Electrotherapy

"to zap or not to zap… and why or why not?"

Brief History of Electrotherapy

• Eels for gout and headaches (46 AD)

Brief History

• Electrical generator for constipation (1772)
Brief History

- ES used as a diagnostic tool (1840)

- Strength Duration Curves (1909)

- Animal resuscitation (1931)

Figure 3.19. Stimulus strength-duration curves for the three classes of peripheral motor fibers and denervated muscle.
Gate Control Theory for pain relief
Melzack & Wall (1965)
Endogenous opiates (1980s)
Hughes & Kosterlitz

Electric Charge
- Repulsion of like charges
- Attraction of opposite charges
Physics of Electricity

- Charge can be transferred from one object to another
- Charge cannot be created or destroyed

Physics of Electricity

- Electric Field
  - Force between oppositely charged particles

Physics of Electricity

- Voltage
  - The change in electrical potential between 2 points in an electric field. Voltage is the potential energy that makes the electrical current flow in a circuit by pushing the electrons around.
Assume two containers connected with a channel. When one is higher than the other one, as shown in the figure below, the water in the higher container starts running from the top one to the bottom one creating a current. This happens because the water in the higher level relative to ground has a higher potential energy.

Physics of Electricity: Electromotive force
- Difference between concentration of electrons in one area relative to another
- Measured in volts (implies push)

Physics of Electricity
- Conductor
  - Material that transmits charge when a potential difference exists
  - Nerves and muscles
Physics of Electricity

- **Insulator**
  - Materials that inhibit the transfer of charge
  - Adipose tissue

- **Current**
  - The movement of charged particles through a conductor as a result of an applied electric field
  - Requires freely moveable charged particles,
  - Applied force

- **Current**
  - The amount of charge per unit of time as measured in a conductor
Physics of Electricity

- Ohm's Law
  - The degree of current is directly proportional to the strength of the voltage applied, and

- Ohm's Law
  - The degree of current is inversely proportional to the degree of resistance

Current = V/r

I = Voltage /Resistance

Physics of Electricity

- **Conductance**
  - The ease of transfer of electrical current,
  - Inversely related to resistance
  - High resistance = poor conductance

- **Capacitance**
  - The ability of an electrical system to store charge

- **Impedance**
  - The opposition to the flow of alternating current
  - Measured in Ohms
Types of Current

- Direct Current (DC)
  - Continuous unidirectional flow of charged particles
  - Results in a "net charge" (there's some charge left over)

- Alternating Current (AC)
  - Continuous bi-directional flow of charged particles
  - Resulting in NO "net charge"
  - (There's the same amount of "+" and "-" ions)

- Pulsatile Current
  - Uni or bi directional flow of charged particles,
  - Periodically ceasing for finite periods of time
What about pulsed medium frequency? Waveforms that are interrupted with a carrier frequency?

Terminology
- Shape
- Balance
- Symmetry
- Phase relationship
Descriptions
  • Amplitude
    • How strong is it?

Amp

Pulse duration
  • How long is it on?

time

Frequency
  • How many of them are there?

1 second
What is the rate of rise of rate of decay?

Is it an interrupted carrier?

Amplitude
• Intensity
• Voltage
• Strength
• Volume

Frequency
• Rate
• Pulses per second
  • pps
• Cycles per second
  • cps
• Hertz
  • Hz
**Electrical "Synonyms"**
- Pulse Duration
  - μseconds (micro seconds)
  - Pulse "width"
  - "PW"

**Electrical "Synonyms"**
- Carrier Frequency
  - Pulse trains
  - Pulse burst

**Electrical Stimulation Principles**
- Ion flow
  - Anode
    - The positive electrode
    - Negative ions are attracted
    - HCL is formed
    - Coagulation of proteins
    - Hardening of tissues
    - Circulation increases due to the body's attempts to restore homeostasis and restore the pH to more neutral levels

- Ion flow
  - Cathode
    - The negative electrode
    - Positive ions migrate
    - Alkaline is formed
    - Hypersensitivity
    - Tissue fragility
    - Circulation decreases due to the body's attempts to reduce the pH and maintain homeostasis
**Electrical Stimulation Principles**

