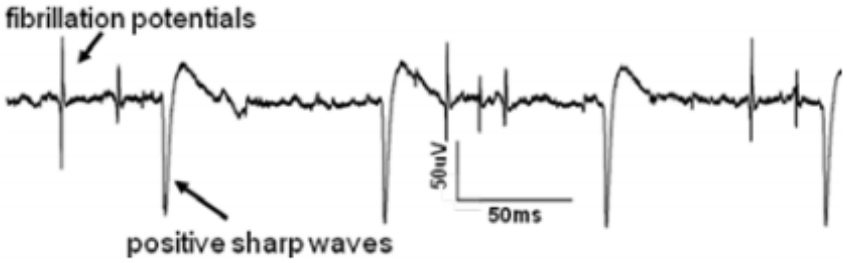


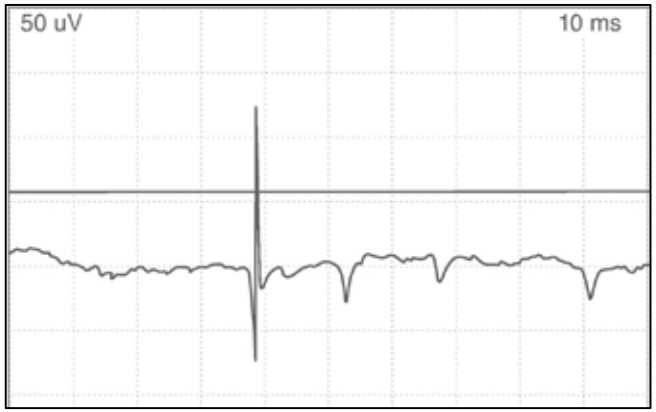


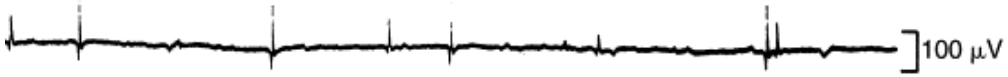
Positive Sharp Waves

- Initial positive phase
- Return to baseline (monophasic) or small negative deflection phase (biphasic)
- Regular > irregular
- Dull thud
- *Probably* the same clinical significance as fibs: muscle membrane instability, axonal loss
- Appear earlier than fibs

Fibrillation potentials (Fibs)



