Electrotherapeutics - Introduction of Terms & Concepts
Reading: Cameron chapter 11

Terminology and Basic Concepts

I. Perspectives on Electrotherapy
   a. What is it?
   b. Does Physical Therapy own Electrotherapy?
   c. APTA House of Delegates Position Statement on exclusive use of modalities.

II. Electricity Knowledge Map
   a. Types of electrical current
   b. Forms of pulsed current
   c. Graphical representations of each: ID types, forms, and characteristics

III. Descriptive characteristics of pulsed and alternating current waveforms. (Identify illustrations of each)
   a. Phases -
   b. Symmetry -
   c. Balance -

IV. Quantitative characteristics & Units of measurement of pulsed current waveforms.
   1. Phase duration (phase width)
   2. Pulse duration (pulse width)
   3. Pulse rate (frequency)
   4. Amplitude (intensity)

V. Modulation of pulsed current characteristics & the effect on the waveform
   a. Modulation = changing, altering, or varying a characteristic such as amplitude, duration, frequency, etc . . .
   b. Modulating the Pulse Duration/Width controls and its effect on the waveform
   c. Modulating Pulse Rate controls and its effect on the current
VI. Terminology

- **Polarity**
  a. the free movement of electrical current thru a medium.

- **Voltage**
  b. the magnitude/intensity of the electrical current.

- **Amperage**
  c. indicates the type of charge (+ or -) of the poles of an electrical circuit.

- **Conductance**
  d. relationship between voltage, amperage, & resistance. \( V = I \times R \)

- **Resistance**
  e. the combined capacitive and resistive opposition to movement of alternating or pulsed current thru a medium (applicable to e-stim of human tissue).

- **Impedance**
  f. the electrical "potential" between the poles of an electrical circuit; ie. the driving force that makes the current flow.

- **Ohm's Law**
  g. the opposition to movement of direct current thru a medium.

VII. Electrical stimulation of tissues

a. Conductivity of tissues
   Regardless of the type of current used, there is always at least some static resistance present, thus making it relevant in all situations. Because the skin is such a good insulator for the body, the clinician should do everything that is possible and reasonable to minimize the amount of impedance and/or resistance to electrical stimulation in their patient. In biological tissue, resistance to electrical current is directly related to the amount of water present. As such, epidermis, bone, and fat have the most resistance; muscle, nerve, and blood has the least resistance. Ligament, tendon, capsule, and dermis fall somewhere between that of fat and muscle/nerve. As such, high quality electrodes and adequate coupling such as gel, water, etc. is essential to the successful use of therapeutic electrical stimulation.

b. Once electrodes are applied to tissue, the conduction of current occurs via ion movement
   Bidirectional movement with AC, biphasic & polyphasic current

c. In Electrotherapy, we are mostly, but not exclusively, interested in stimulation/depolarization of specific nerve fibers. What about the direct stimulation/depolarization of muscle cells?

VIII. Classification of peripheral nerve fibers

IX. The amplitude (strength) & duration relationship (the S-D Curve) helps you understand what is required to depolarize the various types nerve fibers.

a. The order of stimulation/excitation in a mixed nerve vs the order with artificial stimulation thru the skin.

b. Once again, how do you go about causing these 3 responses??

c. Typical range of pulse duration/width (sometimes pre-set, sometimes adjustable) is 20 - 350 microseconds.
X. Terminology for describing electrode placement or arrangement

a. Monopolar - 1 channel, only one end (pole) of the circuit is on the target tissue.
b. Bipolar - 1 channel, both ends (poles) of the circuit is on the target tissue.
c. Quadpolar - 2 channels, all poles on the target tissue

d. Does attention to polarity (cathode/anode) in electrode placement matter with use of AC or biphasic pulsed current ???

XI. Current Density is amount of electrical charge in an area per unit of time.

Current density is **increased** by any of the following: Increasing the amplitude, Increasing the pulse duration, Increasing the frequency, Increasing the electrode conductivity (via pressure), Decreasing the electrode size or contact area, Decreasing the distance between electrodes in a circuit (condenses the electrical field).

- The patient will perceive any of the above changes as STRONGER stimulation; Safety features in many devices prevent changing some of above without first stopping stimulation.

XII. Depth of Current Penetration: All else being equal, depth of current penetration is **Increased** by ....

Increasing the amplitude, Increasing distance between electrodes, or Decreasing pulse duration.

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**End of Terminology and Basic Concepts**

**Neuromuscular Electrical Nerve Stimulation (NMES)**

Reading: Cameron chapter 12

I. Important foundations to understand for NMES

- What is the target tissue?

- What are the expected responses?

- How does pulse rate (freq) and motor response relate?

- Can neural accommodation / adaptation exist?

- Are polarity issues important?

