ELECTRICAL STIMULATION FOR MUSCLE (INNERVATED/DENERVATED) CONTRACTION

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OBJECTIVES

OUTLINES

- Muscle contraction in innervated muscles
- Parameters for electrical stimulation of denervated muscles
- Parameters for electrical stimulation of innervated muscles
- indications for use of electrical stimulation for muscle contraction
- Contraindications/ precautions for use of electrical stimulation for muscle contraction
- Clinical case study

NEUROMUSCULAR ELECTRICAL STIMULATION (NMES)

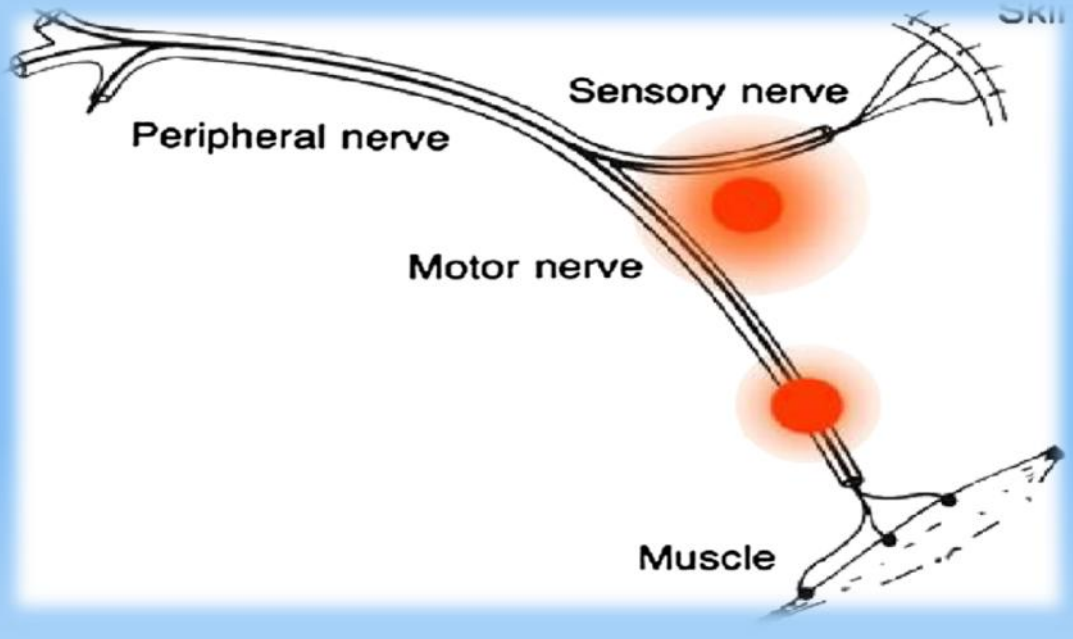
Neuromuscular electrical nerve stimulation (NMES) is electrical stimulation of innervated muscles using surface electrodes to Induce Muscle Contraction Aiming for.

- Muscle re-education
- Prevention/Retardation of disuse atrophy
- Muscle strength and /or endurance
- Reduce edema (Muscle pump contraction)

WHAT IS THE MOTOR POINT?

Motor point

- Superficial located on the surface of the skin
- Usually located at muscles belly between the proximal one third & distal 2/3 fleshy part of the muscle fibers.
- Point of great density of terminal motor end plates
- Point of great excitability to E-stim.

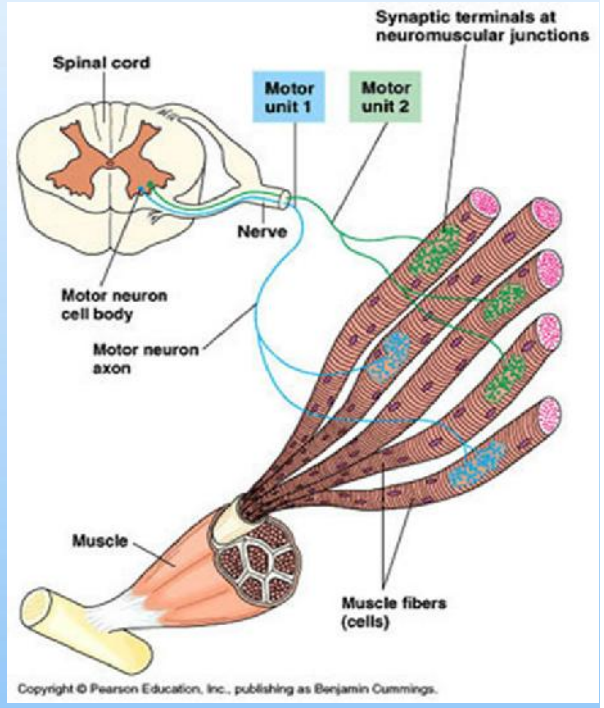


WHAT IS THE MOTOR UNIT?

Motor unit

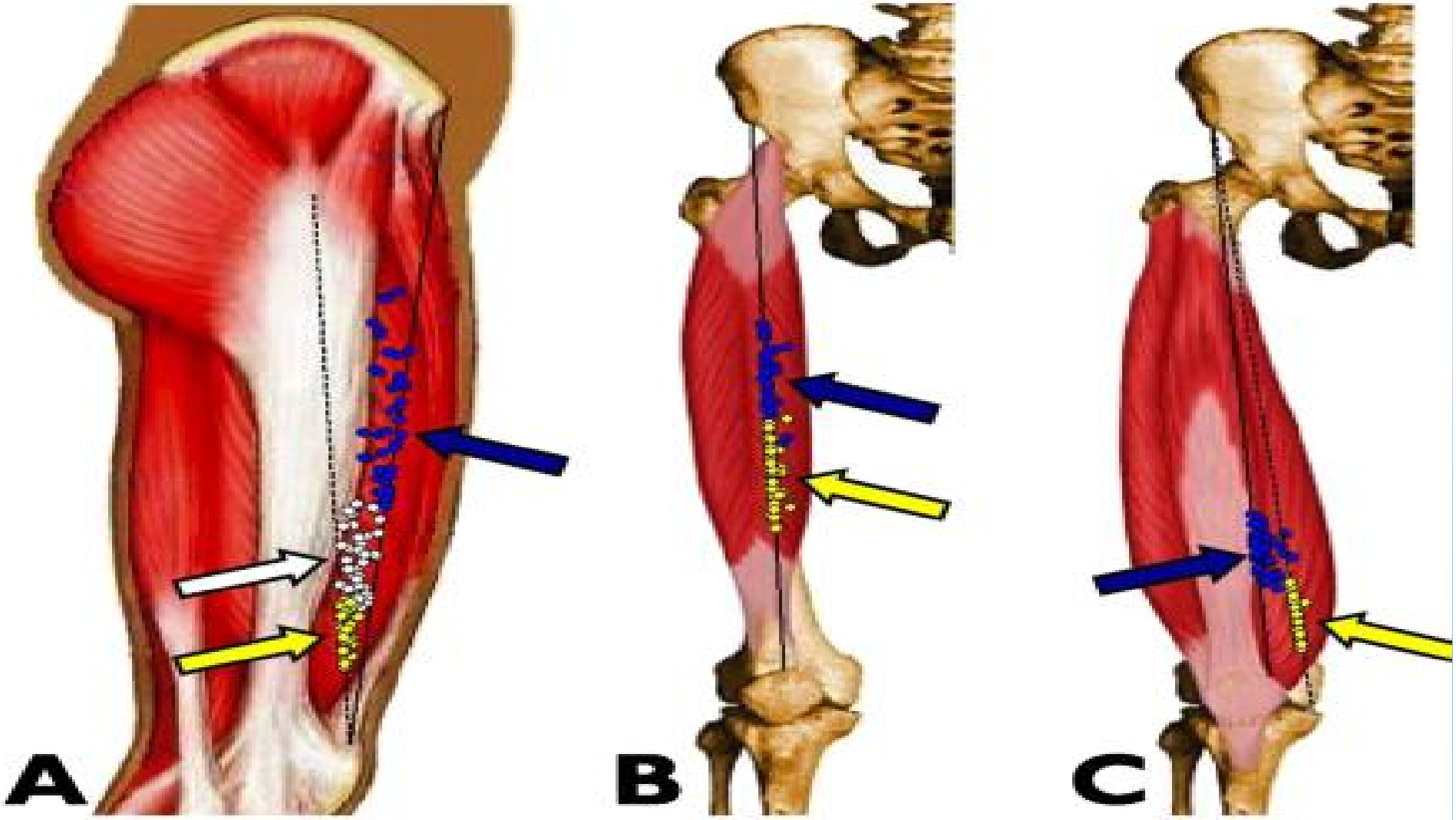
- Single motor neuron (alpha motor neuron) from anterior horn cell and all the muscle fibers it stimulate.
- Each motor unit supplies from 4-00 muscles fibers.
- Dependent on movement precisions

  e.g. Gastrocnemius 2,000 muscle fibers per motor neuron
- Motor neuron determines fiber type