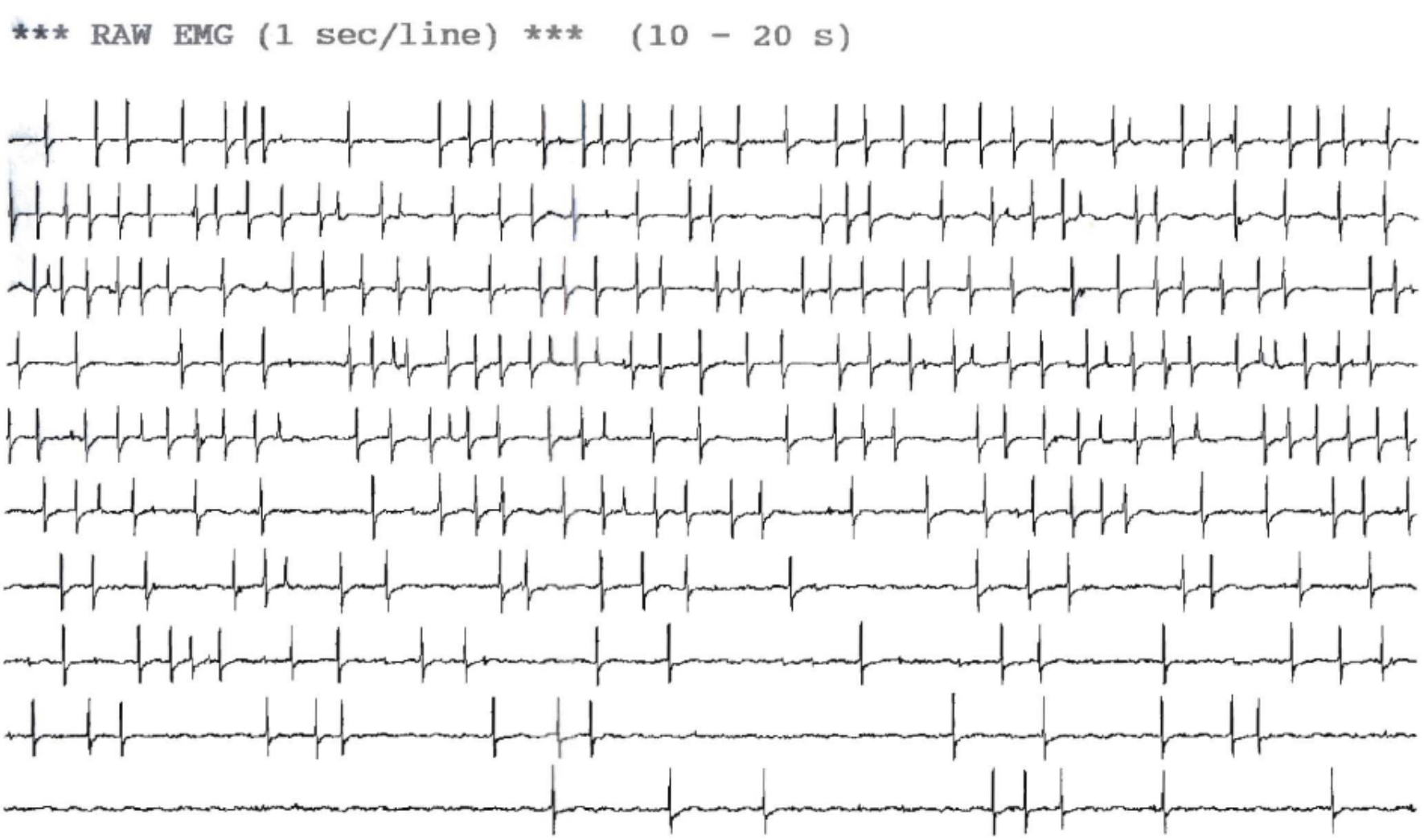




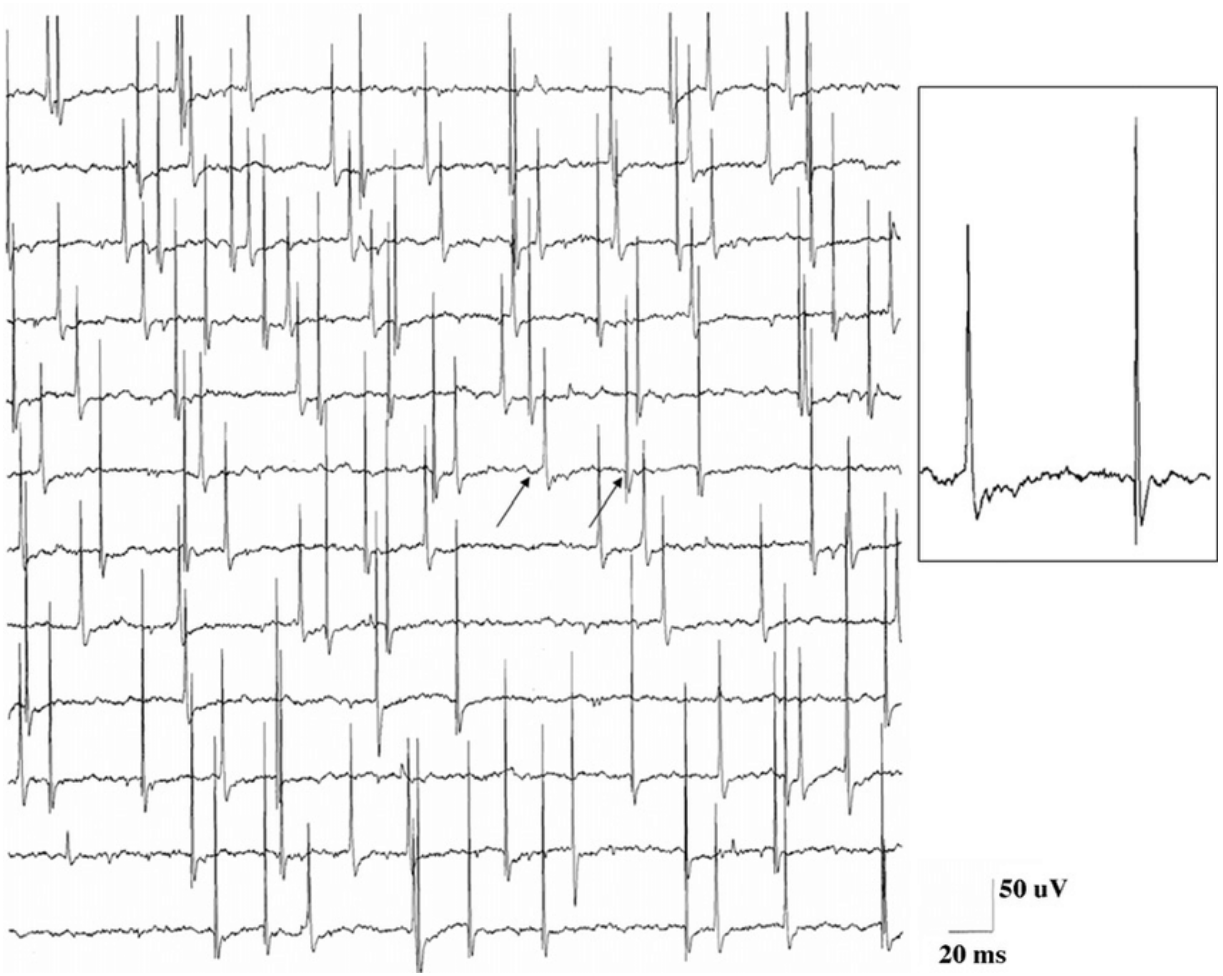
Fibrillation Potentials:

- bi/tri-phasic spike (**initially positive**)
- 1-5 ms, 20-1000 μV
- Within 1-3 (proximal-distal) weeks of neurologic injury
- Regular > irregular
- Snap, tick
- *Probably* the same clinical significance as PSWs
- Diminish in size over time, may persist for years

