Basic principles of needle EMG and Clinical applications

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Introduction

- **EMG (needle electromyography)**
  - Inserting a **needle electrode** into muscle tissue and recording the ensuing **electrical activity**

- By Adrian and Bronk, 1929
  - Concentric needle electrode

Preparation for Needle Examination

- **Patient**
  - Somewhat uncomfortable
  - Inform : Reason, pain, muscle soreness

- **Examiner**
  - History taking, Physical examination → Correct diagnosis
  - Discussion with referring physician

- **Equipment**
  - Instrument's amplifier
  - Optimal filter settings
  - Analog-to-digital converter
  - Cathode ray tube (CRT) resolution
  - Type of needle electrode (monopolar or concentric)

The Art of Needle Examination

- Technical skill '**in the hands**' of the examiner
  - Specific muscles selection
  - Minimize pain
  - Patient's confidence

- Examining the muscle **at rest**
  - Needle should be inserted along a particular line and then withdrawn to the subcutaneous position and redirection along another path while still in the *same muscle*

- Voluntary action
  - Withdraw the needle to the subcutaneous position to avoid muscle bending needle or needle tearing muscle tissue

Performing the Needle EMG

- "Johnson's five steps to the needle examination", modified
  - Muscle at rest (spontaneous activity)
  - Insertional activity
  - Minimal to moderate isometric contraction
  - Information synthesis
  - Impression formulation

Muscle at Rest
(spontaneous activity)

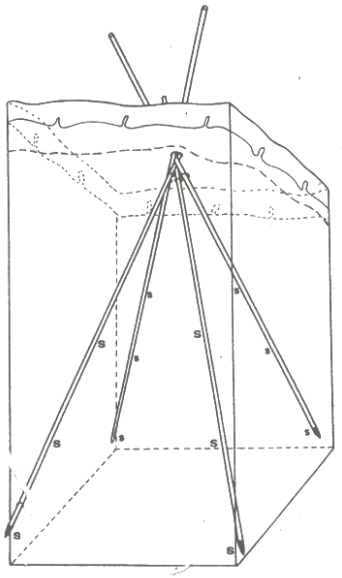
- Amplifier
  - Sensitivity : 50 (100) μV/div
  - Filter setting

    Low Fq filter : 10-30Hz, High Fq filter : 10000-30000Hz
  - Sweep speed : 10 ms/div

- Patient
  - Supine or prone, completely relaxed
  - Individual muscle is positioned to facilitate relaxation

- Needle should be quickly inserted through the skin to minimize patient discomfort

Insertional Activity

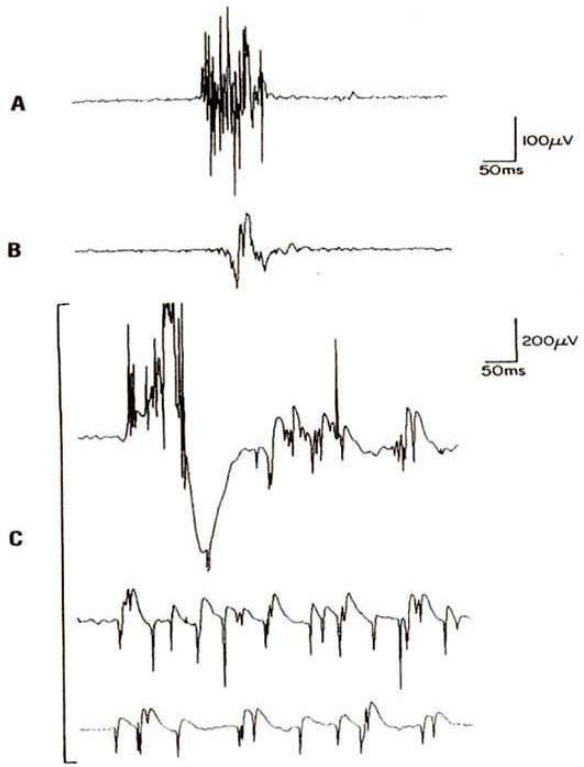


- Needle is sequentially inserted in **0.5 - 2 mm** increments with **several seconds pause** between each insertion
- Exact **number of serial insertions** along **one** depends on muscle's thickness
- Withdrawn to subcutaneous tissue
  – redirected to different axis
- Healthy muscle - bursts of electrical potentials, crisp sound

