

# ELECTRICAL THERAPY

POD22PMX  
Podiatric Management

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## Lecture Outline

- ELECTRICAL THERAPIES
  - Basic principles of electricity
  - Electrical stimulating currents
  - Therapeutic uses of electrically induced muscle contraction
  - Therapeutic uses of electrical stimulation of sensory nerves
    - Review pain theory
    - Transcutaneous Electrical Nerve Stimulation (TENS)
- LIGHT THERAPY
  - Low Power Lasers
    - Physics
    - Types
    - Treatment techniques
    - Clinical applications

## Electrical therapy/Electrotherapy

### ■ What is electrotherapy?

*“At its simplest level electrotherapy can be defined as the treatment of patients by electrical means. By implication this means that electrical forces are applied to the body bringing about physiological changes for therapeutic purposes.”*

Low & Reed, 1994

## Basic Principles of Electricity

- All matter composed of atoms that contain +’ve and –’ve charged particles called *ions*.
- Ions possess electrical energy
  - Move from high concentration → low concentration
  - An electrical force can move these particles from higher to lower energy levels, creating an *electrical potential*
  - Particles with a +’ve charge will move towards those with a –’ve charge and vice versa.

- Electrons – particles of matter of –’ve charge
  - Net movement of electrons = **electrical current**
  - Occurs from higher electrical potential to lower electrical potential
  - **Ampere** = 1 amp. is the movement of 1 coulomb ( $6.25 \times 10^{18}$ ) electrons/second
    - In electrical therapeutics, current measured in milliamperes (mA) or microamperes ( $\mu$ A)
- Volt
  - This is the electromotive force which must be applied to produce the flow of electrons
  - Defined as the difference in electron population between 2 points (potential difference)
  - Voltage: force resulting from the accumulation of electrons at one point in an electrical circuit, usually corresponding to a deficit at another point in the circuit
    - If a conductor exists to connect these 2 points, electrons will flow from the area of high population to the area of low population.
- Ohm
  - Unit of measure of the electrical impedance or resistance of a conducting material to electron flow.
  - An electrical circuit with high resistance (ohms) will have less flow (amps) than a circuit with less resistance & the same voltage.

Ohm’s Law

$$\text{CURRENT FLOW} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

### Flow of water

- Need 'pump' to create force to produce movement of water
- Resistance to water flow depends on
  - Length, diameter, smoothness of water pipe
- Amount of water flowing measured in litres
- Amount of energy produced by moving water determined by
  - Number of litres flowing per unit of time
  - Pressure created in the pipe

### Flow of electricity

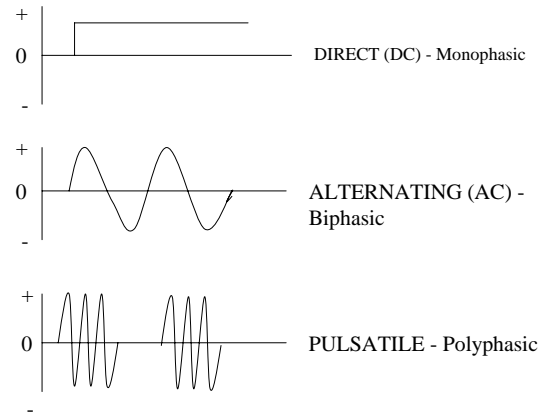
- Volt is the 'pump' that produces electron flow.
- Resistance to electrical flow depends on
  - Characteristics of the conductor
- Amount of electricity flowing measured in amperes (amps.)
- Amount of electrical energy (power) determined by
  - Voltage (electromotive force)
  - Amount of current flowing

$$\text{ELECTRICAL POWER (in Watts)} = \text{VOLTS} \times \text{AMPERES}$$

The Watt indicates the rate at which electrical power is being used. A watt is defined as the electrical power needed to produce a current flow of 1 amp at a pressure of 1 Volt.