Fibrillation potentials are regular > irregular



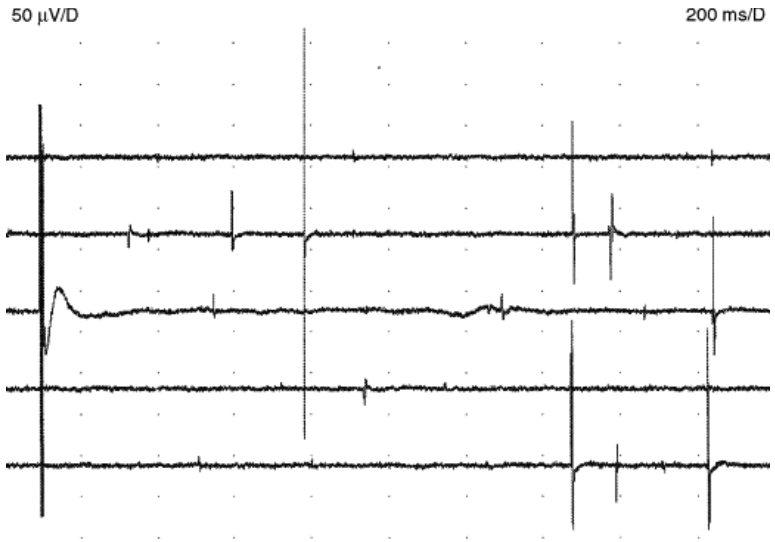
End Plate Spikes are highly irregular

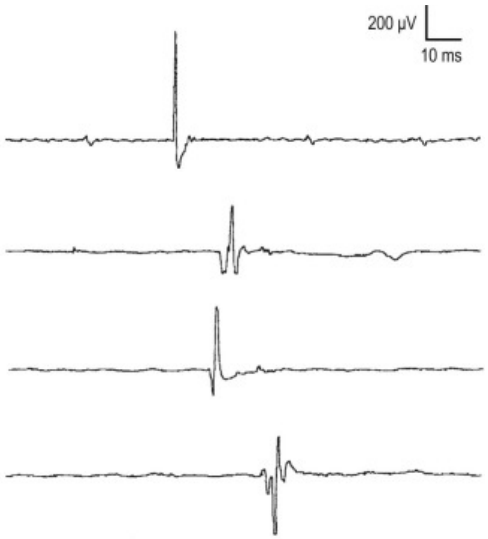


End Plate Spikes:

- Single spikes, biphasic
- **Initial negative deflection,** then positive
- **Highly irregular**
- 3-4 ms
- 100-200 µV
- “Ouch!”

Fasciculation Potentials





Fasciculation Potentials:

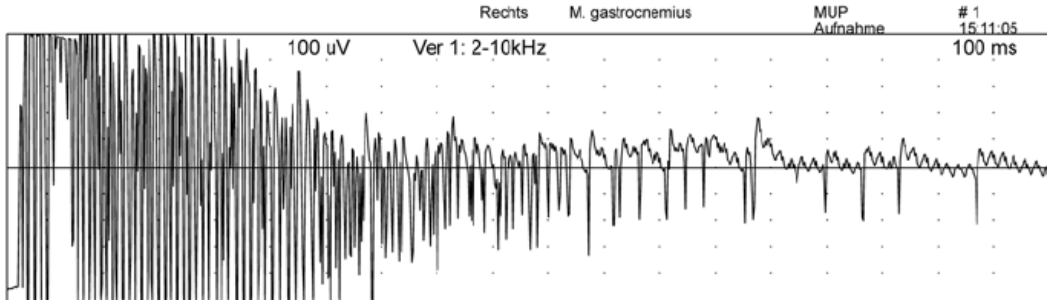
- Same waveform morphology as volitional MUPs (often short duration but can be polyphasic).
- *Not* under voluntary control (not influenced by contraction agonists/antagonists)
- **Randomly irregular**
- Significance interpreted by the "company they keep" (bad company = muscle membrane instability, jitter/blocking SFEMG)

Complex Repetitive Discharges

Complex Repetitive Discharges:

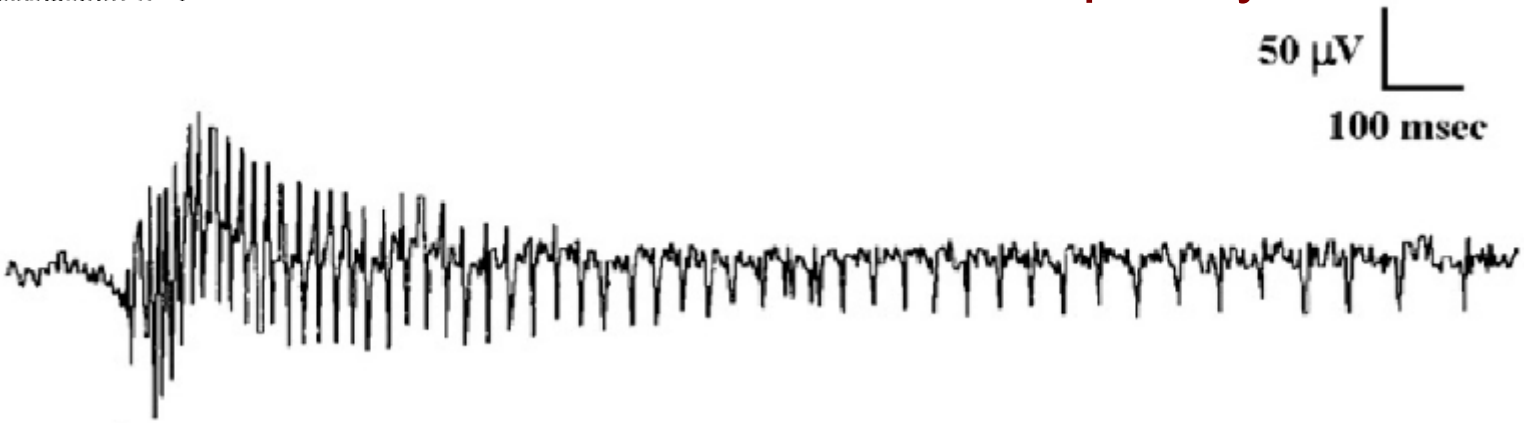
- Stable (consistent, identical discharges; can superimpose)
- Regular, mechanical
- **Abrupt onset and cessation** (take your hand off the electrode)
- Spontaneous or provoked by needle movement, percussion, contraction
- Cross-talk or ephaptic conduction