Insertional Activity

Result from mechanically depolarizing the muscle fibers (injury potentials)

- Normal
- Increased
  - normal variant
  - denervation
  - myopathy
- Decreased
  - fat
  - fibrosis
  - periodic paralysis



normal

decreased (DIA)

increased (IIA)

Figure 7–4. **Insertional activity. A**, Normal insertional activity resulting from a brief needle electrode insertion. **B**, Decreased insertional activity noted in fibrotic muscle tissue. **C**, Increased insertional activity as routinely described by most practitioners. A large burst of electrical activity is associated with needle movement immediately followed by florid positive sharp waves and fibrillation potentials that eventually result in a quiet baseline over the course of several hundred milliseconds to seconds.

Spontaneous activity

- Healthy muscle fiber
  complete electrical silent
  endplate zone : MEPP, Endplate spike,
- Abnormal spontaneous activity
  fibrillation potential
  positive sharp wave
  complex repetitive discharge
  myotonic discharge
  abnormal spontaneous potentials
    fasciculation potentials, myokymic discharge...

Fibrillation potentials
Positive sharp waves

a. Muscle disorders
   - Inflammatory myopathies
   - Inclusion body myositis
   - Congenital myopathies
   - Some muscular dystrophies
   - Hyperkalemic periodic paralysis
   - Rhabdomyolysis
   - Muscle trauma following muscle biopsies
   - Trichinosis

b. Neurogenic disorders
   - Anterior horn cell disorders
   - Radiculopathies
   - Plexopathies
   - Mononeuropathies
   - Peripheral neuropathies
   - Entrapment neuropathies
   - Upper motor neuron disorders (stroke, head injury, and spinal cord injury)

c. Neuromuscular junction disorders
   - Myasthenia gravis
   - Botulism

Fib & PSW Clinical Findings

- **Neurogenic and myopathic state:** membrane instability
- **Grade**

Table 7-9. Grading of Fibrillation Potentials[61]

Grading	Characteristics
0	No fibrillation potentials
1+	Persistent/unsustained single trains in at least two muscle regions
2+	Moderate numbers in three or more muscle areas
3+	Many in all muscle regions
4+	CRT baseline obliterated with fibrillation potentials in all areas of muscle examined

- Degree of fibs and amount of nerve loss is not quantifiable

M

Complex Repetitive Discharge

- Spontaneously firing group of action potentials
- Mostly **long standing disease** with often fibrillating potentials

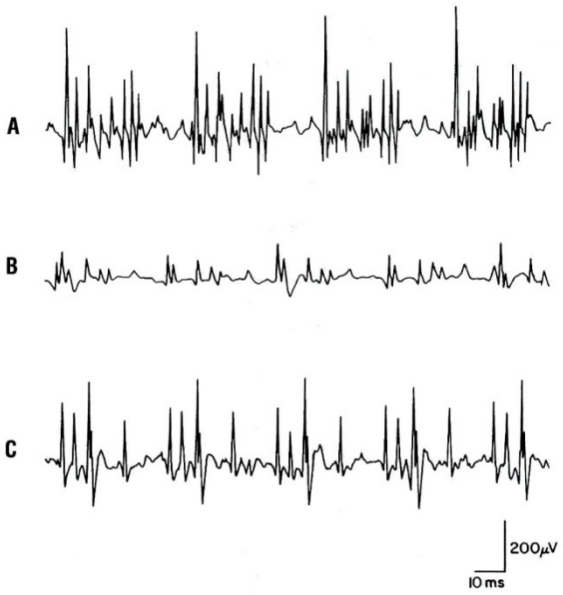


Figure 7-17. Three examples (A-C) of **complex repetitive discharges.** Note how the same potentials appear in the same repetitive groups. The minor differences between discharges is due to baseline irregularities.