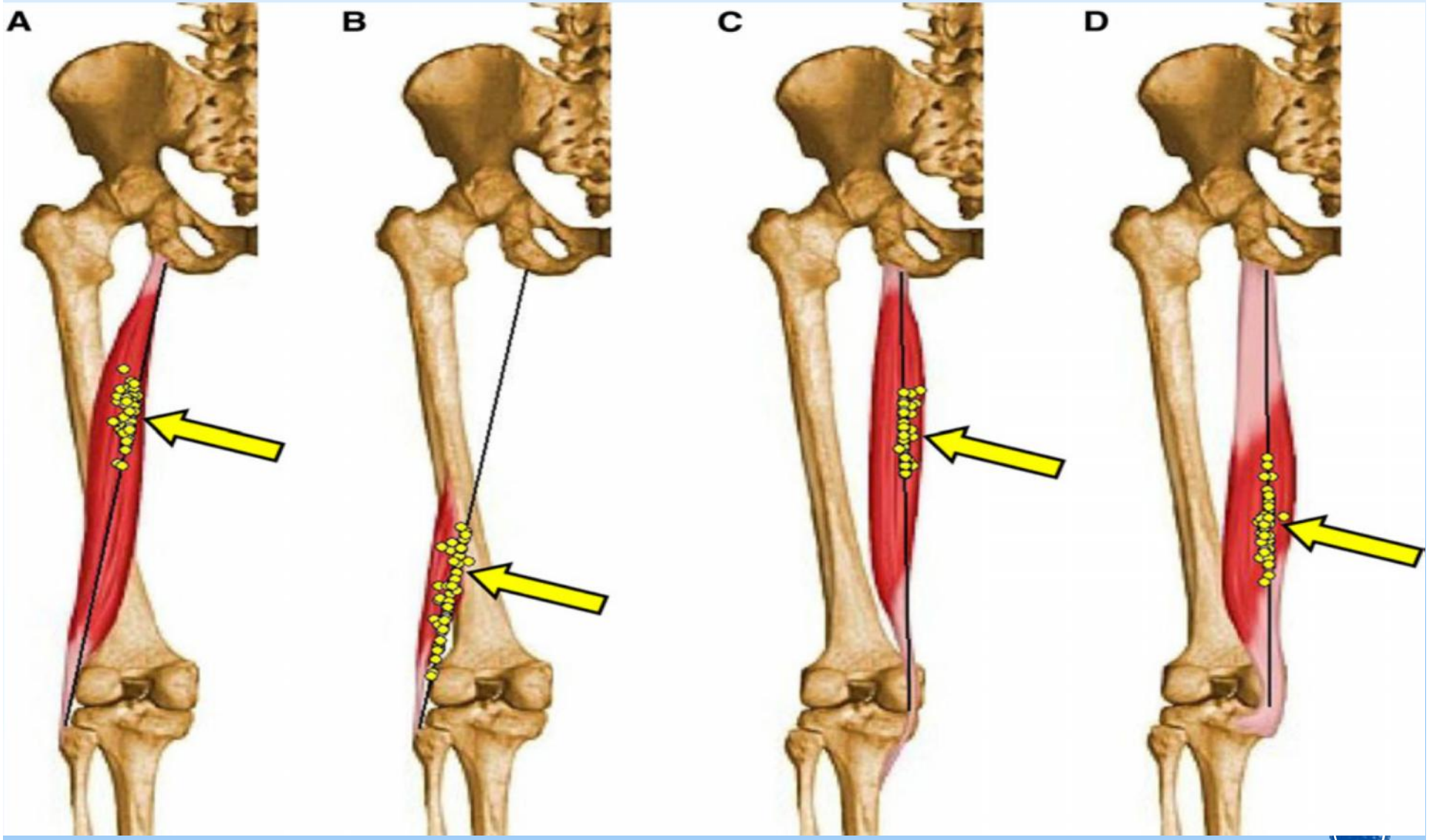


Motor unit classification	Muscle fiber classification
Slow	Type I slow oxidative (SO)
Fast fatigue resistance	Type II a fast oxidative glycolytic (FOG)
Fast fatigue	Type IIb fast glycolytic (FG)

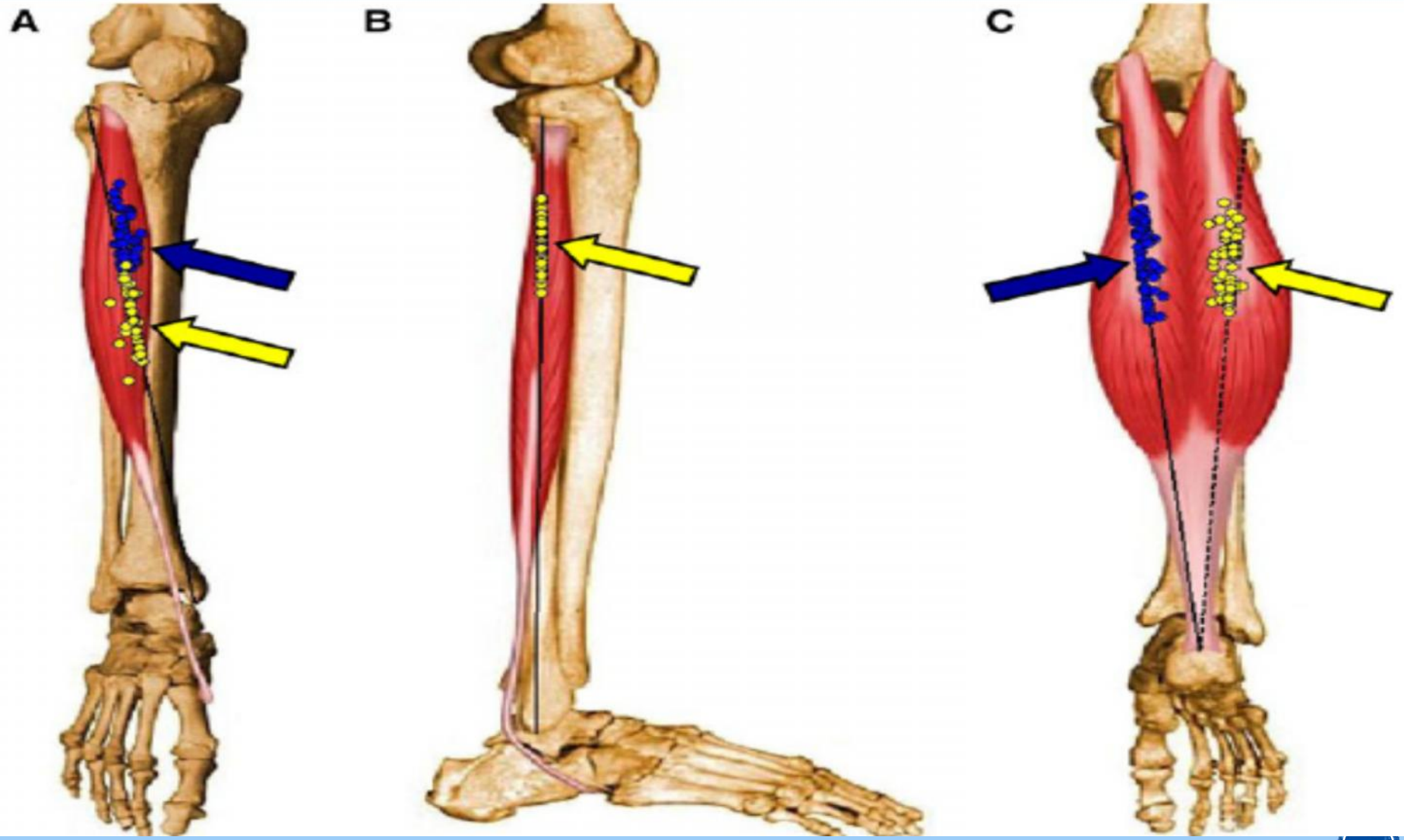
POSITION OF THE MP OF QUADRICEPS MUSCLES