## Electrotherapeutic currents

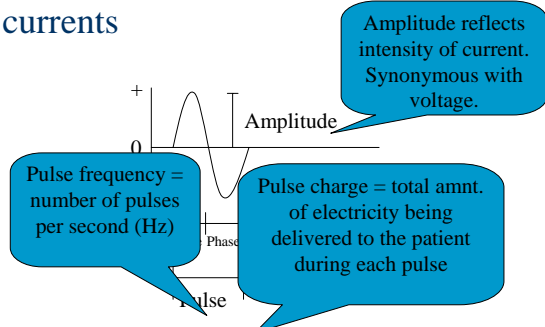
- 3 different types of current
  - Alternating (AC)
  - Direct (DC)
  - Pulsatile
- Direct current
  - Uninterrupted, unidirectional flow of electrons toward the positive pole
- Alternating current
  - Continuous flow of electrons constantly changes direction or, reverses its polarity
  - Electrons in AC always move from -'ve pole to +'ve pole
- Pulsatile currents
  - Usually 3 or more pulses grouped together interrupted for short periods of time and repeat at regular intervals



## Generators of electrical currents

- Much confusion surrounding terminology
- Transcutaneous electrical stimulators
  - All therapeutic electrical generators that deliver currents through electrodes attached to the skin
- If they are used to stimulate peripheral nerves
  - Transcutaneous Electrical Nerve Stimulators (TENS)
- Neuromuscular Electrical Stimulators (NMES) or Electrical Muscle Stimulators (EMS)
  - Electric current used to stimulate muscle directly not transcutaneously

## Other characteristics of electrical currents



## Current modulation

- any alteration to the magnitude or any variation in the duration of electrical pulses
- 4 types
  - Continuous
  - Interrupted
  - Burst
  - Ramped

- Continuous modulation
  - Amplitude of current remains constant for several secs. or mins.
  - Often used with alternating current to elicit muscle contractions
- Interrupted modulation
  - Current flows for some period of time (“on time”) & is then periodically turned off during the “off time”
  - Monophasic & biphasic currents
  - Clinically, for muscle reeducation, strengthening & improving ROM

- Burst modulation
  - Pulsed current flows for a short duration (milliseconds) then turned off for short time (milliseconds) in a repetitive cycle
- Ramping modulation
  - Current amplitude increases or “ramps up” gradually to preset maximum & may also ramp down.
  - Clinically, elicit muscle contraction
  - Very comfortable type of current

## Physiological responses to electrical current

- Effect on each cell & tissue electricity passes through
- Type & extent of response depends on
  - Type of tissue & its response characteristics
  - Nature of the applied current
- *Tissue should respond to electrical energy in a manner similar to that in which it normally functions or grows*

- Thermal
  - All electric currents cause a rise in temp. in a conducting tissue
  - Resistance of tissues varies
- Chemical
  - Most biologic tissue contains -ve & +ve ions
  - Current causes migration of ions toward pole of opposite polarity
  - At +ve pole, -ve ions cause an acid reaction = coagulation of protein & hardening of tissues.
  - At -ve pole, +ve ions cause alkaline reaction = liquefying protein & softening of the tissues
- Physiologic
  - Muscle contractions
  - Modification of pain impulses through effects on motor or sensory nerves


## Clinically,

- Create muscle contraction through nerve or muscle stimulations
- Stimulate sensory nerves to help treat pain
- Create an electrical field in biologic tissues to stimulate or alter the healing process
- Create an electrical field on the skin surface to drive ions beneficial to the healing process into or through the skin (iontophoresis)



## Normal bioelectric fields

- Skin surface is always -'ve relative to the dermis
- Long bones – midpoints +'ve compared to ends; epiphyseal plate area more -'ve than other areas
- Skin wounds – current moves from +'ve dermis into wound area and reenter skin below stratum corneum
- “Current of injury” (Becker, 1962) – produced by any cellular trauma & plays key role in stimulating healing & regen. of tissue



## Therapeutic uses of electrically induced muscle contraction

- Various types of equip. can be used to stim. muscle contraction
- Consider potential muscle fatigue
  - By considering intensity, pulse rate, on & off times
- Uses:
  - Muscle re-education
  - Muscle pump contractions
  - Retardation of atrophy
  - Muscle strengthening
  - Inc. joint ROM



## Muscle re-education

- Post-injury & post-surgery
- Initiates artificial use of inactive synapses
- Objective is to re-establish control not strengthen
- Forced contraction inc. sensory input from muscle
  - Patient feels the m. contract, sees the m. contract & can attempt to duplicate the response



## Muscle-pump contractions

- Calf muscle pump to assist venous return
- Electrically-induced m. contractions can stimulate circulation
- In animals, sensory level stimulation can dec. oedema in sprain & contusion injuries



## Retardation of atrophy

- Post-injury maintenance of m. tissue where injury prevents normal exercise
- Electrical stim. reproduces physical & chemical events assoc. with normal m. action & maintains normal m. function



## Muscle strengthening

- Used in patients with weakness or denervation of a muscle group
- Some good results reported in literature
- More research required to clarify procedures & generalise results to other conditions.