- Ion Flow
  - Cathode
    - The negative electrode
    - Positive (Na) ions are attracted
    - NaOH formed
    - a base which increases the alkalinity of the area
    - Bases are corrosive, especially to fatty tissue making it gray and soapy and slippery
    - They also may cause painful and burning sensations
    - Promotes liquefaction of proteins
    - Tissue softening

- Membrane depolarization
  - At the cathode
    - "the active electrode"
    - Principal site of depolarization
    - If there is sufficient charge
      - It will generate an action potential
      - The addition of more current will not enhance the response

**Action Potential Review...**
Membrane depolarization At the anode
- “the indifferent electrode”
- No threshold change
- No depolarization

The sum of the resistance of the tissue
Capacitance of the tissue (ability to store charge)
Conductance of the tissue (ability to transmit charge)
Low impedance allows for an easier flow of current

Higher impedance values will require more voltage to drive the current through the skin

Skin stratum corneum insulates against the flow of current

Conductivity of tissues is related to the water content
- Muscle 75%
- Adipose 15%
Critical Factors of Stimulation

- Transverse conduction in muscle is 4x more difficult than longitudinal conduction

Current Density
- The amount of current flow per unit area
- Equally sized electrodes are potentially equal
- Unequally sized electrodes
  - The smaller electrode is more active
  - Larger electrodes typically have lower impedance values and lower current densities than smaller electrodes
Electrodes are capable of delivering electrical current to the patient, but only if the conditions are favorable. Moist and electrically conductive electrodes are required for effective stimulation.

The source of most skin impedance is in the stratum corneum of the epidermis. If the outer horny layer of dead cells is removed by light abrasion using sandpaper, the impedance could be reduced by 50-100 fold. Of course, this would cause additional skin irritation and is **NOT** performed.

The closer the electrodes are to each other, the shallower the depth of penetration. But the current density is greater.
The farther apart the electrodes are to each other, the greater the potential for depth of penetration. But the current density will be lower.

Remember your treatment goal! Are you attempting to stimulate muscle? Do you want to cause a muscle contraction? If yes, you need to use motor points. More than one electrode needs to be placed on the same muscle. If not, you do NOT want to use motor points. Do you want a sensory response? Do you want the current to be superficial or deep?

Constant Current Generators maintain the current regardless of changes in the resistance. Predictable physiologic outcome (GOOD). Chance for increased current density (BAD).
**Current Source & Current Type**

- **Constant Voltage Generators**
  - Maintain the voltage regardless of the changes in resistance
  - Less predictable physiologic response
  - No danger of increased current density if an electrode should lift off or dry out during treatment

**Examples of Constant Current Generators**

- Iontophoresis units
- Muscle stimulators for denervated muscles (DC units)
- Most TENS units

**Examples of Constant Voltage Generators**

- Clinical electrical stimulation units
- Some micro-current stimulators

\[ I = \frac{V}{R} \]
Direct Current Stimulation

- DC = the un-interrupted unidirectional flow of charged particles

Applications
- To deliver/introduce a medication across the skin
- Iontophoresis
- To elicit a response from denervated muscle

Chemical responses at the skin interface
- Positive pole
  - Acid effect, HCl production
  - Decreased density of proteins
  - Sclerolytic effect
  - Skin irritation
  - Vasomotor stimulation and mild heating
  - Decreased nerve root activity

Chemical responses
- Negative pole
  - Alkaline reaction, increasing the density of proteins
  - Increasing nerve root irritability
  - Vasomotor stimulation, mild heating
  - Skin irritation, erythema
Ionization and Ion Transfer

- Like ions repel each other
- Opposite ions attract each other

Ionic repulsion will cause drug delivery of ionized drugs

- The active electrode will be the same polarity as the medication to be delivered
- The active electrode will be placed over the delivery site
Medication Delivery

- ...with iontophoresis
- Clean the skin before the Rx
- Use of the proper polarity is CRITICAL
  - Know the polarity of the medication
  - Place the medicated electrode under the proper pole
  - Place the proper pole over the Rx area
  - Moisturize the skin after Rx

Safety with Iontophoresis

- Drug allergies MUST be solicited from the patient prior to application
- Skin inspection is CRITICAL
  - Scar tissue vascularity will effect drug delivery and current density