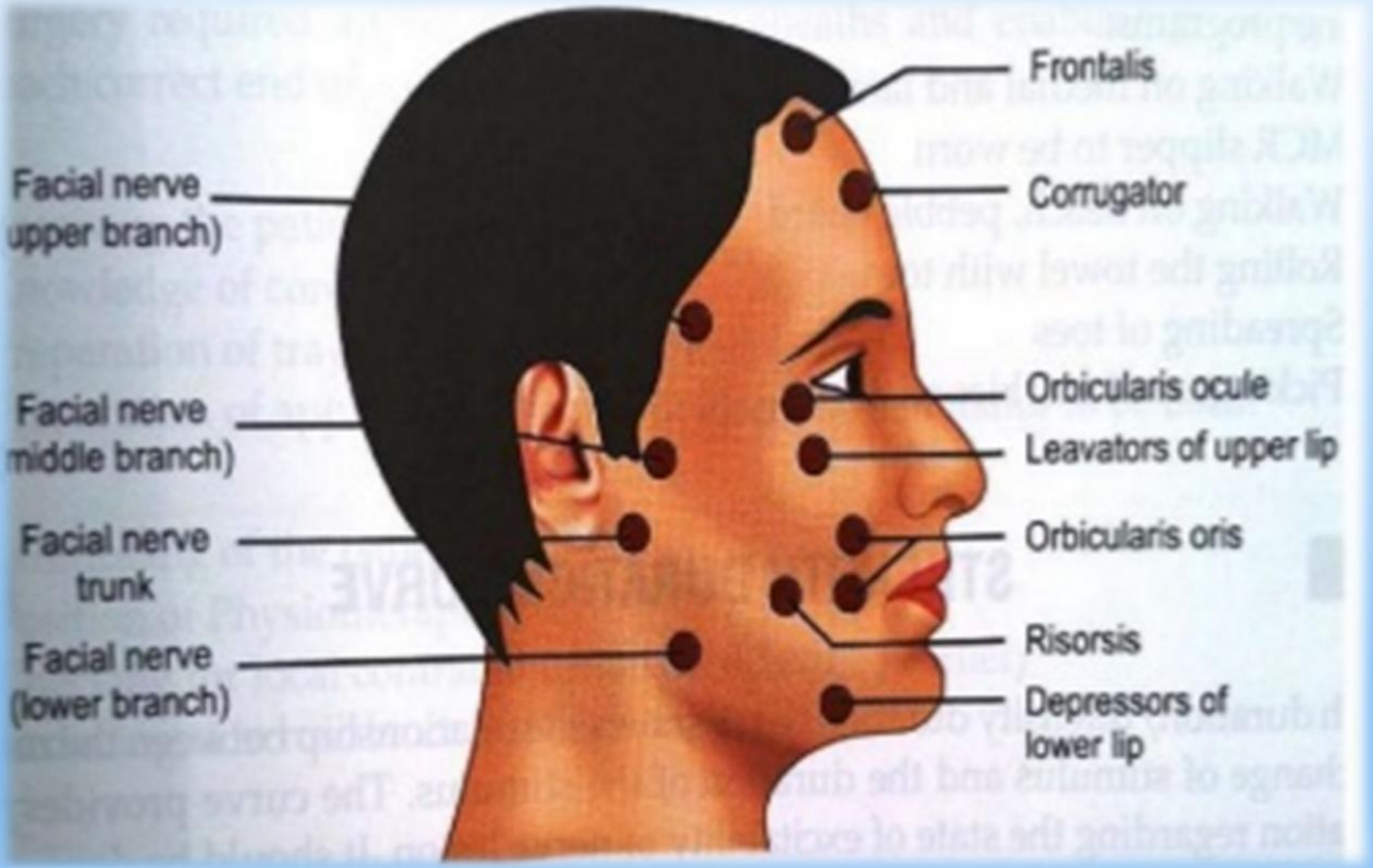
POSITION OF THE MP OF HAMSTRING MUSCLES



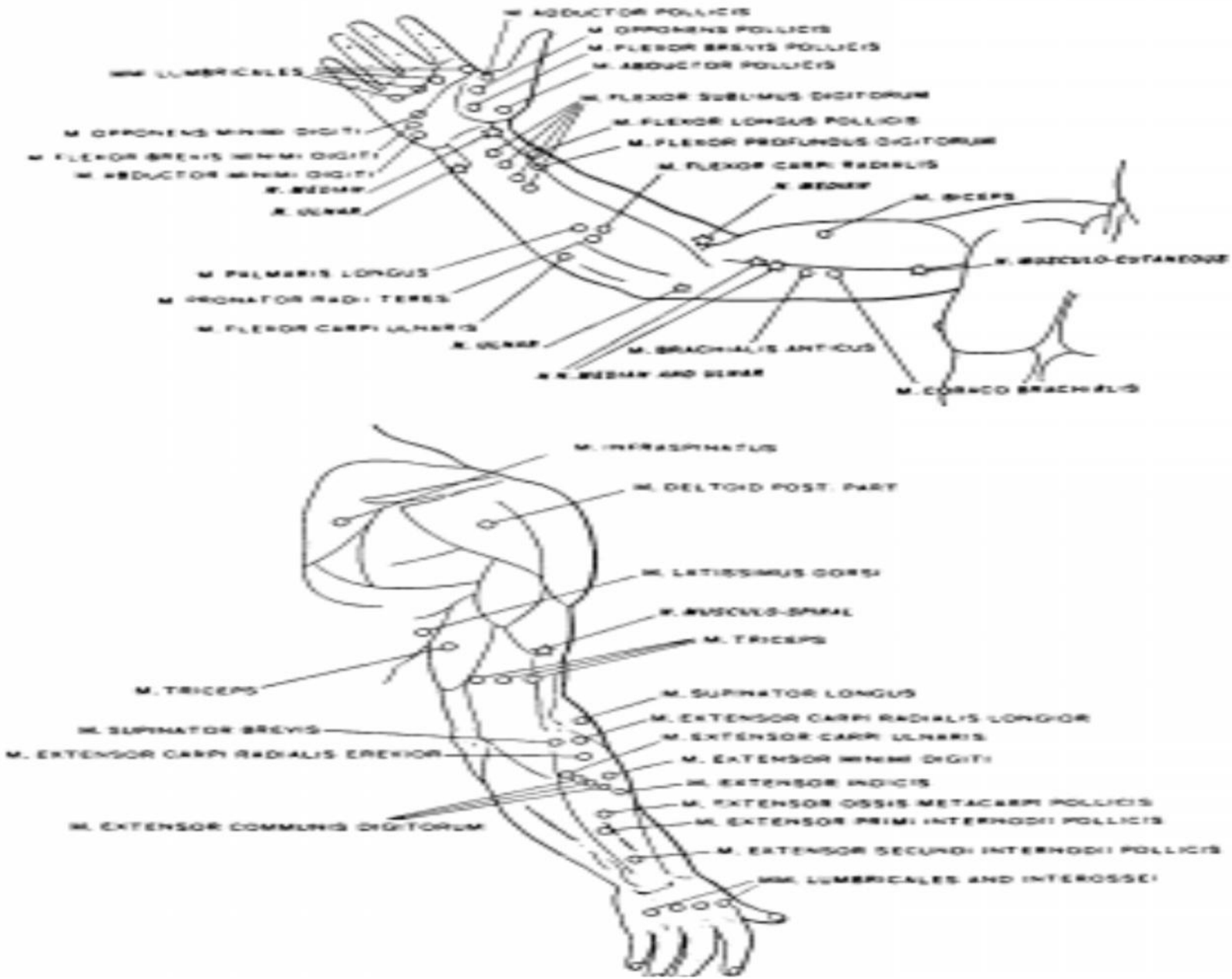
POSITION OF THE MP OF LEG MUSCLES



POSITION OF THE MP OF FACIAL NERVE



Locations of the Motor Points

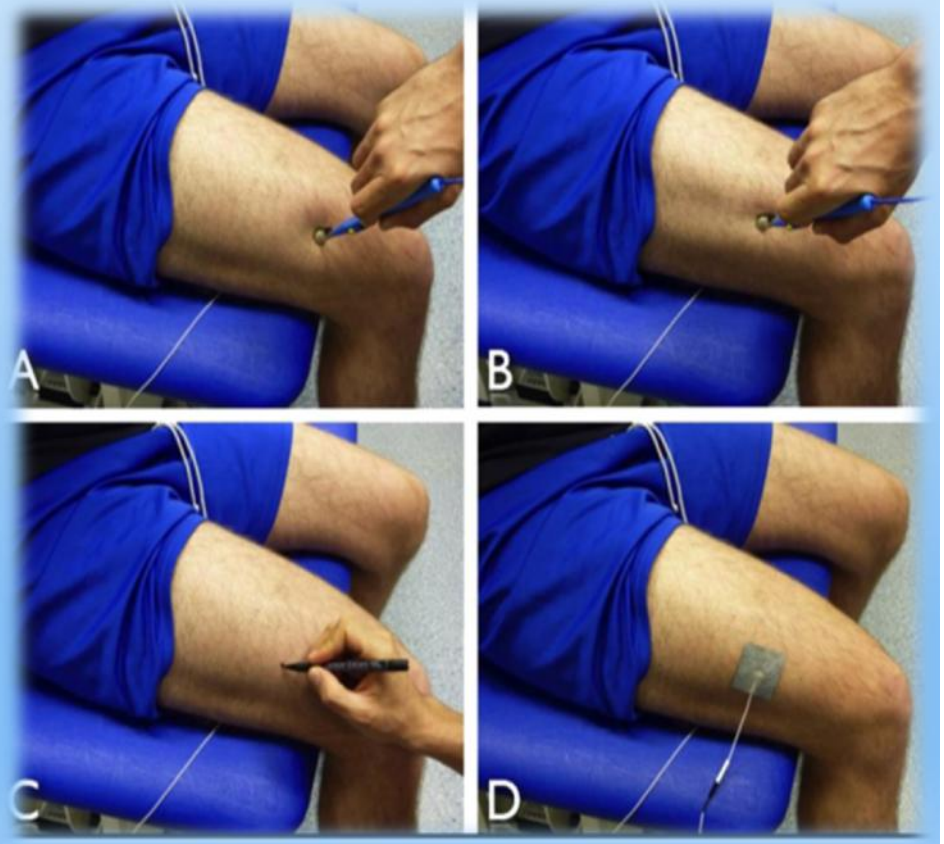


CLINICAL PRACTICE; DETERMINATION OF MP

To trace motor point

1. Interrupted direct current at **0.1ms** (100µs) for **innervated muscle**
2. Interrupted direct current at **10ms** for **denervated muscle**

- ES parameters
- F(1-20Hz)
- Intensity (start 1mA)
- Pulse duration 100-1000µseconds
- Pen electrodes (active)
- Dispersive electrode
- Alcohol swap (cotton) and markers
- A, B, C, D,



http://www.youtube.com/watch?v=ltQTB5ekhf4

VOLUNTARY VERSUS E-STIMULATION CONTRACTION

	E-stimulation contraction	Voluntary MS contraction
Order of recruitment	Fast twitch type II, then slow twitch type I	Slow twitch type, followed by fast twitch Tpe I MU fire first, then Type II. Type IIb brought in last of
Pattern of recruitment	Synchronize	A Synchronize
Fatigability	Easy and rapid	Resistance & delayed
Force of contraction	Quicker & Strongest	Slower and low force
