SCOREBUILDERS

"Let's Just Go with the Flow": Clinical Decision Making for Ultrasound and Electrical Stimulation Parameters

Presented by Holly Daniel, PT

Objectives

- Review basic terminology associated with application of ultrasound (US) and electrical stimulation (E-stim)
- Discuss a clinical decision-making process for use of ultrasound
- Understand appropriate choices for parameters when using US and E-stim

Habit 2: “Begin with the end in mind”

- The 7 Habits of Highly Effective People
- First published in 1989
- Written by Stephen Covey
- New York Times Bestseller for 5 years

Fundamentals of Ultrasound

- **Administered using a transducer with a piezoelectric crystal** with a moving (dynamic) or stationary technique (e.g., pulsed US with low intensity)
- **Coupling agent is required** for both direct technique (e.g., coupling gel) and indirect techniques (e.g., water, gel pads)
- **Transducer must be parallel with the treatment surface** so that sound waves are introduced at a 90-degree angle

Fundamentals of US (Indirect Technique)

- Indirect methods (e.g., water immersion) used when treatment area is excessively small, irregularly shaped or unable to tolerate direct pressure
- Best practice for water immersion method keeps transducer moving parallel to treatment surface at a distance 0.5-3.0 cm away from skin; increased intensity (as much as 50%) may be necessary due to dispersion and energy absorption by the water

Ultrasound (US) Parameters – Intensity (W/cm^2)

- **Intensity**: Quantity of energy delivered per unit area (**W/cm^2**) = spatial-averaged intensity
- **Spatial-peak intensity:** Intensity of the US beam at its highest point
- **Beam nonuniformity ratio (BNR):** Ratio between the spatial-peak intensity and spatial-averaged intensity (the higher the quality of the crystal, the lower the BNR - since patients would be less likely to experience hot spots during Rx)

US Parameters – Frequency (MHz)

Frequency: Primary determinant in the **depth** of US penetration

- Higher frequency setting (3 MHz) affects more superficial tissues (1-2 cm)
- Lower frequency setting (1 MHz) affects deeper tissues (up to 5 cm)
- US delivered at a high frequency (3 MHz) is absorbed more rapidly than US delivered at a lower frequency (1 MHz)

US Parameters - Duty Cycle (%)

Duty cycle: Portion of treatment (Rx) time that US is generated during the entire Rx (i.e., continuous vs. pulsed mode)

- Calculated by dividing the on time by the total time (on time + off time)
- If on time was 1 msec and off time was 4 msec, the duty cycle would be 20%
- Continuous (100% duty cycle) used for thermal effects
- Pulsed US (with typically 20% duty cycle) used primarily for nonthermal effects

US Parameters - Duration

Duration: Based on size of treatment area, depth of penetration, and desired therapeutic effects

- Typical duration guideline = 5 minutes for an area 2-3 times the size of the transducer
- Longer duration may be necessary when using lower intensities or lower frequencies or when therapeutic objective is higher tissue temperatures

Phonophoresis

Use of US for the transdermal delivery of medication

(Can be used with both continuous and pulsed techniques)

Most common used medications in phonophoresis include:

- Anti-inflammatory agents (e.g., hydrocortisone, dexamethasone, salicylates)
- Analgesic agents (e.g., lidocaine)

***Lack of strong evidence to support efficacy of phonophoresis**

US Contraindications

- Vascular abnormalities (e.g., vascular insufficiency, DVT) or excessive bleeding
- Areas of decreased temperature sensation
- Infection
- Malignancy
- Over carotid sinus, eyes, heart, and genitalia
- Over epiphyseal areas in young children
- Over a pacemaker
- Over plastic or cement implants
- Over pelvic, lumbar or abdominal areas in pregnant women

Clinical Decision-Making for US Parameters

1st Question: “Why am I doing this?” (Therapeutic objective)

This question determines **Duty Cycle** (continuous vs. pulsed)

If answer is tissue healing (nonthermal effects) = pulsed (20%)