- What size electrode should be used and where should they be placed?
  - In general, the best motor response is produced when the current contacts the motor point. Often, the # electrodes equals the number of target motor points. However, might it be possible to target several motor points with just one electrode? How? Where?
Is there a difference between voluntary ms contraction and NMES ms contractions?

Implications
• NMES can be more effective at specifically strengthening muscle fibers weakened by disuse. Why?
• If possible, patients should perform both stimulated and voluntary exercises to optimize functional integration of strength gains. Why?
• Since NMES contractions are more fatiguing than voluntary contractions, long rest times should be provided between contractions.

II. Types of current suitable for NMES

Russian Pulsed Current: a strong ___________________ pulse that is balanced & symmetrical. Internal frequency of each pulse is 2500 Hz, which only gives ______ nerve depolarization; It is very different than Burst on a TENS unit. Found on AC plug-in units

Biphasic Pulsed Current: same as what we used with TENS; now we will increase the pulse width to ___________________. Common current used on battery operated NMES units

III. Jargon & Parameters to know for NMES (over and above amplitude, width, & pulse rate)

- Continuous Mode:

- Ramp-Surge Mode: can be done with...
  1 Channel
  2 Channels Synchronous mode (co-contract),
  2 Channels Alternate mode (reciprocal)
  o Relevant parameters are ON time, OFF time, Ramp time, On/Off Ratio (Duty Cycle)

- Alternate Mode: requires 2 or more channels that are on/off at different times
IV. Physiological Effects / Clinical Uses of NMES (listed based on treatment goal, can you ID the impairment?)

- Increasing vascular flow via ms. pump in subacute or chronic condition
- Decreasing painful muscle spasm / guarding
- Muscle re-education (facilitating innervated ms with impaired motor control); improve motor control
- Muscle strengthening or to slow the rate of muscle atrophy
- Maintain or increase joint range of motion
- Temporarily reduce muscle spasticity / hypertonicity
- Act as an orthotic device to improve function at a moveable area. (Functional Electrical Stimulation [FES])

Relating the motor response to the physiological effect / clinical use

- **Intermittent or Continuous** muscle twitches
  - increase vascular flow
  - decrease ms. spasm.
- **Treppe** (incomplete/unfused tetany)
  - decrease ms. spasm
- **Sustained** (prolonged) tetanic contraction
  - decrease ms. spasm
  - reduce spasticity temporarily
- **Intermittent tetanic contractions**
  - increase vascular flow
  - decrease ms. spasm/guarding
  - ms. re-education
  - muscle strengthening
  - increase or maintain joint ROM
  - reduce ms spasticity temporarily
  - functional electrical stimulation (FES)

V. Relationship between On/Off Ratio & NMES Ms. Fatigue AND Pulse Rate & NMES Ms. Fatigue
# NMES Treatment Recommendations

*(Condensed and Lacks Some Detail)*

Always compare to updated literature and be willing to scrutinize, update, and put to the test in clinical practice.

<table>
<thead>
<tr>
<th>Rx Goal</th>
<th>Type of NMES Contraction &amp; pps</th>
<th>Contraction Strength</th>
<th>Ramp (sec)</th>
<th>Ratio</th>
<th>On time (sec)</th>
<th>Add Resist?</th>
<th>Voluntary Input</th>
<th>Amount</th>
<th># of treatments</th>
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<tbody>
<tr>
<td><strong>Strengthen OR Slow ms. Atrophy</strong></td>
<td>Intermitt Tetanic (50 pps)</td>
<td>Max* (progressively increase during Rx)</td>
<td>for comfort (2)</td>
<td>1:4 to 1:5 can reduce over time/days</td>
<td>8-10 sec</td>
<td>yes; isometric, gravity, or isotonic</td>
<td>Optional; hurts less if done &amp; w/ exercise is good</td>
<td>10-30 reps</td>
<td>3-4 X/wk</td>
</tr>
<tr>
<td><strong>Re-educate and/or Facilitate</strong></td>
<td>Intermitt Tetanic (30+pps)</td>
<td>Mild to Mod (enough to facilitate)</td>
<td>4+</td>
<td>1:2 to 1:3 can reduce over time/days</td>
<td>2-5 sec depends on the activity</td>
<td>No</td>
<td>Yes</td>
<td>Until pt fatigues mentally</td>
<td>Can be Daily; even multiple X/day</td>
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<tr>
<td><strong>Spasm Reduction</strong> (break pain/spasm cycle)</td>
<td>Any (fast twitch or treppe often best tolerated; don’t cause pain)</td>
<td>Mild (ms pump)</td>
<td>n/a unless doing intermitt</td>
<td>n/a unless doing intermitt</td>
<td>n/a unless doing intermitt</td>
<td>No</td>
<td>No</td>
<td>20+ min; combine with other Rx; if not tolerated, do TENS / IFC</td>
<td>Can be Daily; even multiple X/day</td>
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<tr>
<td><strong>Reduce Edema</strong> (subacute or chronic only)</td>
<td>Contin intermittent Tetanic (30+pps)</td>
<td>Mild</td>
<td>n/a (ms pump)</td>
<td>n/a</td>
<td>n/a</td>
<td>No</td>
<td>No</td>
<td>20+ min; combine with other Rx to reduce edema</td>
<td>Can be Daily; even multiple X/day</td>
</tr>
<tr>
<td><strong>Spasticity Reduction</strong> (temporary agonist fatigue)</td>
<td>Intermitt Tetanic (max pps) OR Sustained Tetanic (max pps)</td>
<td>Mod to Max*, as tol (progressively increase during Rx)</td>
<td>for comfort</td>
<td>1:1 or less n/a</td>
<td>As tolerated n/a</td>
<td>No</td>
<td>No</td>
<td>Until spasticity reduces (ms fatigued); ck every few minutes</td>
<td>Can be Daily; even multiple X/day</td>
</tr>
<tr>
<td><strong>ROM of joint</strong> while research supports, question any widespread use of NMES for ROM</td>
<td>Intermitt Tetanic (30+pps) Alternate mode IF ranging both directions</td>
<td>Enough for ROM* (depends on Rx goal)</td>
<td>for comfort (2)</td>
<td>1:2 to 1:3 can reduce over time/days</td>
<td>2-5 sec if no stretch; much longer to stretch</td>
<td>No</td>
<td>Optional (be productive during the off time)</td>
<td>Varies based on situation/goal; 5-15 min</td>
<td>Can be Daily; even multiple X/day</td>
</tr>
</tbody>
</table>