a. Myopathies
   Polymyositis
   Limb-girdle dystrophy
   Myxedema
   Schwartz-Jampel syndrome
b. Neuropathies
   Poliomyelitis
   Spinal muscular atrophy
   Amyotrophic lateral sclerosis
   Hereditary neuropathies
   Chronic neuropathies
   Carpal tunnel syndrome
c. "Normal"
   Iliopsoas
   Biceps brachii

Myotonic Discharge

- Phenomenon of delayed m. relaxation following m. contraction

Figure 7–19. **Myotonic potentials** demonstrating an alteration in firing rate and declining amplitude. The spike form (top trace) and positive potential form (bottom trace) are pictured. (From Streib EW: AAEM Minimonograph No. 27: Differential diagnosis of myotonic syndromes. Muscle Nerve 1987;10:603–615, with permission.)

a. Myopathies
   - Myotonic dystrophy
   - Myotonia congenita
   - Paramyotonia
   - Polymyositis
   - Acid maltase deficiency
   - Hyperkalemic periodic paralysis

b. Other
   - Chronic radiculopathy
   - Chronic peripheral neuropathy

Fasciulation potentials

- Visible spontaneous intermittent contraction of a portion of muscle
- Normal condiction

  : fatigue, coffee, tension

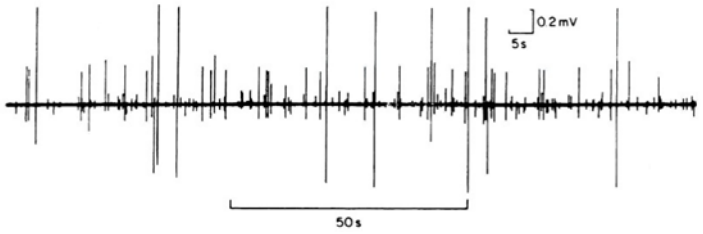


Figure 7-20. Multiple **fasciculation potentials** recorded from a patient with amyotrophic lateral sclerosis. The firing frequencies, although irregular, range from 0.005 to 0.01 Hz. (From Brown WF: The Physiological and Technical Basis of Electromyography. Boston, Butterworth, 1984, pp 317–368, with permission.)

a. Normal individuals
   Spontaneous
   Following exercise
b. Lower motor neuron disorders
   Amyotrophic lateral sclerosis
   Creutzfeldt-Jakob disease
   Radiculopathy
   Peripheral neuropathy
   Entrapment neuropathy
c. Metabolic disorders
   Thyrotoxicosis
   Tetany
   Anticholinesterase medication

Minimal to Moderate Contraction

- Evaluate the electrical potentials generated by the voluntary activation of **motor units**

- Moderate to maximal contraction

  Show overlap of multiple MUAPs known as the **interference pattern**

Motor Unit Action Potentials (MUAPs)

- **Motor unit**
  - **1 ant. horn cell + its peripheral nerve + innervated muscle fibers**

- **Motor unit action potentials (MUAPs)**
  Voluntary muscle contraction
  → **summation** of action potentials resulting from single muscle fibers innervated by one anterior horn cell

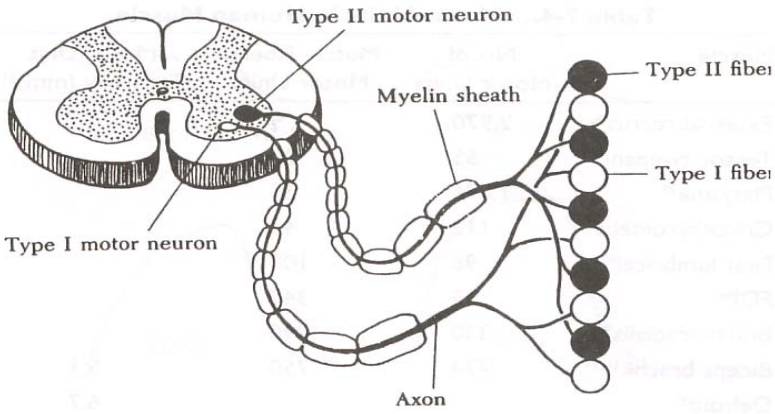


Figure 7-8. **Two motor units** (type I and II) are depicted. Note how fibers from one motor unit are interspersed with those from another motor unit. (From Oh SJ: Clinical Electromyography: Nerve Conduction Studies, 2nd ed. Baltimore, Williams & Wilkins, 1993, with permission.)