If answer is to heat the tissue (thermal effects) = continuous (100%)

Clinical Decision-Making for US Parameters

2nd Question: "What tissue am I treating?" (Determines depth)

This question determines **Frequency**

If answer is a superficial tissue (1-2 cm) = 3 MHz

If answer is a deeper tissue (up to 5 cm) = 1 MHz

Clinical Decision-Making for US Parameters

Once these two questions answered:

(Determines **Intensity**)

If **nonthermal** effects (pulsed) and superficial (3 MHz) = 0.5 W/cm^2; deeper (1 MHz) = 1.0 W/cm^2

If **thermal** effects (continuous) and superficial (3 MHz) = 0.5 W/cm^2; deeper (1 MHz) = 1.5-2.0 W/cm^2

Fundamentals of Electrotherapy

- **Current:** Refers to the directed flow of charge from one place to another (measured in amperes)
- **Voltage:** Driving force that moves the electrons or charges (measured in volts)
- **Resistance:** Ability of a material to oppose the flow of ions through it (measured in ohms)
- **Ohm's law:** Current = Voltage/Resistance

Direct Current

- Constant flow of electrons from the anode (i.e., positive electrode) to the cathode (i.e., negative electrode) for > one second without interruption
- Polarity remains constant and determined by the therapist based on Rx goals
- **Most common clinical example for use of direct current:** Iontophoresis

Alternating Current

- Polarity continuously changes from positive to negative with the change in the direction of current flow (**always biphasic**)
- Frequency of cycles is measured in **cycles per second** or **hertz**
- **Common clinical examples for use of alternating current:**

Neuromuscular E-stim (NMES), TENS, Interferential (IFC)

Pulsatile Current

- Non-continuous flow of direct or alternating current
- Pulsed waveforms may be monophasic or biphasic
- Monophasic pulsed current produces a polarity effect (e.g., HVPC used for wound healing)

Electrodes

- Size of electrodes (small vs. large) dependent on size of treatment area
- Small electrodes have increased current density, increased impedance, and decreased current flow
- Current density influenced by size of electrodes and distance they are apart
- Closer proximity of electrodes = current density greater in superficial tissues
- Electrodes farther apart = more current density in deeper tissues

Electrode Placement Techniques

- **Monopolar:** Active electrode (usually smaller) placed over target area and dispersive electrode placed away from target area; monopolar technique used for iontophoresis and use of e-stim for wounds or edema reduction
- **Bipolar:** Two active electrodes (usually equal in size) from one channel placed over target area; bipolar technique commonly used for neuromuscular facilitation
- **Quadripolar:** Four active electrodes from two separate channels; quadripolar technique used for interferential current (IFC) and pain management (TENS)

Common Parameters on E-Stim Devices

Amplitude: magnitude of current (intensity) - may be expressed in volts, millivolts, microvolts

Rise time: time it takes for current to move from zero to the peak intensity, often expressed in milliseconds