## Increasing ROM

- Can inc. ROM in contracted joints by stimulating muscles that cross the joint
- Needs to be applied over an extended period of time

## Stimulation of denervated muscle

- Denervated m. = m. that has lost periph. nerve supply
- Aim here is to minimise atrophy while nerve regeneration occurs
- Denervation leads to
  - Progressive anatomic, biochemical & physiological changes
  - Size of individual m. fibres & diameter & weight of m. decreases

- Degenerative changes continue until m. is reinnervated by axons regenerating across the site of the lesion
- If no reinnervation after 2 yrs.
  - Fibrous connective tissue has replaced contractile elements of m. & recovery of m. function is not possible
- General agreement in lit. advocating the benefits of electrical stim. of denervated m.
- Some studies suggest electrical stim. interferes with reinnervation & delays functional return

## Therapeutic uses of electrical stimulation of sensory nerves

- Used to alter patient's perception of pain from an injured area.

## Pain theory (a quick review)

- Pain receptors (nociceptors)
  - Where?
  - Types?
    - A delta fibres (pressure & texture)
    - C fibres (pain & temperature)
- Path to the brain
  - A delta & C fibres travel through dorsal root, synapsing with other nerve fibres in dorsal horns of the spinal cord.

## Pain theory (a quick review)...

- Path to the brain (cont.)
  - A delta & C fibres release substance P (a NT) into the synaptic cleft
  - Impulse travels up to the thalamus
  - Thalamus sends 2 messages
    - 1st to cerebral cortex (assesses damage & locates original pain signal)
    - 2nd to original pain location to get nociceptors to stop sending more unnecessary pain impulses
  - Cerebral cortex informs limbic centre (responsible for perception of pain - can lessen or intensify pain by controlling emotional responses)

## Pain theory (a quick review)

### ■ Path to the brain (cont.)

- Cerebral cortex alerts ANS (breathing, blood flow, heart rate)
- Body responds in different ways to pain
  - Hormones control many of our perceptual and physical reactions to pain

### ■ Pain theories

- Gate theory of pain
- Endorphin theory
- Others?

## Pain theory (a quick review)...

### ■ Gate theory

- Pain blocked by closing 'gates' in spinal cord & thalamus
- A delta fibres (large) transmit tactile sensations
- C fibres (small) transmit pain & temperature
- Stimulating larger fibres 'closes the gate' and prevents smaller fibres from getting through

### ■ Endorphin theory

- Polypeptide neurotransmitters & neurohormones (endorphins) produced by body - body's homemade painkillers

## Pain theory (a quick review)...

### ■ Endorphin theory (cont.)

- Stimulation of nociceptors or deep pressure receptors stimulates release
- Endorphins travel through blood to brain and block nociceptive pathways...therefore, suppressing pain response

*In real life, pain control is probably a combination of the gate and endorphin mechanisms*

## T.E.N.S – Transcutaneous Electrical Nerve Stimulation

The use of therapeutic electricity for analgesia

## T.E.N.S (Transcutaneous Electrical Nerve Stimulation)

### ■ History

- Electrical stimulation to relieve pain dates back to 46 A.D.
  - Scribonius Largus described use of torpedo fish & electric eel to control pain
- 1965: Melzack & Wall develop gate control theory of pain
- 1967: Mortimer & Shealy develop DCS (dorsal column stimulator) for surgical implantation
- T.E.N.S originally used in screening for DCS suitability; noticed pain relief during screening; thus became acceptable alternative method for pain relief

## How does it work?

- Poorly understood
- Placebo response 32%
- TENS believed to stimulate A-delta fibres, thereby blocking pain messages from C-fibres - "closing the gate"?
- TENS may stimulate endorphin release?

## The Unit

- Battery operated with alkaline or nickel/cadmium battery
- Lead wires
  - Connect unit to electrodes
- Electrodes
  - Sponge with conducting gel (cg)
  - Carbon/silicone with cg
  - Conductive tape strips, karaya gum electrodes



## Types of T.E.N.S

- High Rate
  - Preset rate (R) ~  $80 \pm$  pps
  - Preset pulse width (W) ~ 60ms
  - Adjust amplitude (A) to produce altered sensation
  - Slowly increase (A) to produce discomfort or muscle twitch

## Types of T.E.N.S

- Low Rate
  - Preset (R) at ~ 1-4 pps
  - Preset (W) at ~ 200-300 ms
  - Adjust (A) to produce visible muscle twitch (within tolerance levels of patient)