Myotonic Potentials

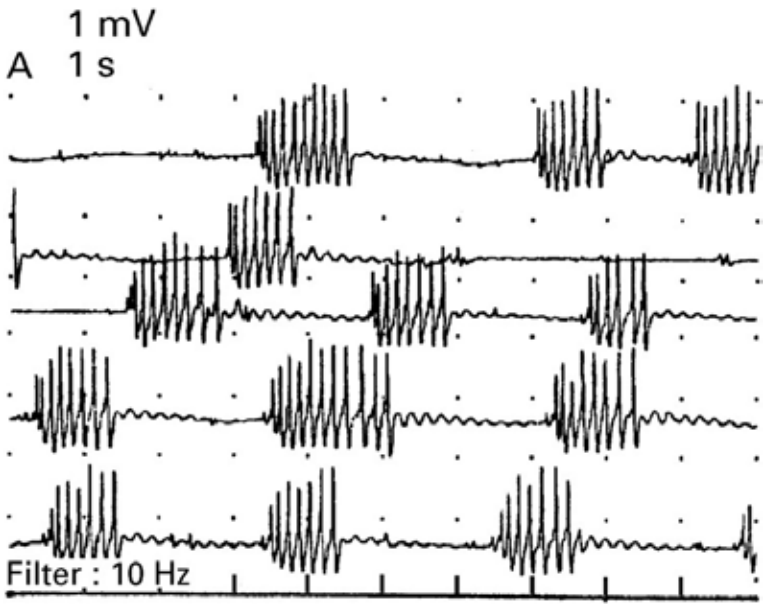


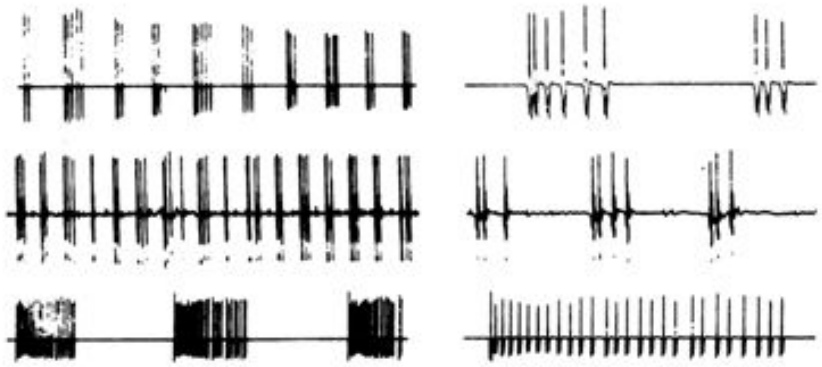
Myotonic Potentials:

- Repetitive rapidly-firing of waveforms that resemble either (1) PSWs or (2) triphasic potentials
- **Waxing/waning** amplitude and frequency



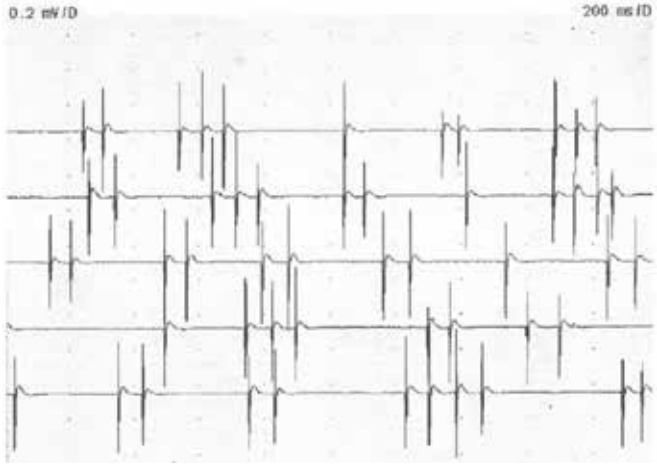
Myokymic Potentials



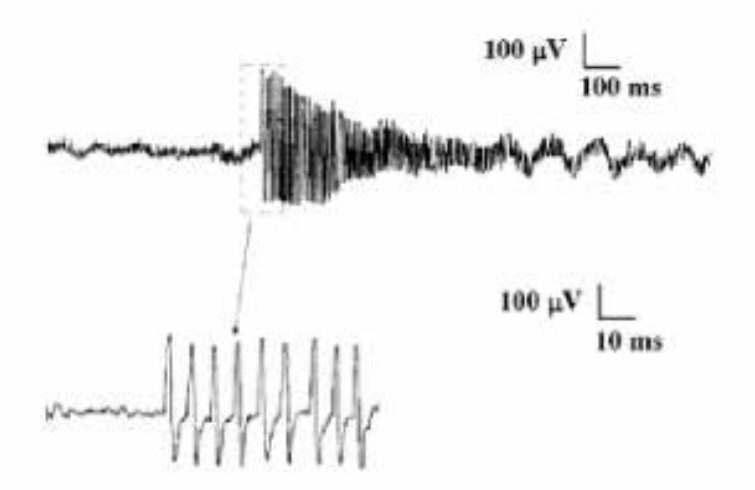


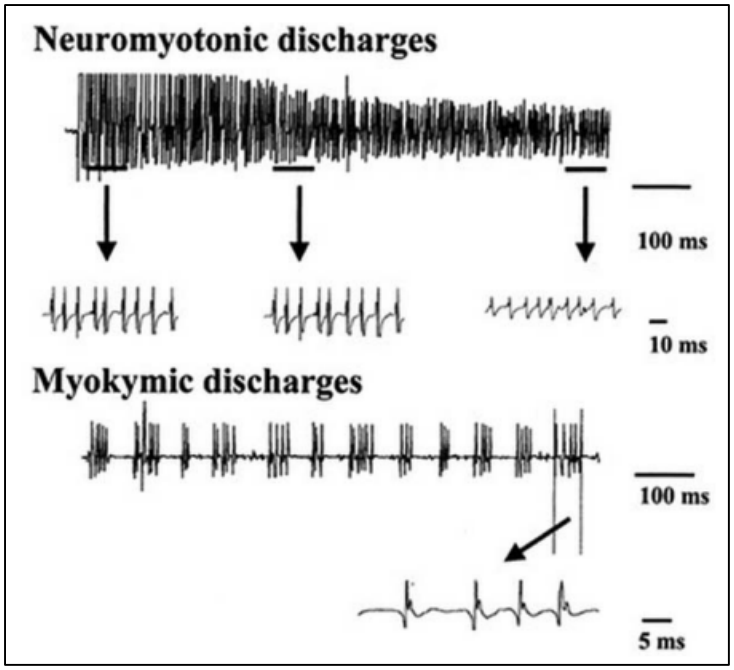
Myokymic Potentials:

- Semirhythmic bursts of potentials with **intervals of silence**. Bursts are non-identical, 20-250 Hz.
- Not affected by voluntary contraction



Neuromyotonic Potentials





Neuromyotonic potentials:

- Continuous muscle fiber activity
  - Stiff person syndrome
  - Issac's syndrome (neuromyotonia)
- Highest frequency (150-300Hz)
- Burst with waning amplitude (not frequency), declines till exhaustion
- 'Pinging' sound
- Spontaneous or provoked by ischemia or electrical nerve stimulation
- Not influenced by voluntary contraction*

Neuromyotonic Potentials

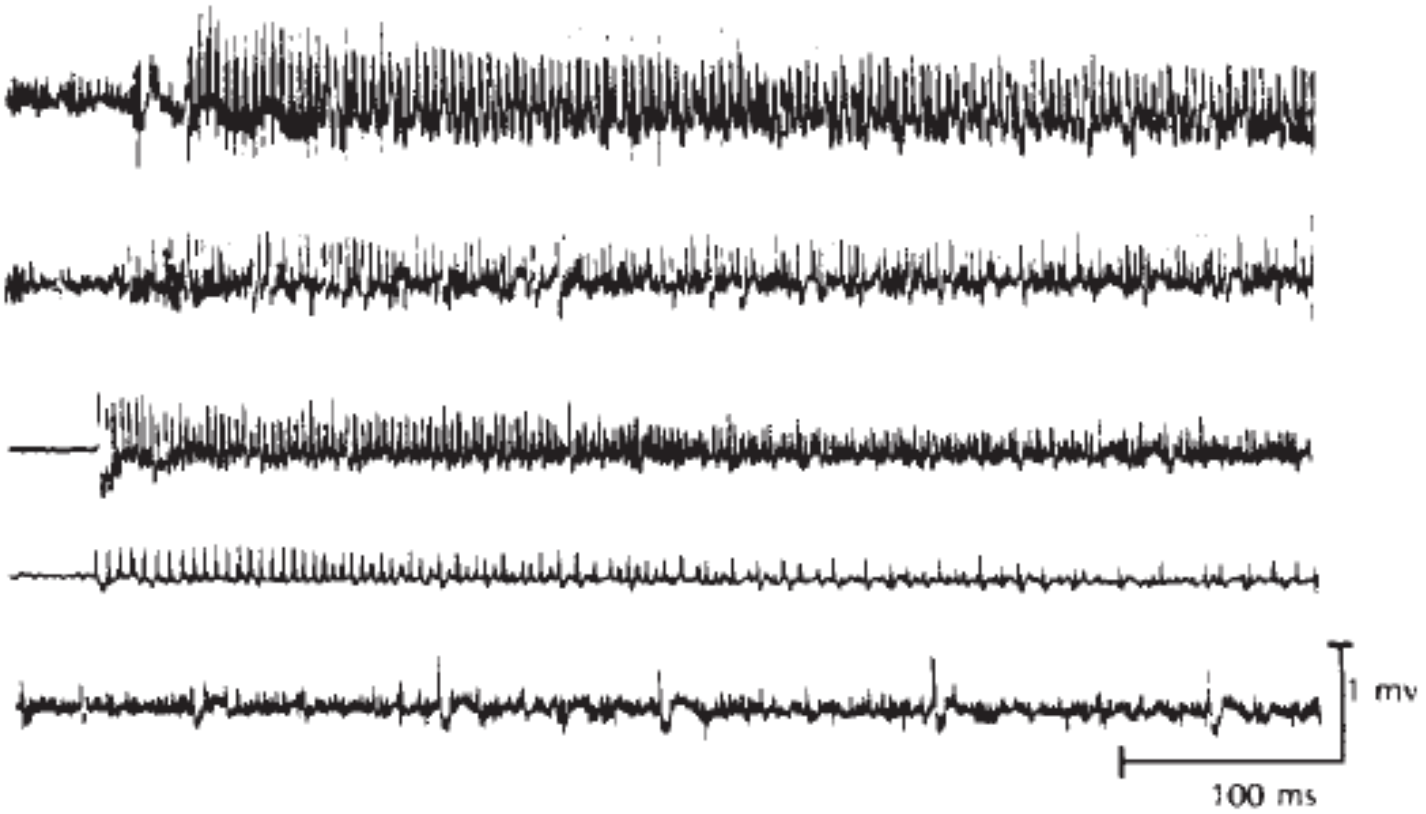
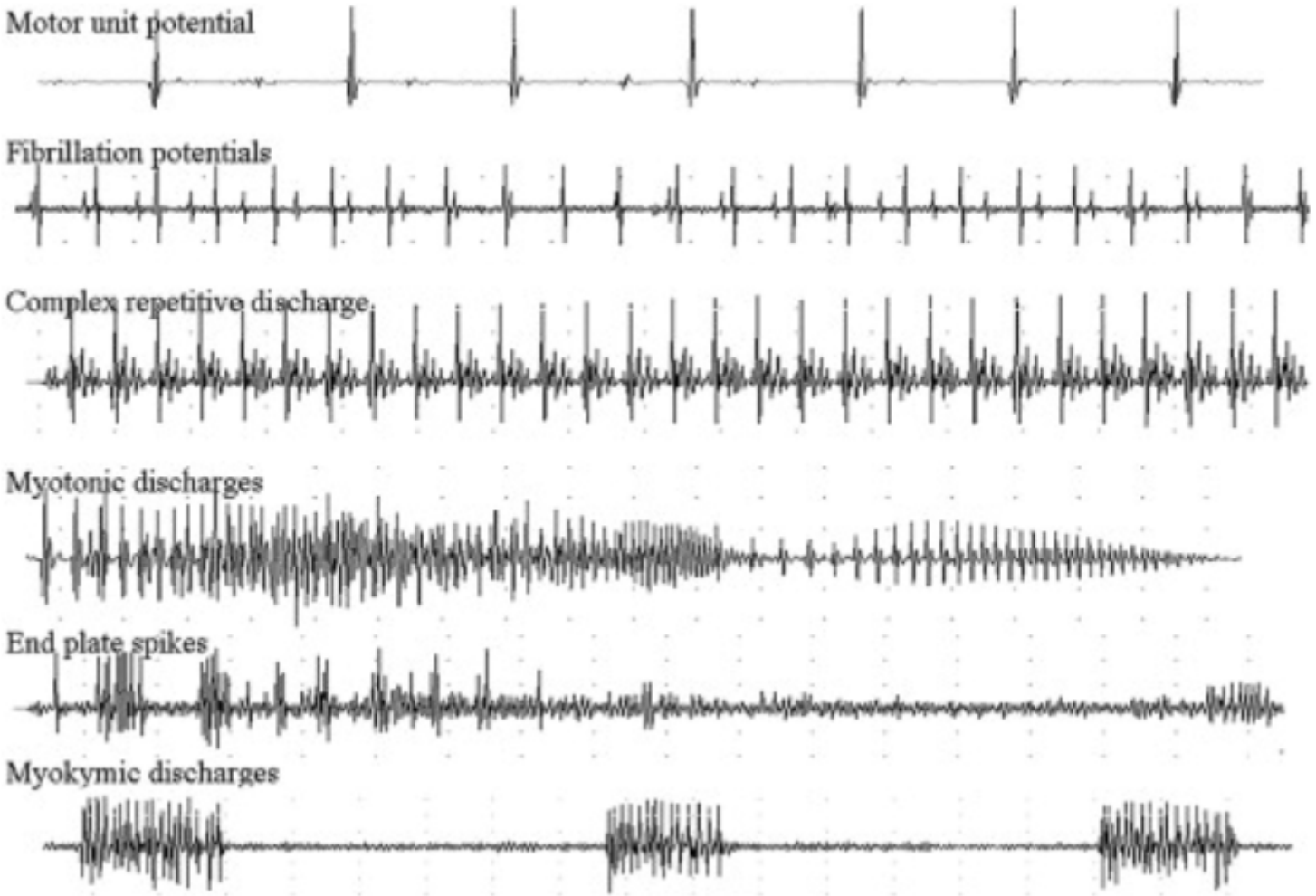