- Freckles have higher resistance values than non-freckled areas
- Hair follicles are not uniformly resistance to current flow
- Sweat glands have low resistance levels
- Anesthetic areas are to be avoided!
Treatment Techniques

- Utilize a constant current device
- Patient will probably not feel anything
- Clean and inspect the skin

Common “Ionto” Medications

- Anti-inflammatory agents
- Analgesics
- Sclerolytic agents
  - Iodine is used as a vasodilator agent, an anti-inflammatory agent, and as a sclerolytic agent in cases involving scar tissue, adhesions, calcific deposits and adhesive joints.
- Vasodilators
- Others
  - Single elements

Iontophoresis

- Skin irritation following Rx is common
- Itching following Rx is common
- Moisturize the skin after Rx
Iontophoresis

Treatment Techniques
- Check the surface of the electrodes to make sure that they are:
  - Smooth
  - Regular
  - Electrode interface touches the skin NOT the electrode itself

Intensity
- Do not exceed 1 mAmp/cm² of the active electrode
- Rx time = closely monitored for irritation
- Goal = 40mAmp x min
  - 40 = 2mAmp x 20 or 4 mAmp x 10 etc.

Contraindications to Iontophoresis
- Drug allergy
- Over anesthetic area
- Directly over a fresh wound
- Directly over new scar tissue
- Over the eye
Contraindications to Lontophoresis

- Over a pregnant uterus
- In the presence of a pacemaker
- With cognitively impaired patients

Precautions with Lontophoresis

- Electrodes must **not** directly touch the skin
- Medicated surface **MUST** uniformly touch the skin
- Patient must report sensations felt during Rx
- Must be a constant current generator

Safety with Electrotherapy

- The patient
  - Contraindications & Precautions must be reviewed prior to Rx
- The Device
  - Inspect all components & review operation procedures prior to Rx
General Precautions with ES
- Joint replacements & Acute fractures
  - Avoid ES elicitation of a strong muscle contraction other than isometric, until healed and stable

- Scar tissue
  - Impedance will vary dependent upon the age of the scar and general skin condition of the patient

Maintain a sterile environment
Closely monitor the wound
Document
  - Size
  - Depth
  - Width
  - Color
  - Odor
Wound Care with ES
- Color changes may indicate a need for polarity changes
- Sensation will be altered, so close monitoring will be necessary
  - Pulsed waveforms are preferable, specifically HVPC

More Safety with ES
- Patient Instruction
  - The Rx itself, and what to expect
  - How long it will take
  - What it will feel like
  - How to call for assistance & when to call

- Inform the patient
  - Not to change his or her position during Rx
  - Not to touch or move the electrodes during Rx
  - Not to touch the equipment during Rx
Positioning the Patient

- Support the area being treated and the area proximal to it
- Disrobe, elevate and clean the area
- Drape the patient to maintain his or her dignity
- Ease the patient’s fears to promote relaxation

Positioning the Equipment

- It should be easily accessible to the clinician
- The exit to the Rx area should be clear

Rx Sequence with ES

- Check the equipment
  - Frayed wires
  - Inspection stickers
  - Additional warnings
Rx Sequence with ES

- Check the electrodes
  - Wear
  - Cracks
  - Uniformity in coloration

- Review the operation of the unit
- Return all output controls to "0"
- Check the patient's skin
  - Sensation
  - Possible contraindications

- Select electrodes
- Attach electrodes to lead wires
- Plug the unit in
- Turn the power "On"
- Select and set the Rx parameters based upon Rx goals
Rx Sequence with ES
• Prepare the electrode interface
• Attach the electrodes to the patient
• Position and support the patient
• Patient education
• Adjust the intensity controls
• Re-check the patient after about 5 minutes

Did you know that......
• Amperes indicate the rate of electron flow, whereas coulombs indicate the number of electrons.
• In the case of therapeutic modalities, current flow is generally described in milliamperes
  • 1/1000 of an amp, denoted as mA
• Or microamperes
  • 1/1,000,000 of an amp, denoted as μA

• So for electrical stimulation, we use mA or μA as our unit of measure.
  • However; the resistance makes the actual value irrelevant on a day to day basis!

• Transcranial applications are contraindicated!
Other than resistance, why would the number be irrelevant?

What types of things would make the resistance change from day to day?