Onset of contraction	Rapid &jerky	Slow and smooth

STRENGTH DURATION CURVE (SDC)

The SD curve is a graph representation of non liner relationship between intensity and duration of current.

The purpose of S-D curve is to know whether the stimulated muscle is innervated, denervated or partially denervated

It depends on;

- Numbers of motor units recruitment
- Intensity and frequency of current.
- Placement of electrodes.
- Degree of injuries

Optimum timing of SDC:

10 – 14 days post injury

There are also other method for this purpose like EMG and NCV.

STRENGTH DURATION CURVE (SDC)

Methods of SDC:

Take a neuromuscular stimulator unit having rectangular waveform with pulse duration i.e. 0.2, 0.4, ,0.6, 0.8, 1, 1.2. 10, 30, 100, 300ms and constant current.

Put the active electrode over the fleshy belly of the muscle

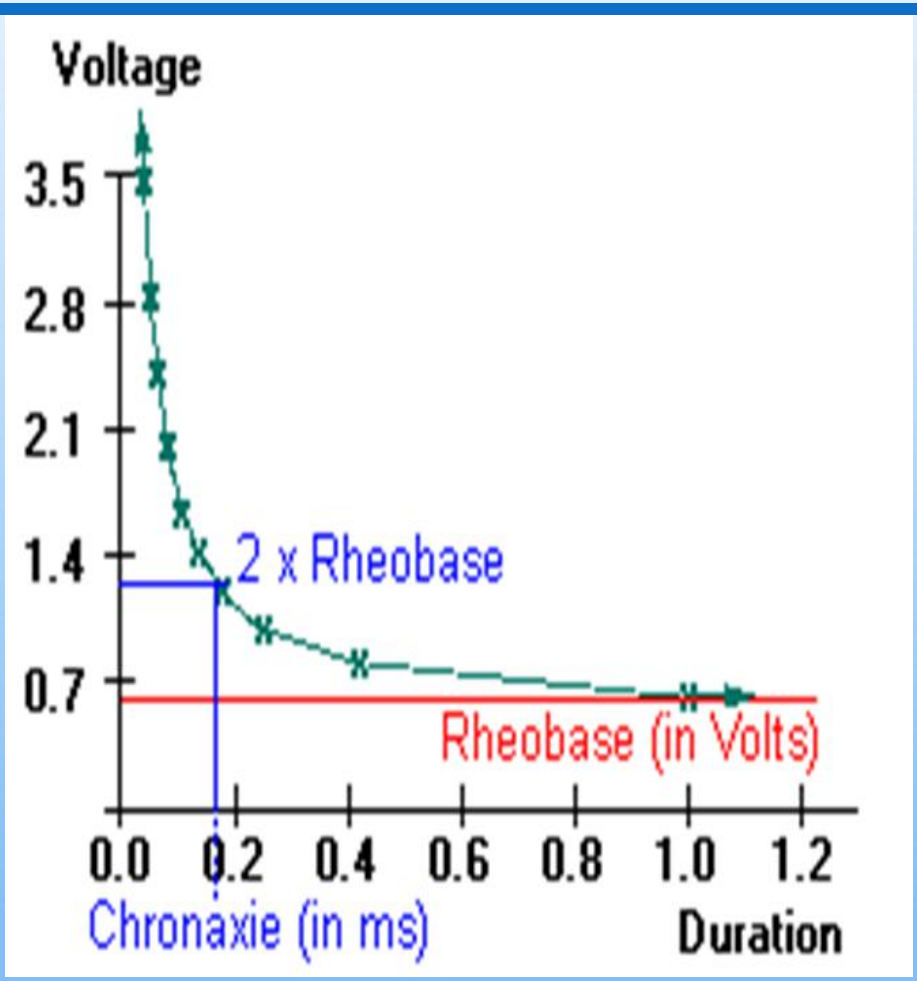
First apply current having longest duration and look for minimum perceptible contraction,

Gradually shorten the impulse duration and note the corresponding increase in current strength.

The electrode placement should not be changed through out the test.