FIGURE 17. Examples of neuromyotonic (neurotonic) discharges in Isaac's syndrome.

Quick glance - waveform overview



Firing patterns

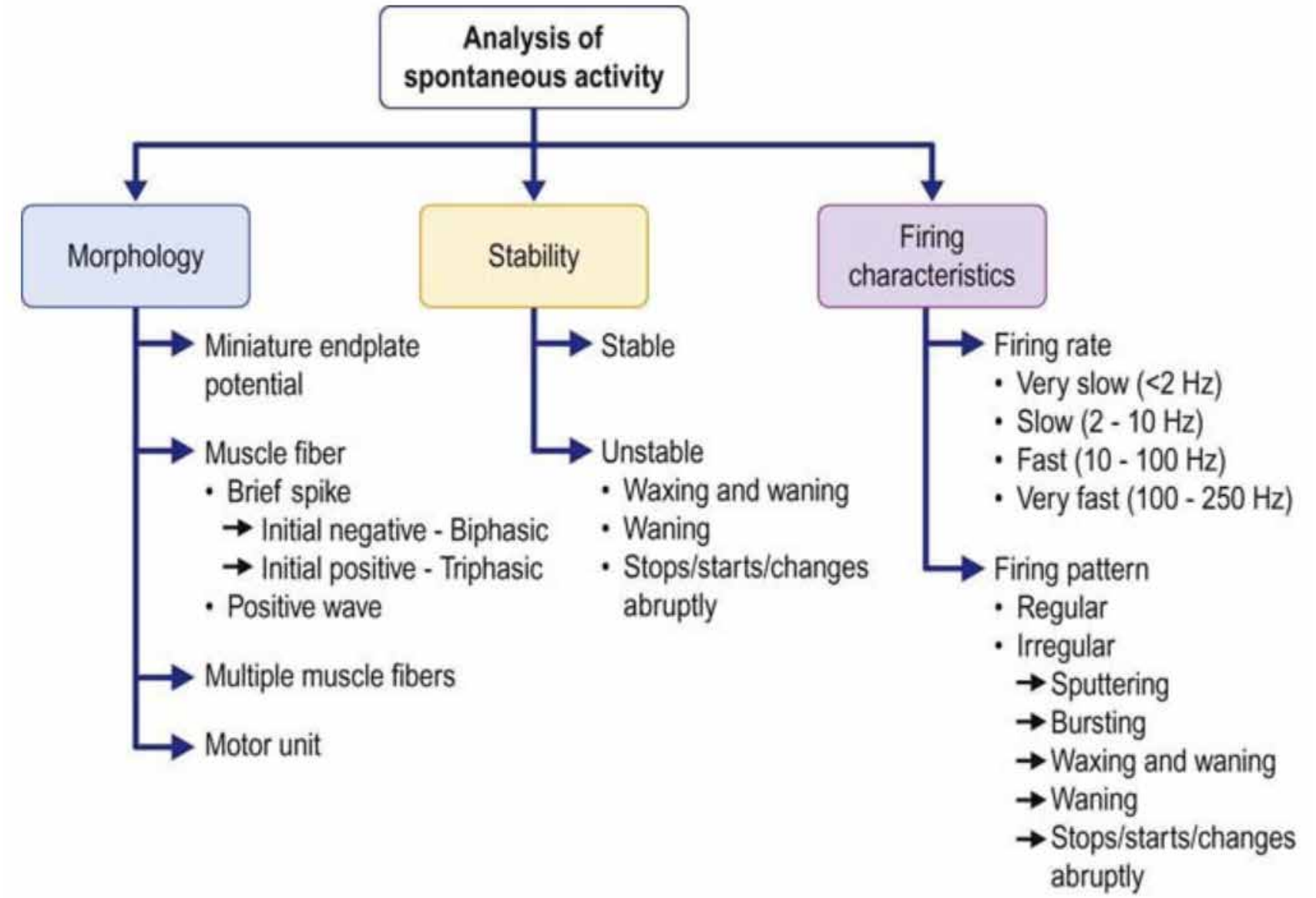
Table 2
Patterns of firing of EMG waveforms