Motor Unit Action Potentials

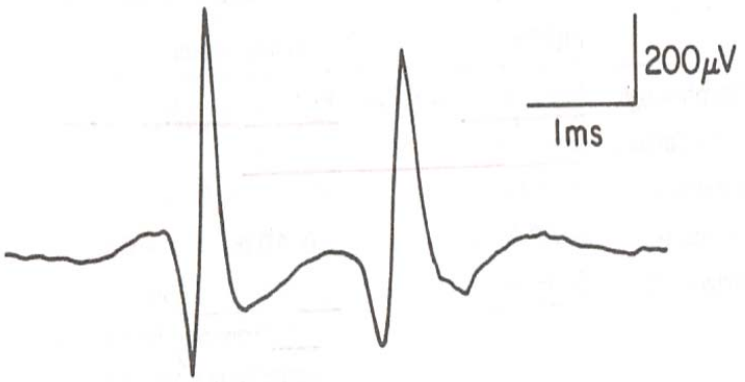


Figure 7-7. Two triphasic **single muscle fiber waveforms** belonging to the same motor unit recorded from a normal extensor digitorum communis muscle.

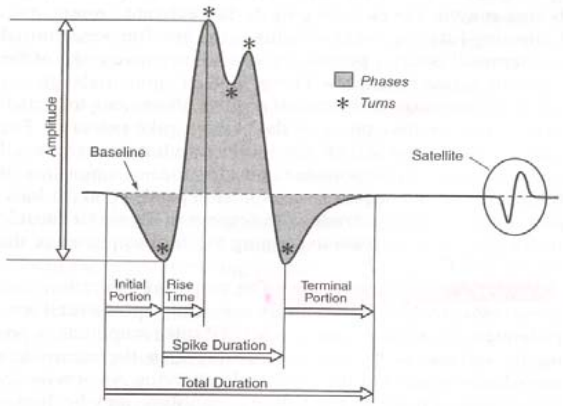


Figure 7-15. **MUAP parameters.** A single MUAP waveform with its morphologic parameters delineated. (From Johnson EW: The EMG examination. In: Johnson EW (ed): Practical Electromyography. Baltimore, Williams & Wilkins, 1988, pp 1–21, with permission.)

- Depolarization of single muscle fiber : triphasic waveforms, biphasic wave forms (endplate)
- Summation of single muscle fiber
- Evaluation
  - amplitude
  - duration
  - phase

MUAP in neural loss

- **Motor unit**
  - Complete denervation
    - F&P, no MUAP
    - Reinnervation : regrowth of the peripheral nerve along its original course
  - Partial devervation
    - F&P, some MUAPs (denervated & intact motor units)
    - Reinnervation
      - **Regrowth of axons** along the previous neural pathways (3~4mm per day)
      - **Collateral sprouting** (terminal axons from neighboring motor units)

