Electrical Stimulation for the Upper Limb

CHARLES COSTELLO, PT, PHD, CHT

Electrotherapy has been used for a long time

Since it’s “discovery”, practitioners have looked for therapeutic applications

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Therapeutic Indications for Electrical Stimulation

- **Pain Control**
- Strengthen Weak Muscles
- **Retard Muscle Atrophy**
  - Innervated
  - Denervated
- Facilitation / Reeducation muscle function
- Maintain / **Increase ROM**
- Orthotic Substitution
- Reduce Increased Muscle Tone
  - Spasm
  - Spasticity (temporary)
- Deliver medication
- **Reduce Edema**
- Increase circulation
- Accelerate inflammation
- Bactericidal effect
- **Promote Wound Healing**

Therapeutic currents: DC vs. AC

- **Direct or Monophasic:**
  - Current flows in one direction only
  - Polarity (+ or -) of source stays constant
  - Chemicals accumulate at each electrode (electrolysis)
  - Depends on amount of charge flowed
  - Potential for alkali chemical burn at negative electrode (caustic cathode)
  - Except high volt

- **Alternating or Biphasic:**
  - Current flows alternately in each direction
  - Polarity of electrodes reverses each phase
  - Neutralizes chemical reactions if “balanced”
  - Equal amount of charge flows in each direction
Biphasic pulse waveforms

- **Symmetric Biphasic waves**
  - Equal amplitude and duration during both phases
  - Always balanced
    - No chemical build-up
  - Equal stimulation at each electrode

- **Asymmetric Biphasic waves**
  - Have one phase of lower amplitude, but longer duration than other
  - May be unbalanced
    - May cause chemical burn at more negative electrode
    - Read manual: “Balance wave” or “zero net DC effect”
  - More negative electrode is more stimulating

Pulse Components

- **Pulse Rise**
- **Peak Amplitude**
- **Negative Phase**
  - **Phase charge**
  - **Phase duration**
- **Positive Phase**
  - **Pulse duration**

**Amplitude (mA)**

**Time (ms or μs)**
Amplitude - Duration Curve
(Synonymous terms: Intensity / Strength - Duration)

Amplitude (mA)
- 30
- 20
- 10
- 1

Pulse Duration (ms)
- 0.1
- 1
- 10
- 100

Nerve Fibers

Denervated Muscle

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Medium Frequency Currents

- Interferential
  - 4 electrodes, 2 currents
  - 1 current fixed (4000 Hz)
  - 1 current variable (4001 – 4150 Hz)
  - Interference beat frequency forms in tissues, equals difference between the two

- Premodulated
  - Medium Frequency (>1 KHz) base current
  - Cycled at low frequency (1 – 150 Hz)

Shift with (vector) scan
Orientation of interference field
Primary field force lines

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Contraindications

General Contraindications to Electrical Stimulation

- Demand type cardiac pacemaker or autodefibrillator.
  - Could shut down pacemaker or cause shock
- Stimulation or passing a current through the chest, especially close to the heart.
  - Cardiac failure – extra caution
- Stimulation over the carotid sinus
  - Drop in BP
- An area with venous or arterial thrombosis
  - Could loose embolus
- Occlusive vascular disease or arterial thrombosis
  - Could cause tissue avascular necrosis
General Contraindications to Electrical Stimulation

- Pregnancy – Stimulation to the abdomen or low back during the first or third trimester
  - ?acupuncture “forbidden-abortion points”?
    - LI4, SP6, ST6, SP34-36, SP3, BL31-34
- Other:
  - Obesity
    - May be ineffective or not tolerated
  - high spinal cord injury
  - reflex sympathetic dystrophy
- Patients who are confused and/or disoriented
  - Unable to cooperate or follow warnings or instructions
- Over open wounds (e.g. abrasions), osteomyelitis, scars, skin lesions or areas receiving radiation therapy; or protruding metal implants.
  - Unless treating wound

Pain Control with Electrical Stimulation

TENS
TENS Modes

- Conventional or High Rate
  - Best for acute pain
  - Setting up TENS program
- Acupuncture-like or Low Rate
  - Usually for chronic pain
- Brief Intense
  - To relieve pain during a procedure
    - e.g. wound debridement
- Hyperstimulation analgesia
  - Acute or chronic pain