Plot a SD graph

STRENGTH DURATION CURVE (SDC)



- Chronaxie of innervated muscles is less than 1ms (range 0.05-0.5ms).
- Chronaxie of fully denervated muscle may be 30 to 50ms

Rheobase is a minimal intensity of the current required to produce a minimal visually perceptible muscle contraction (300ms).

- Normal values are (2-18mA)

Chronaxie is the duration of pulse in milliseconds with the two-fold intensity of the rheobase which just reaches the stimulation threshold at which a muscle twitch occurs.

STRENGTH DURATION CURVE (SDC)

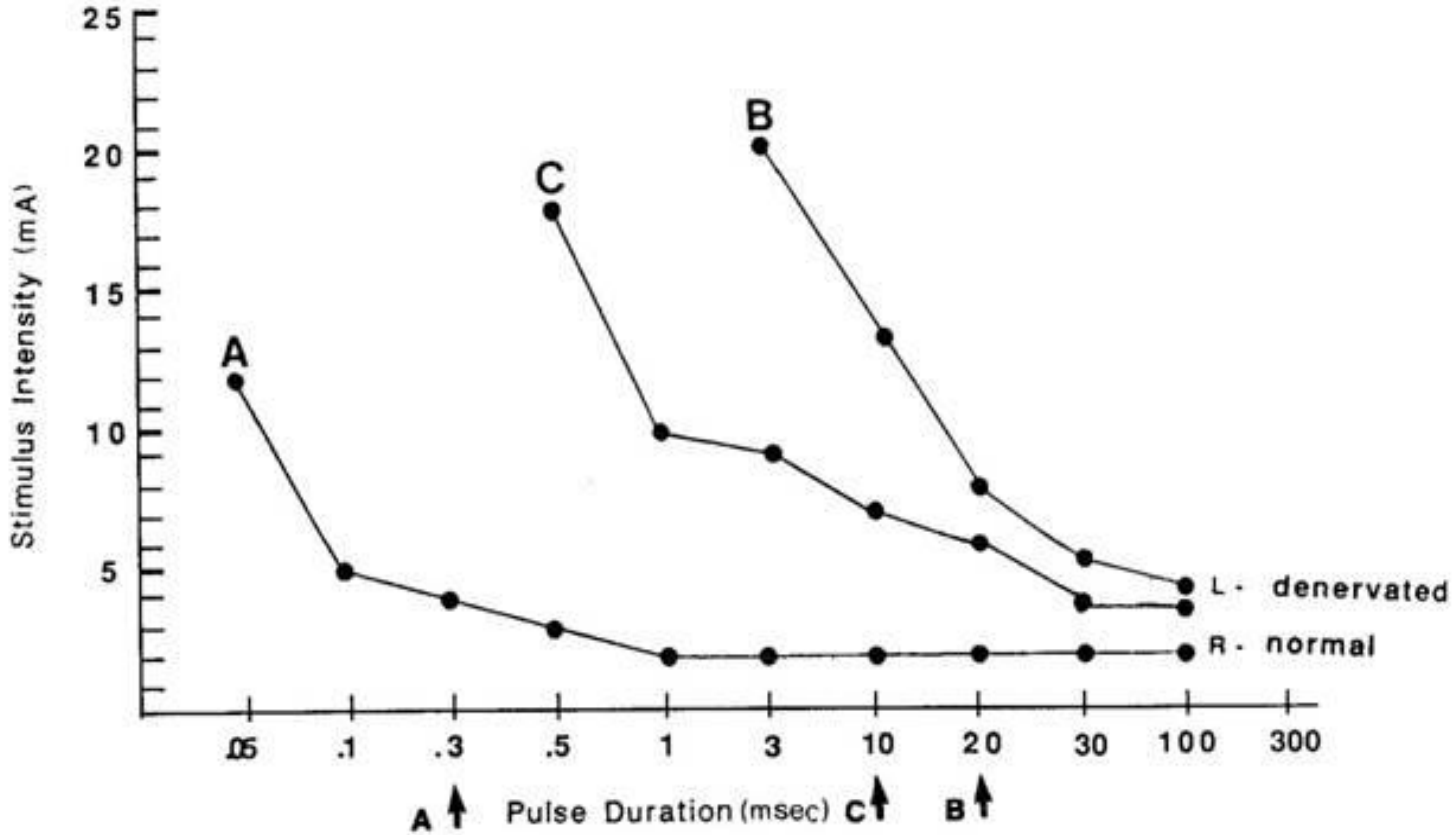
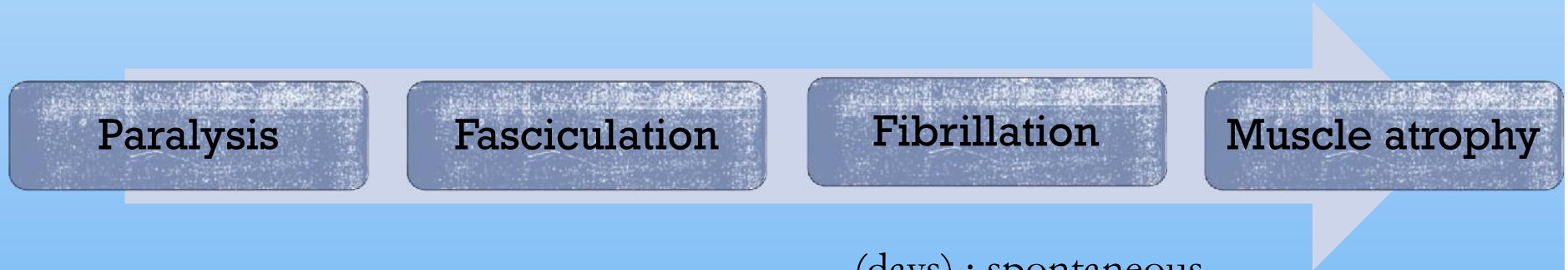


FIGURE 4–3. Plot of strength duration test values recorded in Figure 4–2 with chronaxies marked by arrows. (*A*) Normal abductor digiti minimi muscle on right hand, chronaxie 0.3 ms; (*B*) denervated muscle on left hand 2 weeks after injury, chronaxie 20 ms; and (*C*) partially reinnervated muscle on left hand 6 weeks after injury, chronaxie 10 ms.

DENERVATED MUSCLES

Loss of nerve supply. Causes of denervation include disease, chemical toxicity, physical injury, or intentional surgical interruption of a nerve.

- Complete denervation (CD), all motor unit loses all innervation
- Partial denervation (PD) some of motor unit in the muscles lose its innervation



Paralysis	Fasciculation	Fibrillation	Muscle atrophy
Immediately loss of sensation and motility	immediately: spontaneous firing of the injured axon, causing twitching of motor units.	(days) : spontaneous twitching of individual muscle fibers due changes in muscle excitability (e.g., Na channels)	>1 week): loss of muscle proteins

KEYS CHANGES IN DENERVATED MUSCLES

Denervation of muscles leads to

- Loss of voluntary and reflex activity,
- Muscle atrophy (Decrease size, and diameter of muscles fibers)
- Changes in muscle excitability

(Decrease amount of tension and Increase time required for contraction)

- Muscles fibrosis

If re-innervation does not occur within 2 years fibrous connective tissue replaces contractile elements and recovery of muscle function is not possible

STIMULATION OF DENERVATED MUSCLES

Parameters of E-Stim of Denervated Muscles

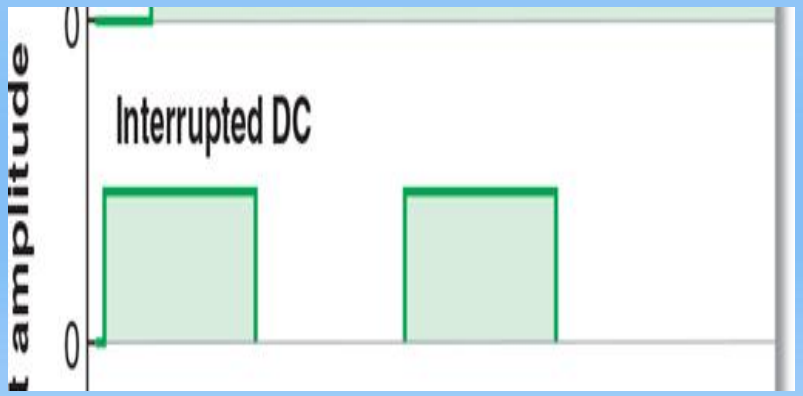
Long Duration Interrupted direct current (LIDC)