* The more, the better.
VI. Discussion of NMES Issues

Strengthening muscle with NMES
- In normal subjects, max voluntary force (MVIC) is > max electrically induced force; the range varies & exceptions exist (ie. Dr. Kotz & Russian athletes); average e-stim ms force is ~60% of voluntary ms force in studies on normal subjects. In patient populations, it is more variable and less is known; speculation is that it may be a higher % in some pt populations/conditions.
- Endurance effects of NMES are largely unknown.
- NMES & exercise combined have shown no benefit over either done separately in normal persons but has shown benefit in patients.
- Evidence exists that NMES may have the capacity to produce greater strength gains than voluntary exercise in research done with patient populations.

NMES for Muscle Facilitation / Re-education. To Strengthen or Re-educate, that is often the Question.
RE-EDUCATE when: there is any loss of voluntary muscle control (eg. ms inhibition) due to trauma/surgery, swelling, pain, immobilization, or CNS injury. When in doubt, RE-EDUCATE first - - - the parameters are similar to strengthening but not as aggressive and is a good way to acclimate the patient to NMES.

NMES for Temporary reduction/fatigue of muscle spasticity (hypertonicity) due to upper motor neuron lesion. (to relax the agonist temporarily)
Other approaches for muscle spasticity using NMES
- Perform facilitation treatment on the antagonist musculature to cause reciprocal inhibition.
- Perform alternate activation of the agonist (for fatigue) and antagonist (for recip. inhibition).
- Prolonged sensory stimulation (hours) to desensitize hyperactive cutaneous reflexes, which will also reduce motor activity.
- Which approach is better?? All have shown benefit but none significantly superior to the other.

Additional advanced uses of NMES:
- NMES FOR INCONTINENCE (urinary and/or fecal) – potential coverage in MS II and clinical
- FES – exposure in Neurorehab Adult (Bioness) and some in Physical Rehabilitation. See websites
- EMS – electrical muscle stimulation (denervated muscle)

US/E-Stim in combination: When doing US/Estim Combo therapy, the most common use of the electrotherapy component of the Rx is for pain, muscle spasm or vascular flow (rare). The procedure to follow can be one of the following options:

Option 1: Once the machine is programmed and you are ready to start - Turn on the stim first and note the amplitude level needed/tolerated, turn it down; then begin ultrasound & establish US intensity; continue the US and then turn the e-stim back up as you move the sound head.

Option 2: Similar to option #1 BUT begin the US after the e-stim is adjusted (ie. don't turn the e-stim down when initiating the US) but be cautious about the US intensity and avoid pain. (this is the quickest but not always safest way)
NOTE: Option 1 is the slowest but the safest if doing US for thermal effects b/c the paresthesia from the e-stim DOES NOT interfere with the patient giving accurate feedback about the thermal response.

Reminders: The sound head is an active electrode (monopolar placement); the larger inactive electrode should be on a large area of soft tissue.
- A motor response will only occur when the current (sound head) goes over a motor point.
- Doing ultrasound (while delivering e-stim thru the US head) will require movement of the sound head during treatment, so the motor response will occur only as the sound head moves toward and away from the motor point(s).
- A sensory response will always occur; some areas may be more sensitive than others. Avoid removing or tilting the sound head away from the skin during stimulation b/c of current density issues.