Conventional / High Rate TENS

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Gate control theory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By stimulation of fast-conducting afferent neurons</td>
</tr>
<tr>
<td>Indications</td>
<td>Acute pain, post surgery, labor &amp; delivery</td>
</tr>
<tr>
<td>Pulse rate (pps)</td>
<td>50 – 150 (80 – 125)</td>
</tr>
<tr>
<td>Pulse Duration (μs)</td>
<td>Between 50 (75) and 150 (comfort)</td>
</tr>
<tr>
<td>Amplitude:</td>
<td>Perceptible tingling, less than motor</td>
</tr>
<tr>
<td>Treatment time (min)</td>
<td>20 – 120 (indefinite)</td>
</tr>
<tr>
<td>Analgesia period</td>
<td>Minutes to hours</td>
</tr>
</tbody>
</table>
### Acupuncture-like / Low Rate TENS

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Endorphin release</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By activation of slower-conducting afferent neurons with a noxious level stimulus</td>
</tr>
<tr>
<td>Indications</td>
<td>Chronic pain</td>
</tr>
<tr>
<td>Pulse rate (pps)</td>
<td>&lt;20 (2 or 4, usually)</td>
</tr>
<tr>
<td>Pulse Duration (µs)</td>
<td>Between 200 and 300 (&gt;150)</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Strong muscle twitch</td>
</tr>
<tr>
<td>Treatment time (min)</td>
<td>20 – 40 (60)</td>
</tr>
<tr>
<td>Analgesia period</td>
<td>Hours</td>
</tr>
</tbody>
</table>

### Amplitude - Duration Curve

(Synonymous terms: Intensity / Strength - Duration)

<table>
<thead>
<tr>
<th>Nerve Fibers</th>
<th>Amplitude (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>A&lt;sub&gt;8&lt;/sub&gt;</td>
<td>20</td>
</tr>
<tr>
<td>A</td>
<td>30</td>
</tr>
</tbody>
</table>

Denervated Muscle

<table>
<thead>
<tr>
<th>Pulse Duration (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

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### Brief Intense TENS

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tends to block neuron transmission</td>
</tr>
<tr>
<td>Indications</td>
<td>Before &amp; during painful procedure</td>
</tr>
<tr>
<td>Pulse rate (pps)</td>
<td>75 – 150</td>
</tr>
<tr>
<td>Pulse Duration (µs)</td>
<td>Between 150 and 300</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Muscle fasciculation</td>
</tr>
<tr>
<td></td>
<td>Why time period is limited – sustained contraction.</td>
</tr>
<tr>
<td>Treatment time (min)</td>
<td>Up to 20</td>
</tr>
<tr>
<td>Analgesia period</td>
<td>Minutes to hours</td>
</tr>
</tbody>
</table>

### Hyperstimulation Analgesia

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</tr>
<tr>
<td>Indications</td>
<td>Chronic pain</td>
</tr>
<tr>
<td>Pulse rate (pps)</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Pulse Duration</td>
<td>1 ms or longer</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Noxious</td>
</tr>
<tr>
<td>Treatment time</td>
<td>30 sec. to 1 min.</td>
</tr>
<tr>
<td>Analgesia period</td>
<td>Hours</td>
</tr>
</tbody>
</table>
Current Modulations

- Use with high rate TENS
- Prevent adaptation to a constant stimulus
- Varies pulse rate &/or duration &/or amplitude
- Some vary duration and amplitude simultaneously along amplitude (strength) -duration curve (SD)

Zynex NexWave®

- TENS settings:
  - Lmd – most like high rate
    - Pulse rate sweeps between 66.7-100 pps and back over 12 seconds. Pulse duration decreases to 150 μs when rate is rising and increases to 300 μs when rate is decreasing.
  - Hmd – most like low rate
    - Same as LMD, but rate sweeps over a 2 second period
  - Sweep – combination; could use for brief-intense
    - Pulse rate decreases 125 pps to 11 pps over 4 seconds. During this time, the pulse duration increases from 120 μs to 300 μs. Then the rate is decreased from 10 pps to 1 pps over 2 seconds; the duration held at 300 μs. Then the rate increased from 11 pps to 95 pps over 4 seconds while the duration decreases from 300 μs to 120 μs.