MUAP in Denervation / Reinnervation

- Reinnervation Following **Complete or Profound Denervation**

1. Temporal dispersion
   - Immature myelination – decreased conduction velocity

2. Asynchronous summation

→ **Small, highly polyphasic** and occasionally **long duration** MUAP

MUAP in Denervation / Reinnervation

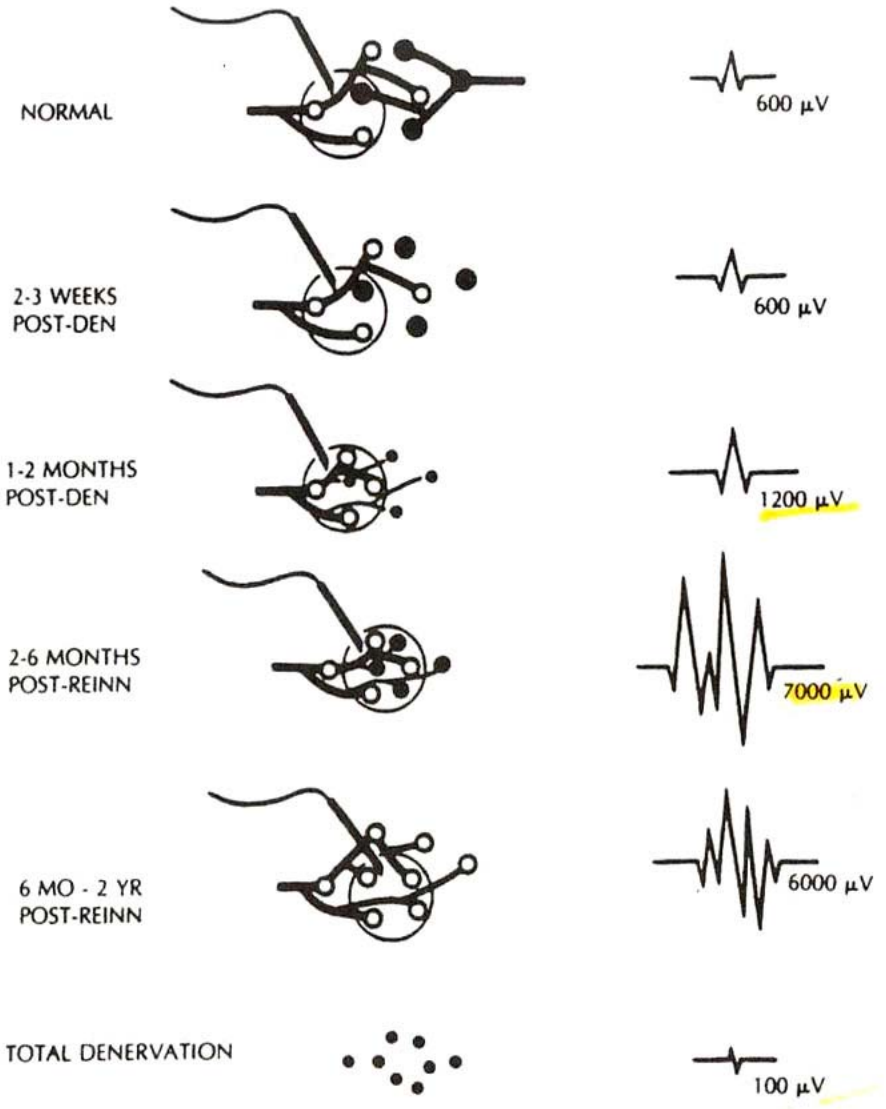
- MUAP Remodeling
- Reinnervation

1. Temporal dispersion

   Immature myelination – decreased conduction velocity

2. Asynchronous summation

   → **Small, highly polyphasic** and occasionally **long duration** MUAP



MUAP in muscle loss

- Random loss of muscle fibers
- Small fiber size

→ small **amplitude**

- Diminished smooth summation
- Alteration in size
- Immature terminal axons

→ increase in **phases**

- "**Myopathic potentials**"
  - **Small amplitude** and **short duration** MUAP with **increase** in the number of **phases**
  - "**Brief small abundant polyphasic potentials** (BSAPP)"

Recruitment Principles

- Definition of “recruitment”
  - activation of the **same** and **additional** **motor units with increasing strength** of voluntary muscle contraction

- Increase muscle strength in 3 ways
  - ↑ **Number** of active motor units
  - ↑ Motor unit **firing rate**
  - Combination of the above

Abnormal recruitment pattern

- **Neurogenic Recruitment**
  - damage the neural portion of motor unit

    Fewer motor unit available with large complement of muscle
  - ➢ **Reduced or decreased** recruitment

- **Myogenic Recruitment**
  - Randomly loss of m. fiber

    Net force output from each motor unit is diminished

    multiple motor units fire simultaneously at high rate
  - ➢ **Early or increased** recruitment

Information Synthesis

- Combined with history and P/Ex

Impression Formulation

- Formulate and electodiagnostic medicine impression
- Appropriate recommendations regarding prognosis and treatment options

Contraindications

- **Contraindications** & **Complications** of Needle Exam
  - **No absolute contra Ix**
  - **Relative contra Ix**
    - Coagulopathy
      - Plt < 50000, PT 1.5~2 times, aPTT 1.5~2 times
    - Significant lymphedema (increased infection risk)
    - Skin infection