## Physiological effects of TENS on body systems

- Cardiopulmonary system
  - Stimulates muscle-pumping action
    - Increases venous return & lymph flow to heart
- Endocrine system
  - Inhibits secretion of substance P from T-cells which causes pain
  - Allows release of endorphins &/or enkephalins to counteract substance P

## ■ GI, GU, Obstetrics/Gynaecological Systems

- Counteract visceral pain
- Stim. peristaltic activity in GI tract
- Urinary incontinence 2° to prostatic hypertrophy
- Reduction of labour pain

## ■ Integumentary System

- Inc. blood flow to skin
- Pain assoc. with dermatome

## ■ Musculoskeletal System

- Reproduces physical & chemical events assoc. with normal voluntary m. contraction (with low rate TENS between 20-40pps)

## ■ Neuromuscular System

- Activates large-diameter A-beta fibres that inhibit interneurons (substantia gelatinosa) of spinal cord
  - Inhibition of smaller A-delta & C fibres (pain fibres) & presynaptic inhibition of T-cells to close the “gate” & modulate pain
- Inhibition of release of substance P

## Contraindications

- Cardiac pacemaker
- Over carotid sinus

## Special Precautions

- Pregnancy
- Eyes & bony orbits
- Internal use
- Anterior chest wall
- CVA, TIA, Epilepsy/seizure disorders
- Incompetent patient
- Burns or open wounds

## Skin Reactions

- Electrical
  - Burns may occur with xs stimulation or having electrodes too close together
- Chemical
  - Unlikely because of type of current & pulse duration
- Allergic
  - Rarely reactions to rubber/silicone
  - Occasional reaction to nickel
  - Likely reaction to tape
  - Allergy to coupling gel rare

## Skin Reactions (cont.)

- Mechanical
  - Shearing force between tape & skin
  - Use elastic bandage/clothes
  - Some electrodes self-adhering with gel

## Some examples...

- Achilles tendon injury

**Achilles' Tendon Injury**

As the Tendo-Achilles is the strongest tendon of the body, which requires repetitive strains or a strong pressure for it to be injured. Repetitive injury is predisposed by running on soft tracks, or using a low heel. Injury varies from tendinitis, to the tearing of a few fibres, to complete rupture. The weakest point is at the upper insertion with the Gastrocnemius muscle. Bruising occurs if some of the muscle is torn (See Torn Calf muscle). Injury also occurs to some of the fibres attaching the lower insertion to the Calcaneum. Complete rupture of the tendon may occur from excessively strong strain.

**Aims of Treatment**

- 1 Provide AS during the recovery of the strain.
- 2 The work load must be reduced.
- 3 Rupture requires suture and immobilization, then rehabilitation.
- 4 Apply increase electro-chemical activity to accelerate healing and to increase circulatory flow to the tendon.
- 5 Apply NMS to strengthen the Calf muscle.

**Electrode Placement**



**Prognosis**

Strains recover if professional instructions are followed. Ruptures may require surgery and may take many months to repair and rehabilitate. Do not train on soft tracks and wear a reasonable heel.

## Some examples (cont.)...

- Ankle sprain/ Peroneal injury

**Sprained Ankle / Peroneals**

This is caused by a twisting inward of the ankle under body weight. The lateral ligament is torn, blood vessels are ruptured causing bruising beneath the ankle and along the outside of the foot. The Peroneal tendons and muscles which normally maintain stability of the ankle to prevent this injury are stretched and strained. The ankle swells, bruising and oedema occurs in the foot and ankle regions. The swelling and oedema is frequently more debilitating than the strained ankle.

**Prognosis**

Good if sustained preventive routine is maintained after recovery to strengthen the Peroneals. Should the injury become a chronic disability, then taping and/or an ankle support device may become necessary for training and performing.

**Aims of Treatment**

- 1 Introduce RICE program to prevent oedema at the ankle and foot. Also apply AS First Aid to reduce cellular activity and pain management.
- 2 Increase electro-chemical activity to accelerate healing.
- 3 Continue AS On-demand for pain management as required.
- 4 Provide NMS to:
- Strengthen the Peroneal muscles which stabilise the ankle.
- Increase the circulation to the ankle and peroneal regions.
- 5 Frictional massage to the Peroneal tendons.
- 6 Mobilization of the ankle.
- 7 Use a suitable board for general ankle strengthening.

**Electrode Placement**





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