Pattern	Spike Recurrence	Examples
Regular with no change	Precisely defined intervals that do not change on a moment-to-moment basis	Complex repetitive discharge
Regular with linear change	Precisely defined intervals that change linearly	Fibrillation potential
Regular with exponential change	Precisely defined intervals that change slowly or rapidly in an exponential manner	Myotonic discharge
Irregular	Random intervals with no definable intervals.	End plate spike Fasciculation potential
Semirhythmic	Orderly, but not precise, intervals. The variation in the change of interpotential interval is approximately 10%.	Voluntary MUP
Burst	Groups of single or few spikes firing repetitively in a burst, with the bursts recurring at intervals that may be regular, irregular, or semirhythmic	Myokymic discharge Hemifacial spasm Tremor

Helpful Questions

- Are these potential *at rest*? Or *voluntary* MUPs?
- Is there a characteristic sound?
- What is the frequency or firing rate?
  - Slow/medium
  - Is it fast & noisy and/or mechanical?
- What is the waveform morphology?
  - Low baseline rumble (you should localize, optimize)
  - Spike(s)
    - Positive? Negative? Which came first?
- Does it linger/persist/repeat (is it stable/consistent)?
  - Firing pattern
    - Regular or irregular
    - Waxing/waning, abrupt

Waveform recognition



Normal recruitment and firing frequency/rate

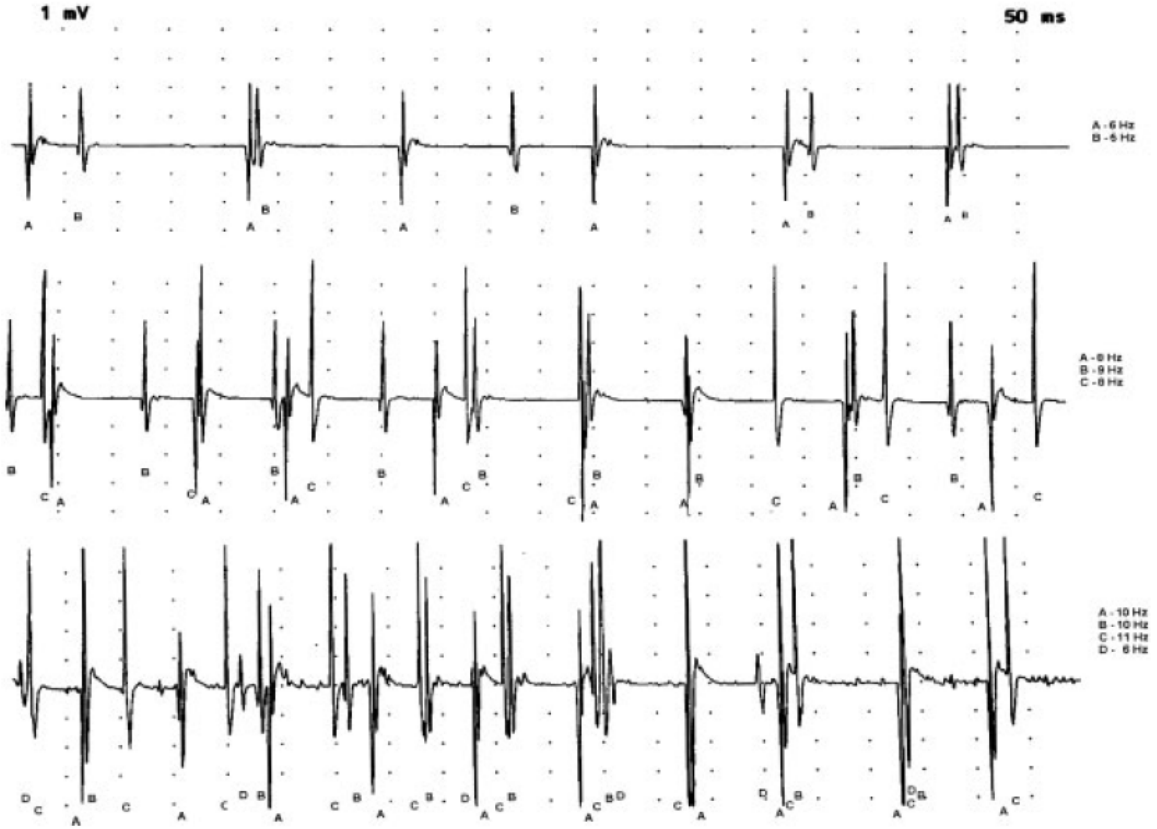


FIGURE 7. MUAP firing under voluntary control showing minimal reduction in recruitment in an extensor carpi radialis muscle with normal strength. Top: Two motor units (A, B) initially fire at 5 and 6 Hz. Middle: With increased voluntary effort, firing rate of A and B increases to 8–9 Hz, with recruitment of a third unit (C). Bottom, With greater effort, the rates increase to 10–11 Hz, with no additional nearby units recruited. Only a small, distant unit begins firing at 7 Hz (D). From: Daube JR. Electrodiagnostic studies in amyotrophic lateral sclerosis and other motor neuron disorders. Muscle Nerve 23:1488–1502, 2000. By permission of John Wiley & Sons.