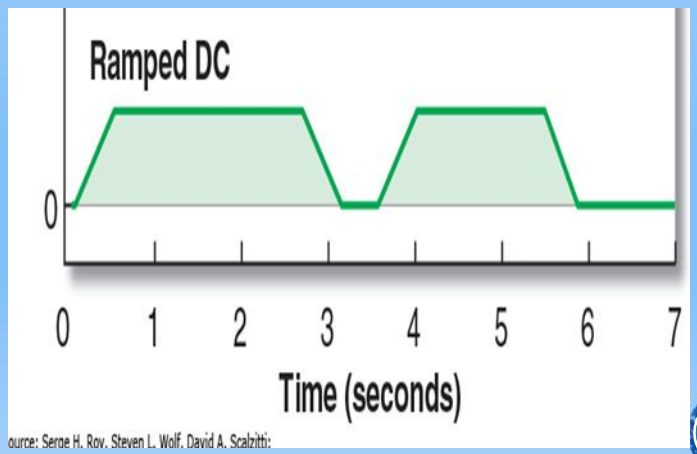
- Retardation of denervated atrophy
- Utilization of substrates
- Prevent venous & lymphatic stasis
- Working hypertophy
- Maintenance of muscle extensibility

LONG DURATION INTERRUPTED DIRECT CURRENT

Unidirectional, interrupted direct current with following characteristic;

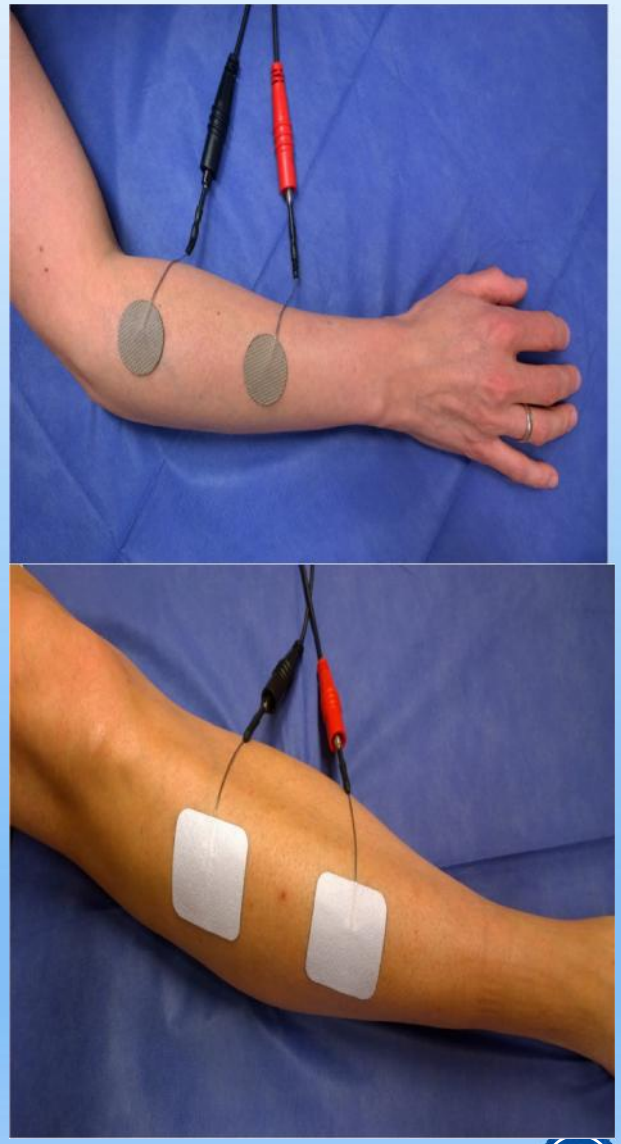
Pulse duration	Inter-pulse interval	Frequency	Waveforms
Long pulse duration (100ms-600ms) 100-300ms PD ≥ 300ms CD	3-5times of pulse duration.	Depends on pulse duration e.g. If Pulse duration = 100ms Frequency of 30 Hz	Saw-tooth, Triangular, & Trapezoid





STIMULATING DENERVATED MUSCLE

- First 2 weeks.
  - Use asymmetric, biphasic waveform and pulse duration < 1 ms
- After 2-3 weeks,
- Interrupted long duration DC of triangular waveform with a pulse duration of 200 -500 ms., and inter-pulse interval 3 to 5 times longer
- Use monopolar or bipolar electrode setup with small diameter active electrode (negative) placed over most electrically active point.
- Stimulation using 3 sets of 5 -20 repetitions, 3/ per week