흔하게 접하는 전기진단

2013.1-2013.12.4 2021개의 근전도 case

Electrodiagnosis	개수
Normal	528
Carpal tunnel syndrome	289
Polyneuropathy (DM, Uremia…)	108
Ulnar neuropathy	70
Facial neuropathy	38
Peroneal neuropathy	32
Radial neuropathy	18
Brachial plexopathy	16

근전도 **Report** 해석하기

Muscle		Insert. act.	Spont. act.	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Lt.	Anconeus	N	F&P (+)			Large	Long	R
	Brachioradialis	N	F&P (+)		Inc.polys			DIS
	Ext. carpi radialis longus	N	F&P (++)	N				S
	Ext. digitorum communis	N	F&P (+~++)	N				S
	Ext. indicis proprius	N	F&P (+~++)	N				S
	Triceps brachii	N	-	N				F
	Pronator teres	N	-	N				F
	Flexor carpi ulnaris	N	-	N				F

근전도 **Report** 해석하기

Examined Muscles	Findings
Flexor carpi ulnaris Abductor digiti quinti	Silent at rest. Large amplitude and long durational motor unit action potentials with reduced recruitment.
First dorsal interosseus	Silent at rest Large amplitude and long durational motor unit action potentials with discrete recrutment
Abductor pollicis brevis Biceps brachii First dorsal interosseous	Silent at rest. Normal motor unit action potentials with full recruitment.

Carpal tunnel syndrome

- 주된 진단은 Nerve conduction study
- cervical radiculopathy, brachial plexopahty, other focal mononeuropathy 와의 ddx 를 위하여 시행
- main findings of needle EMG in CTS
  : thenar muscle abnormality in axonal loss
- Severity 산정을 위하여 검사

Case_Carpal tunnel syndrome

- F/50
- Right hand tingling sensation (onset : 2months ago)

Nerve conduction study

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)	F-wave (msec)
Rt	Median	Wrist/Cubital fossa	APB	11.4*/15.7	3.5*/3.3	18	41.8*	NR*
	Ulnar	Wrist/Below elbow	ADQ	2.6/5.5	10.9/10.4	17	58.6	24.7

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)
Rt	Median	Wrist	III Digit		No response		
	Ulnar	Wrist/Below elbow	ADQ	2.6/5.5	10.9/10.4	17	58.6

Case_Carpal tunnel syndrome

Muscle		Insert. act.	Spont. act.	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Rt.	Pronator teres	N	F&P (+)		Inc. polys			Reduced
	Triceps brachii	N	F&P (+)		Inc.polys			Reduced
	Ext. digitorum communis	N			Inc. polys			Reduced
	Abductor pollicis brevis	N			large			Reduced
	Biceps brachii	N	-	N				Full
	First dorsal interosseous	N	-	N				Full

Right Carpal tunnel syndrome, severe degree
Right C7 radiculopathy

Ulnar neuropathy

- Ulnar neuropathy at the elbow vs Guyon's disease

- Dorsal ulnar cutaneous nerve conduction study
- Flexor carpi ulnaris muscle or Flexor digitorum profundus muscle 의 needle EMG finding

- d/dx. :C8 radiculopathy, Brachial plexopathy medial cord lesion

Case_Ulnar neuropathy

- F/43, right upper extremity tingling sensation (onset: 6 months ago, after liposuction)

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)	F-wave (msec)
Rt	Median	Wrist/Cubital fossa	APB	2.7	11.9	18	54.5	24.5
	Ulnar	Wrist	ADQ	2.6	5.4	17	59.3	24.7
		Below elbow	ADQ	5.3	5.1	10	62.9	
		Above elbow	ADQ	6.9	4.8			

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)
Rt	Median	Wrist	III Digit	2.8	20.2	14	40
	Ulnar	Wrist	V Digit		No response		
	DUCN	forearm	4th web space		No response		
	MABCN	arm	forearm	2.4	10.0	14	46

Case_Ulnar neuropathy

Muscle		Insert. act.	Spont. act.	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Rt.	Flexor carpi ulnaris	N	-			large	long	Reduced
	First dorsal interosseous	N	-			large	long	Reduced
	Abductor digitorum communis	N	-			large	long	discrete
	Biceps brachii	N	-	N				Full
	Pronator teres	N	-	N				Full
	Abductor pollicis brevis	N	-	N				Full