Calculating firing rate

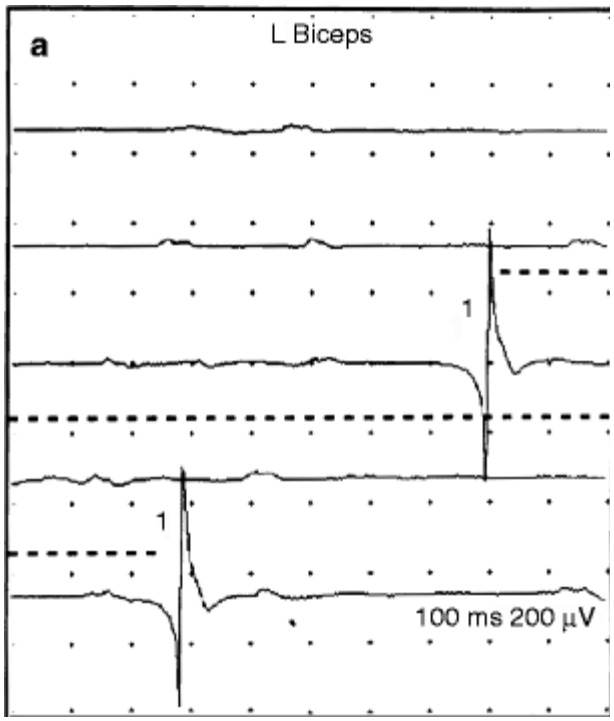
Firing rate (Hz) = 1000 / **interdischarge interval (in msec)**

*check sweep speed!

calculate interval by counting boxes

15 boxes = 150 msec interval

1000 / 150 msec = 6.7 Hz



Normal ~10 Hz

Then what happens?

Recruitment Ratio and the “Rule of 5”

When the firing rate of an initial MUP reaches ~10 Hz, a second should begin to fire (10 Hz / 2 potentials).

1. Obtain a low level of activation (~3-4 MUPs firing)
2. Identify the number of MUPs firing
3. Determine the firing rate of the fastest firing MUP
4. Calculate the recruitment ratio:

RR = firing rate MUP / number of individual MUPs (should be ~5)

When the frequency reaches 15 Hz, 3 MUPs should be firing (RR = 15 / 3 = 5).

With loss of MUs in neurogenic lesions, MUPs fire faster with a reduction in number of units firing (e.g. initial MU fires at 30 Hz before the second MUAP begins firing; 30 Hz / 2 = recruitment ratio of 15). This indicates reduced (neurogenic) recruitment.

References

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6. Mills KR. The basics of electromyography. Journal of Neurology, Neurosurgery & Psychiatry 2005; 76:ii32-ii35.
7. Personal libraries of de-identified waveforms; recorded, captured, assembled, and video-edited by Michele L. Arnold, MD, 2018-2019.

Thank you

Potential	Source Generator/ Morphology	Sound on Loudpeaker	Stability	Firing Rate	Firing Pattern
Endplate noise	Miniature endplate potential (monophasic negative)	Seashell	–	20–40 Hz	Irregular (hissing)
Endplate spike	Muscle fiber initiated by terminal axonal twig (brief spike, diphasic, initial negative)	Sputtering, like fat in a frying pan	Stable	5–50 Hz	Irregular (sputtering)
Fibrillation potential	Muscle fiber (brief spike, diphasic or triphasic, initial positive)	Rain on a tin roof or tick-tock of a clock	Stable	0.5–10 Hz (occ. up to 30 Hz)	Regular
Positive sharp wave	Muscle fiber (diphasic, initial positive, slow negative)	Dull pops, rain on a roof or tick-tock of a clock	Stable	0.5–10 Hz (occ. up to 30 Hz)	Regular
Myotonic discharge	Muscle fiber (brief spike, initial positive, or positive wave)	Revving engine	Waxing/waning amplitude	20–150 Hz	Waxing/waning
Complex repetitive discharge	Multiple muscle fibers time-linked together	Machine	Usually stable; may change in discrete jumps	5–100 Hz	Perfectly regular (unless overdriven)
Fasciculation potential	Motor unit (motor neuron/axon)	Corn popping	Stable	Low (0.1–10 Hz)	Irregular
Doublets, triplets, multiplets	Motor unit (motor neuron/axon)	Horse trotting	Usually stable; may change in number of potentials	Variable (1–50 Hz)	Bursts of twos threes or a few potentials
Myokymic discharge	Motor unit (motor neuron/axon)	Marching soldiers	Usually stable; the number of potentials may change within the burst	1–5 Hz (interburst) 5–60 Hz (intraburst)	Bursting of the same individual motor unit potential
Cramp potential	Motor unit (motor neuron/axon)		Usually stable	High (20–150 Hz)	Interference pattern or one or more individual motor unit potentials
Neuromyotonic discharge	Motor unit (motor neuron/axon)	Pinging	Decrementing amplitude	Very high (150–250 Hz)	Waning
Rest tremor	Motor unit (motor neuron/axon)	Marching soldiers	Rising and falling amplitude	1–5 Hz (interburst)	Bursting – synchronous bursting of many different motor unit potentials