Neuropraxia

Compression on nerve

100ms, rectangular

Axonotmesis

partial denervation

100-600ms,

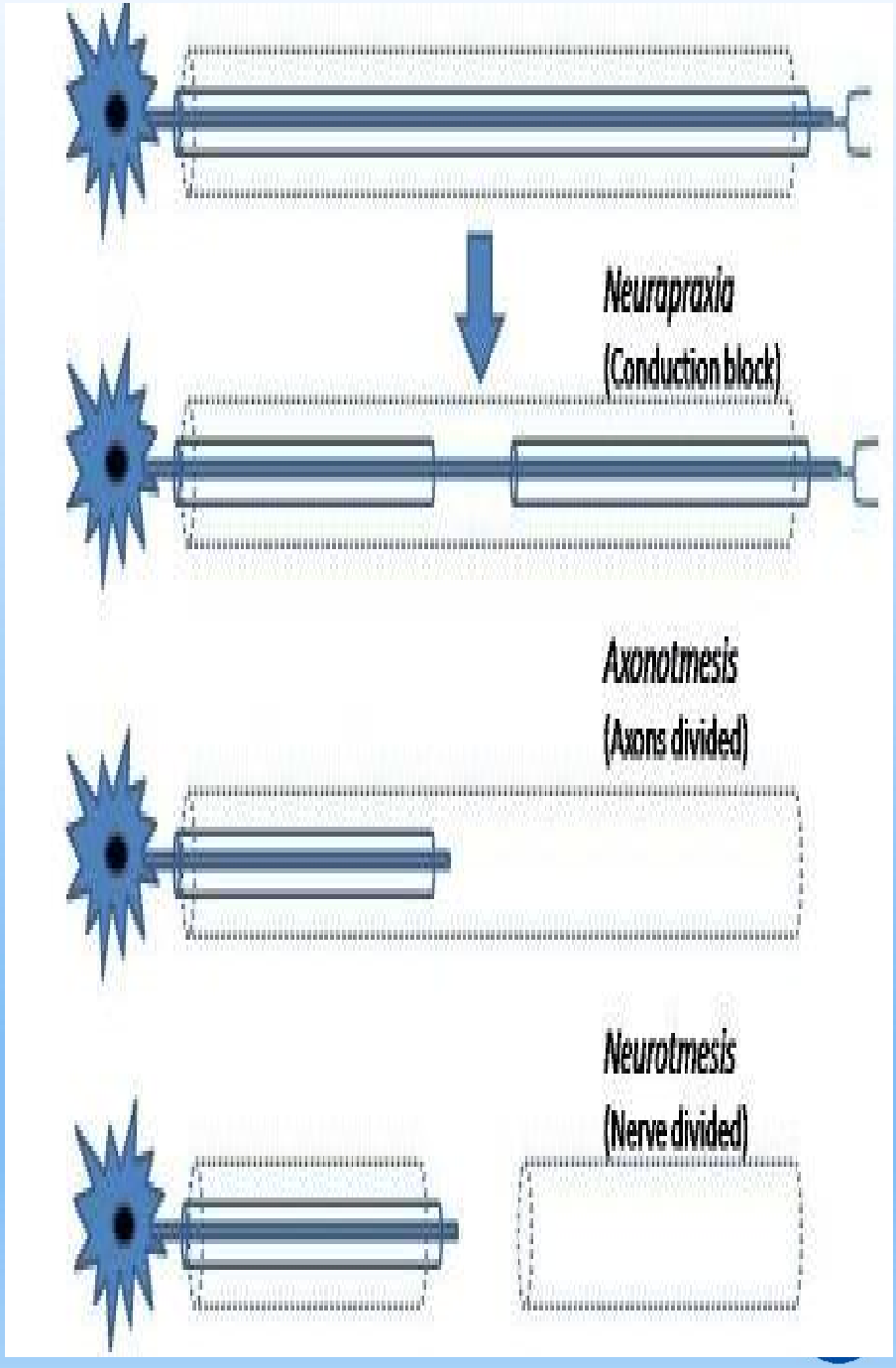
triangular, trapezoidal

Neurotmesis

Complete denervation

100-2000ms

triangular, saw-tooth



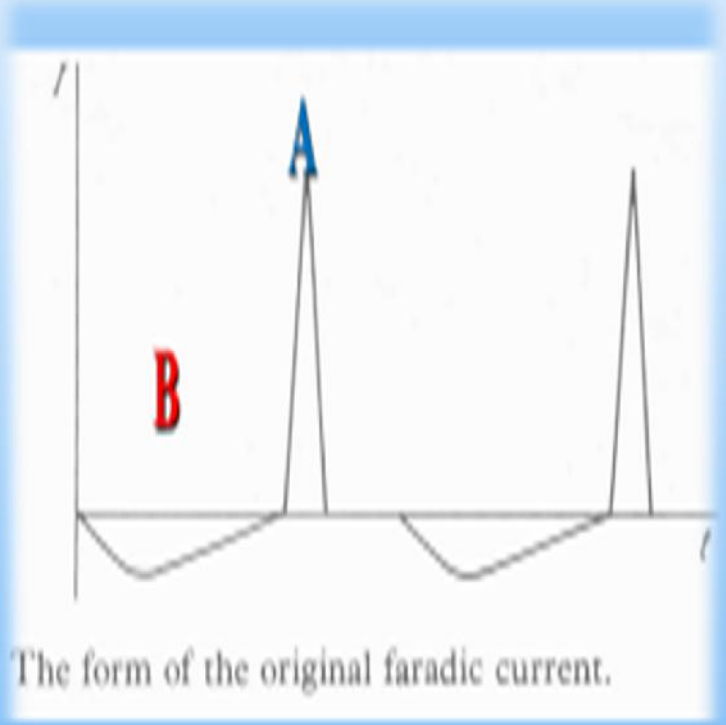
NMES- FARADIC CURRENT

FARADIC CURRENT STIMULATION

- Faradic current is biphasic unevenly alternating current, with frequency 1-150Hz. Each pulse consists of two unequal phases

  B-Negative: Low intensity long duration

  A-Positive: High intensity short duration



The form of the original faradic current.

FARADIC CURRENT STIMULATION

Faradic current is a short-duration interrupted Surged direct current with a pulse duration of 0.1 to 1ms, and frequency of 30 -100Hz

Frequency:

Therapeutic frequency (0.5, 1.5, 10, 50, 75, 100 Hz)In order to achieve a constant contraction, the stimulus must be applied at rate of 30-60stimuli per seconds.

Waveforms

Rectangular shaped pulse more comfortable than triangular pulse for normal muscle contraction.

If disuse atrophy triangular waveform can be used.

Pulse duration (0.02-1ms)

Therapeutic selection 0.02, 0.05, 0.1 & 1ms.

PD=0.1ms , frequency of 70Hz, & Skin resistance = 50Ω,

PD=1ms with frequency of 50Hz, and skin resistance = 1000Ω

Polarity :

Active electrodes usually the cathode (-)

FARADIC CURRENT STIMULATION

Faradic currents are always surged and interrupted to produce a near-normal tetanic like muscles contraction and relaxation.

Faradic current will not stimulate denervated muscles(why?)

PARAMETERS OF CURRENT STIMULATION

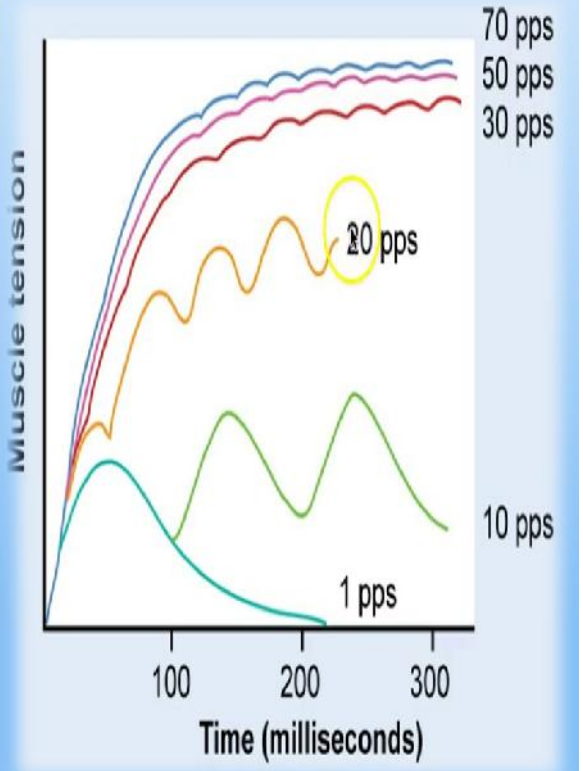
Frequency

Frequency range (10, 50, 75, 100 Hz)
Types of muscles contraction is frequency dependence.

In order to achieve a constant contraction, the stimulus must be applied at rate of 30-80Hz.

For small muscles , the recommended frequency range is (20-30pps).

For large muscles , the recommended frequency is (50-80pps)



FARADIC CURRENT STIMULATION

Waveforms

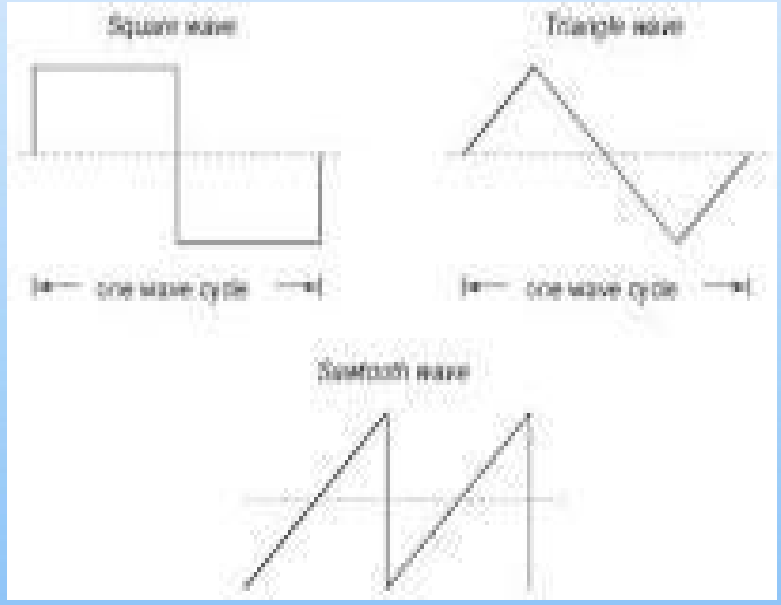
Pulsed biphasic

Normal muscle:

Rectangular waveform is more comfortable than triangular pulse

In disuse atrophy:

triangular waveform can be used.