Right ulnar neuropathy above the elbow

Clinical findings & Electrodiagnosis findings suggest ulnar neruopathy at the axilla, would level

Case_Guyon's disease

- M/45, right hand tingling sensation and atrophy (onset: 3 months ago)

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)	F-wave (msec)
Rt	Median	Wrist/Cubital fossa	APB	2.7	11.9	18	54.5	24.5
	Ulnar	Wrist	ADQ	2.6	3.1*	17	59.3	24.7
		Below elbow	ADQ	5.3	3.0*	10	62.9	
		Above elbow	ADQ	6.9	2.8*			

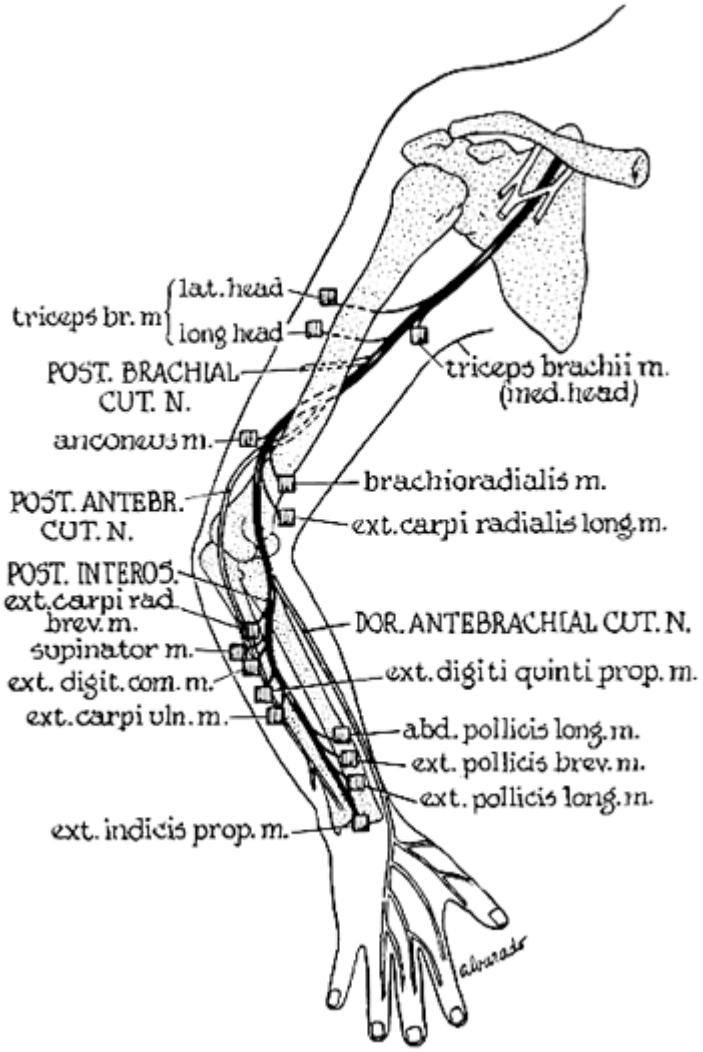
	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)
Rt	Median	Wrist	III Digit	2.8	20.2	14	40
	Ulnar	Wrist	V Digit	3.2	3.0*	14	38
	DUCN	forearm	4th web space	2.5	18.0		

Case_Guyon's disease

Muscle		Insert. act.	Spont. act.	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Rt	First dorsal interosseous		F&P +		Inc. polys	large		Reduced
	Abductor digitorum communis		F&P +		Inc. plolys	large		discrete
	Biceps brachii	N	-	N				Full
	Flexor carpi ulnaris	N	-	N				Full
	Pronator teres	N	-	N				Full
	Abductor pollicis brevis	N	-	N				Full

Ulnar neuropathy at the wrist, guyon's type I

Radial neuropathy



- Lesion을 알기 위해 반드시 needle EMG 필요
- Arm, forearm 에 거쳐 순서대로 innervation 하는 근육들이 있어서 위치를 비교적 구분하기 쉽다.