- IFC settings
  - Low-High – Beat frequency changes from 1 Hz to 128 Hz over 15 seconds
  - Low – Beat frequency changes from 1 Hz to 10 Hz over 15 seconds
  - Combo – 3 cycles of 2 minutes each
    - Low (as above)
    - High (sweep from 64 Hz – 128 Hz)
    - Muscle – fixed 64 Hz, On/Off every 6 seconds

From: NexWave user manual
Electrode Placement

The heART of TENS

TENS stimulation electrodes should be placed at sites where they will provide total, or the best analgesia.

Many times this is determined by trial & error, following established guidelines.

Experience usually allows people to more quickly place electrodes accurately.

Electrode Placement

Most TENS units are equipped with 2 channels, allowing for up to 4 electrodes.

For larger numbers of electrodes, “lead splitters” can be used to double the number at each electrode

Max = 8

Electrode placements: those which provide the best analgesia with the fewest electrodes.
Electrode Placement – guidelines

- Across / around pain site/area
- Along major nerve(s) to site/areas
- Proximally on dermatome of site/area
- Ipsilateral at spinal column
  - across nerve roots to site/area
- Across spinal column
  - Cephalad to site/area nerve root
- Remote sites
  - Low impedance points

Low Impedance Points

- Synonymous with Acupuncture or trigger points.
- High correlation with motor points.
- Provide low impedance path to more comfortably stimulate nervous system.
- Always used with remote site placements.
- Should be used, ideally, with all placements.
- Can sometimes be felt as a slight indentation in the skin
“Hot Finger” technique

- Useful to help identify low impedance points
- Set unit for high rate TENS; pulse rate to between 80 & 150 and pulse duration between 50 & 150 µs (according to your comfort).
- Connect a pair of electrodes to leads.
- Apply 1 electrode on yourself & the other on your partner.
- Moisten a finger tip and make comfortable contact with this on your partner in the area you plan to look for points.
- Turn the unit on and raise amplitude until you feel a mild tingling.
- Slowly move your finger over the skin.
- When you come onto a low impedance point, you will feel a greater current flow through your finger (your partner may also sense this).
- Turn the amplitude to 0.
- Remove the electrode on your partner and reapply on the low impedance point.
- Repeat the procedure to identify low impedance point for the other electrode.

Time to get hands-on
High rate TENS

- Connect leads to the channel you are using
- Apply electrodes to 2 low impedance points:
  - Use hot finger technique
  - on the lateral aspect distal arm and
dorsal thumb web space (near end of crease).
- Press TENS button until display shows “Lmd”
- Raise amplitude (intensity) to comfortable tingling, but
  no muscle contraction
  - If correctly placed, should feel along dorsal forearm, with
    probable change in cutaneous sensibility.
  - You will probably feel the intensity of stimulation wax and
    wane with the pulse duration modulation.

Low rate TENS

- Using the same electrode placement, reduce
  amplitude to 0
- Change TENS setting to “Hmd”
- Raise amplitude until you perceive a strong
  muscle twitching (about 2/sec)
- Compare this sensation to the previous one
  - This may be mildly uncomfortable
  - Fortunately, you would use it only for 20 – 40 min.,
    and it should provide hours of relief
- Reduce amplitude to 0
Brief intense TENS

- Move the electrodes to one each on the dorsal and palmar aspects of the hand, over the 2nd MCP joint
- Change the TENS setting to Swp
- Raise the amplitude until you can no longer feel the tip of the index finger.
- You will likely also have a mild to moderate contraction of the interosseous muscles
- You could use this for up to 20 min. for debridement or other painful procedure

Interferential

- Place 4 electrodes around the elbow (similar to the diagram)
- Connect a pair of leads from each cannal as illustrated, so that the currents would cross
- Select IFC mode Low-High
- Raise the amplitude to get a comfortable tingling sensation.
  - This setting is similar to high rate TENS
- Compare this to the other IFC settings:
  - Reduce amplitude to 0 before changing settings
  - IFC-Low is similar to low rate TENS
  - IFC-Cmb
Neuromuscular Electrical Stimulation (NMES)

- Stimulation of normally innervated muscle to achieve a functional or treatment goal.

Applications:
- Maintain / Increase muscle strength
- Increase Range of Motion – joints or tendon glide
  - 200 contractions daily (over 3 to 4 treatment sessions)
- Facilitate / augment voluntary motor control
  - E.g. Reaching post CVA
- Orthotic substitution (e.g. shoulder post CVA)
- Reduce spasticity
- Metabolic & histochemical changes
  - Similar to the effects of exercise
- Strengthening effective with atrophied and weak musculature.
- No more effective than exercise with normal and strong musculature.