N.B: Russian waveform can be used

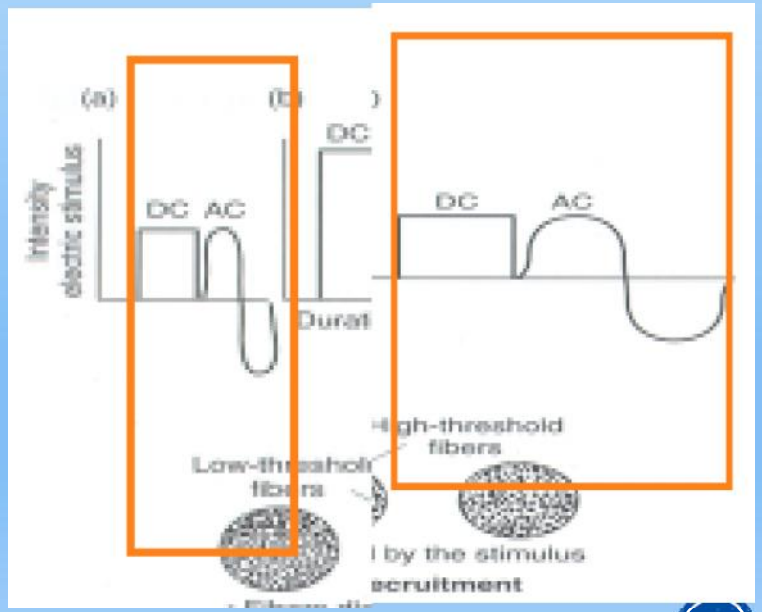
FARADIC CURRENT STIMULATION

Pulse duration

Therapeutic selection 0.02, 0.05, 0.1 & 1ms.
Normal muscles: recommended PD is .15-0.35Msec.

Pulse duration > 10msec is indicated to neurological disorders.

As the pulse duration is shortened, the higher current amplitude is required to achieve the same strength of contraction produced by longer pulse duration,



FARADIC CURRENT STIMULATION

Pulse interval

The current must be interrupted (off-time) to allow the muscles to relax following period of contraction (on-time), to prevent muscle fatigue.

The recommended on: of ration as following
In case of muscle strength 1:3 , 1:4. 1:5
In case of muscle spasm 1:1
In case of muscle pump (edema) 1:1 , 1:2

FARADIC CURRENT STIMULATION

Amplitude

The strength of muscles contraction is amplitude dependence

The recommended amplitude as following

	Normal muscles	Muscles Recovery form injury /disuse	Muscle reeducation	Muscle spasm/edema
Goals	Strength Muscles	Strength Muscles functional recovery	Functional recovery	Decrease spasm Decreased edema
	50% of MVIC	10% of MVIC	Sensory higher motor Lower motor	Visible MS. contraction

TREATMENT TIMES & FREQUENCY

- To be effective 2 & 3 treatments per week for the first 8-12 weeks
- Treatments last 15-20 minutes but no longer than 30 minutes
- It is better to have 3 short treatments per week than 1 long treatment
- For muscle strength several time/day for short time 10minutes is effective

EFFECTS OF FARADIC STIMULATION

Sensory nerves

- Mild prickling due to stimulation of sensory nerve .
- Mild erythema due to local reflex vasodilatation of superficial blood vessels, which causes slight reddening of the superficial tissues.

Motor nerves

- Faradic current stimulates the motor nerves /muscle, causes contraction of the muscles.
- Because the stimuli repeated 50 times (50Hz) or more, the contraction is titanic.
- To avoid muscle fatigue secondary to this contraction the current becomes surged

E-stimulation causes MS-strength through Overload principle and specificity mechanisms

EFFECTS OF MUSCLE CONTRACTION

- Increased muscle metabolism.
- Increase oxygen demand by the muscles.
- Increase output of waste product & metabolites (carbon dioxide, lactic acid).
- Dilatation of capillaries and arterioles
- Increased blood flow
- Increase local temperature.
- Increase venous and lymphatic drainage
- Changes in muscle structure (fast twitch to slow twitch)
- Increase joint range of motion.

CLINICAL APPLICATION OF ELECTRICAL STIMULATION INDUCED MUSCLES CONTRACTION

FACILITATION OF MUSCLE CONTRACTION & RE-EDUCATION

- Pain & muscle spasm,
  - Quadriceps e.g. vastus medialis after knee injury & diseases
- Prolonged disuse, wasting and imbalance
  - Following knee surgery (e.g. ACL, TKR)
  - Scoliosis.
  - Prolonged period of immobilization (following fracture)
- Muscle and nerve repair and transplantation.
- Peripheral Nerve injury
- Pelvic floor Muscle (stress incontinence)

IMPROVE VENOUS AND LYMPHATIC DRAINAGE

Electrical stimulation of the muscle causes increase venous and lymphatic return, increase blood velocity and flow, alter cell membrane permeability, these causes reduction of edema.

The treatment is most effective if the current is applied by the method, termed faradism under pressure

Faradism under pressure is stimulation of the muscle that generally act as the pump muscles and is combined with compression and elevation of the limb to increase venous and lymphatic drainage and hence relive edema.

E-STIMULATION FOR NEUROLOGICAL DISORDERED

Stroke: E-stim of weakened lower limb agonist muscles can improve

- Voluntary recruitment of motor units
- Improve gait
- Increase ankle dorsiflexion torque
- Assist or support joint position during movement
- Can substitute for ankle foot orthosis
- Can substitute for hand function in ADL (e.g. NESS hand rehabilitation system)

- https://www.youtube.com/watch?v=Px6CJUfZOhQ

RETARDATION OF MUSCLE ATROPHY

Maintenance of muscle tissue after injury that prevent normal muscle contraction can be achieved through using an electrical stimulated muscle contraction, which produce the physical and chemical events associated with normal voluntary muscle contraction and helps to maintain normal muscle function.

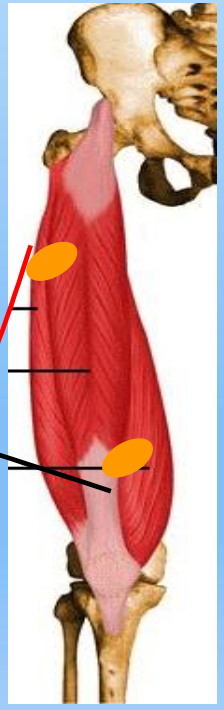
INCREASING RANGE OF MOTION

Muscle contraction pulls the joint through limited range. The continued contraction of this muscle group over an extended time make the contracted joint and muscle tissues modify and lengthen

APPLICATIONS

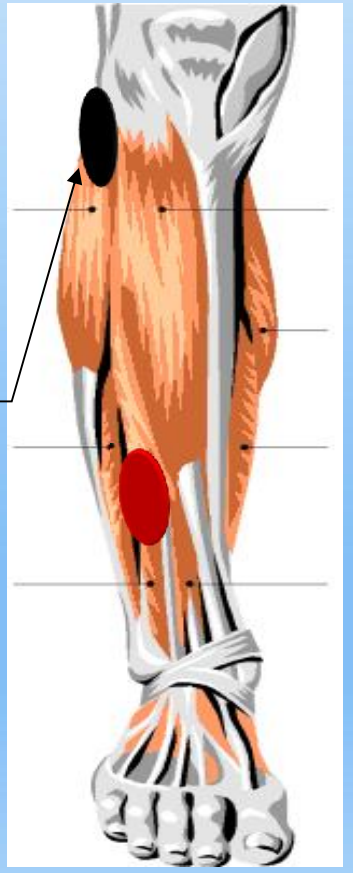
The right quad has atrophied or wasted. Stimulation of the quad can prevent atrophy and increase strength.

The person with foot drop is unable to dorsiflex their foot.



Placement for quad weakness/atrophy.

The approximate electrode placements for foot drop. The negative is placed over the peroneal nerve.



MUSCLE RE-EDUCATION

Post op ACL

- Problem: Quadriceps atrophy
  - Goal: Decrease atrophy, increase strength.
  - Waveform: Symmetric
  - Duty cycle: 25% (4:12)
  - Placements:

Rotator cuff repair

- Problem: Rotator cuff atrophy, poor scapular stability
  - Goal: Decrease/ reverse atrophy, scapular stabilizer re-ed.
  - Waveform: Symmetric/ asymmetric
  - Duty cycle: 25%, hand switch
  - Placements:

Isometric Abduction

Scapular depression

CONTRAINDICATION FOR FARADIC CURRENT STIMULATION

- Skin lesion & dermatological conditions such as eczema.
- Infection such as osteomyelitis.
- Vascular diseases such as thrombosis, & thrombophlebitis.
- Marked loss of skin sensation (chemical burn).
- Unreliable patients.
- Superficial metal (concentration of electricity).
- Metal and cardiac pacemaker
- Over recent or non-union fractures
- Over potential malignancies