Case_Radial nerve

F/53, wrist drop (onset: 1month ago)

Nerve conduction study superficial radial nerve
SNAP decreased.

Examined Muscles	Findings
Brachilradialis Extensor indicis proprius	Increased insertional activity Polyphasic motor unit action potential with reduced recruitment.
Triceps brachii Extensor digitorum communis	A few positive sharp waves and fibrillation s at rest. Polyphasic motor unit potentials with reduced recruitment
Biceps brachii Deltoid Pronator teres First dorsal interosseous	Silent at rest. Normal motor unit action potentials with full recruitment.

- Radial neuropathy at the arm, above the triceps innervated branch.

Peroneal neuropathy

- common peroneal, deep peroneal, superfical peroneal, sciatic neuropathy 를 구분할 수 있어야 함.

- L5 radiculopathy 와의 감별이 가장 중요.

Case_peroneal neuropathy

- F/34
- Right foot drop (onset : 7 days ago)

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (mV)	Distance (cm)	Velocity (m/s)
Rt	Peroneal	Ankle	EDB	4.4	5.2	29	50.8
		Fibular neck	EDB	10.1	5.0	8	42.1
		Popliteal fossa	EDB	12.1	4.7		

	Nerve	Stimulation	Recording	Latency (msec)	Amplitude (uV)	Distance (cm)	Velocity (m/s)
Rt	Superficial peroneal	Leg	ankle	3.7	17.2	14	37.8
	Sural	Calf	ankle	3.4	16.7	14	41.1

Case_peroneal neuropathy

Muscle		Insert. act.	Spont. act.	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Rt	Tibialis anterior	N	-	N				2 MUAP
	Peroneus longus	N	-	N				Single
	Vastus lateralis	N	-	N				Full
	Gastrocnemius medial head	N	-	N				Full
	Tensor fascia latae	N	-	N				Full
	Biceps femoris short head	N	-	N				Full

Common peroneal neuropathy around the fibular head,
However, it’s too early to evaluate the whole extent of nerve injury
Recommend) follow up examination 2 weeks later

Radiculopathy

- 대부분의 경우 nerve conduction study 에서 정상
- Needle EMG 소견이 가장 중요함.
- 두가지 이상의 nerve 의 같은 spinal root innervation 받는 muscle 의 needle EMG에서 이상이 나올 경우 진단이 가능함.

Brachial plexopathy

- Nerve conduction study 와 Needle EMG 소견을 종합하여 진단

- Nerve conduction study에서 sensory conduction study 가 정상으로 나올 경우에는 radiculopathy 또는 brachial plexopathy, preganglionic type 을 진단할 수 있음.

- 대부분 외상을 동반되지만 neuritis 등에 의해 발생할 수도 있으므로 radiculopathy 와의 감별진단이 중요

Motor neuron disease

- Cervical radiculopathy 와의 감별진단이 중요함.

- 초기 소견이 hand distal atrophy 가 prominent 한 경우가 많고 asymmetric 한 경우도 많으므로 C7,8 radiculopathy 로 진단 되는 경우 있음.

Myopathy

Muscle		Insert. act.	Spont. act. (F&P)	Motor unit action potentials				IP
				Normal	Polyphasia	Amplitude	Dura.	
Lt.	Deltoid		F&P (++)		Polys	Small	Short	Early
	Biceps brachii		F&P(++)		Polys	Small	Short	Early
	Flexor carpi radialis	N			Polys	Small	Short	Early
	First dorsal interossei	N			Polys	Small	Short	Early
	Vastus medialis		F&P (++)	N				F
	Tibialis anterior	N			Polys	Small	Short	Early
	Gastrocnemius	N			Polys	Small	Short	Early

Conclusion

- Needle EMG 는 말초신경병증, 근육병증 등의 진단을 위한 검사이며 특히 타 질환의 감별진단을 위하여 중요한 검사다.
- Needle EMG 는 시기에 따라 변화하게 되어 각 시기별 결과의 이해가 중요하다.
- 검사자와 의뢰자간의 충분한 의사소통으로 환자 상태에 대한 많은 정보를 얻을 수 있다.