NMES with NexWave

- Symmetric biphasic square wave (balanced)
  - Pulse duration: 480 μs
  - Pulse rate: 30 pps
  - Duty cycle options, ON:OFF (sec) = 10:30; 10:20 or 10:10
  - Ramp up / down: 3 s / 1 s
  - Both channels active simultaneously
Denervation: Stimulation Parameters

- Pulsed monophasic stimulation
  - Chemical BURN danger at negative electrode
- Pulse duration = 10 - 100 ms.
- Amplitude – sufficient to produce a strong twitch
- 120 ms pulses @ 2 pps for 15 min, daily (Kern)
  - 20 – 30 stimuli each muscle in elongated position
  - Ideally, place electrode at each end of muscle belly
    - If using monopolar technique place -ve at widest point of muscle
- Avoid fatigue
  - May inhibit / retard reinnervation
- Do not stimulate if reinnervating
  - Delays reinnervation
- Amplitude (mA) vs Pulse Duration (ms)

Application: Finger extension

- Place one electrode over the EDC, about 3 in distal to LE
- Place other electrode on dorsum of wrist
- Connect to lead wires & NexWave channel
- Set NMES to 10:10
- Raise amplitude until contraction seen – looking for combined finger extension (possibly with wrist extension)
- If not, lower amplitude and adjust EDC electrode
  - If scissors available, may need to trim smaller
- Possible clinical applications:
  - Retraining grasp release (post CVA)
  - Loosening EDC tendon to metacarpal adhesion
Med Labs: EMS-1c or EMS-2c® Stimulators

- Asymmetric / Pulsed DC Switch
- Padded active
- ON - OFF Button (press)
- Battery compartment
- Amplitude control
- Dispersive

Treatment of edema: Blood & tissue fluid flow

High volt or H-Wave

- High Volt (not available in lab):
  - Negative electrode reduces edema
  - 100 pps, <100 v
  - For hand or finger, can apply under water
- Electrical stimulation increases blood flow & interstitial protein & fluid transport
  - H-Wave, 1-2 pps
  - Other TENS, 10 pps seems to be more effective than 2, 50 or 80 pps
H-Wave: H4 device

- Power ON/OFF
- Amplitude displays: Channels A & B
- Timer display (15 min increments)
- Timer Set/Start
- Amplitude controls: Channels A & B
- Rate settings: Channels A & B (default)
  Low = 1.5 pps; High = 65 pps
- Lead connectors: Channels A & B

H-Wave: changing pulse rate

- Hold both channel A rate buttons while power on
- Note display screen showing high and low rate settings
- Use channel A Low / High buttons to lower or raise low rate
- Use channel B Low / High buttons to lower or raise high rate
H-Wave: Wrist application

- Connect lead to the electrodes and place electrodes on skin according to diagram (ignore C placement)
- Connect leads to channels of H4 device & power ON
- Select “Low” for channel A (1.5 pps); & “High” for B (65 pps)
- Raise amplitude for B until a strong tingling sensation, less than muscle contraction
- Raise amplitude for A until strong muscle twitch perceived
  - Muscle contractions promote muscle pump action to reduce edema. Could enhance with elevation or compression bandage

From: H-wave Clinical Treatment Manual 2014

High volt application in water

Image provided by Saba Kamal

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H-Wave recommended placement & parameters for wrist

**Important**
- The higher the intensity the better. This should be the site where the patient feels the most discomfort (suprascapular nerve). To prevent the patient's arm from dropping.
- Electrostimulation in the high frequency mode brings up the intensity high enough to keep the patient from feeling shots from the patient, manual muscle testing, or muscle volitization.

**TREATMENT NOTES**
- Electrode placement can be adjusted as necessary for proper position.
- Electrode placement varies from patient to patient.
- Electrode placement varies by patient.

**TREATMENT PARAMETERS**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Frequency</th>
<th>Intensity</th>
<th>Int.</th>
<th>HR (BR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>LOW (n)</td>
<td>3-6</td>
<td>4-7</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>HIGH (m)</td>
<td>3-6</td>
<td>4-7</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>LOW (n)</td>
<td>3-6</td>
<td>4-7</td>
<td></td>
</tr>
</tbody>
</table>

From: H-Wave treatment manual, 2014

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Selected references


Thank you

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