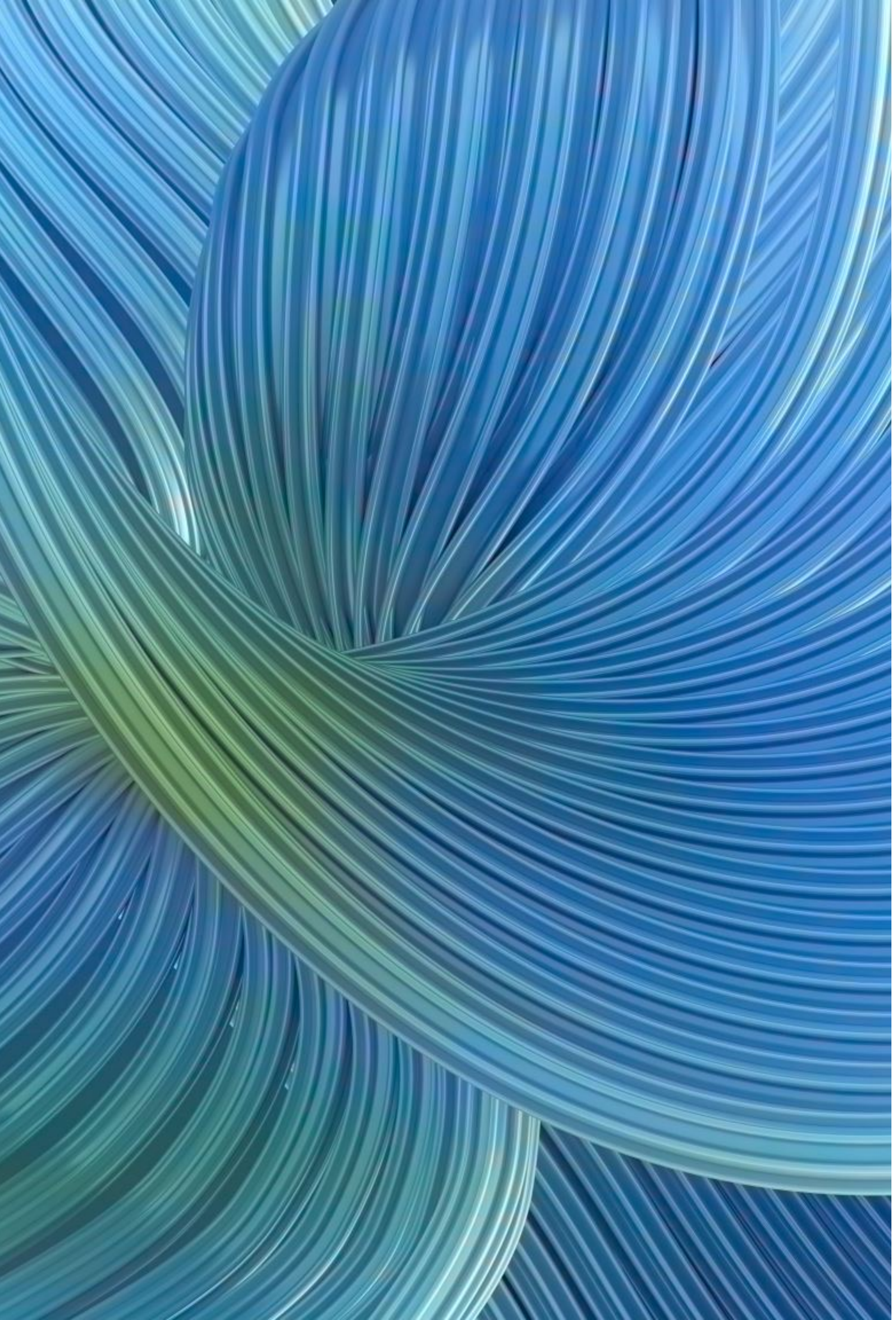
Phase duration: amount of time it takes for one phase of a pulse, typically measured in microseconds

Pulse duration: amount of time it takes for both phases of a pulse with biphasic current (phase duration and pulse duration are the same with monophasic current)

Common Parameters (continued)

Frequency: number of pulses delivered through each channel per second (may be labeled as rate), often expressed in pulses per second or hertz

Current modulation: any alteration in the amplitude, duration or frequency of the current during a series of pulses or cycle (e.g., bursts, interrupted pulses using an on/off time)



Neuromuscular Electrical Stimulation (NMES)

Used to facilitate skeletal muscle activation

Align electrodes parallel to direction of muscle fibers with one electrode over the motor point and separated by a minimum of two inches

Use of e-stim to enhance the performance of a functional activity (e.g., gait) is referred to as functional electrical stimulation (FES)

Parameters for NMES

- **Amplitude:** dependent on the desired strength of muscle contraction
- **Pulse duration:** shorter pulse duration for smaller muscles (150-200 microseconds) and longer pulse durations used for larger muscles (250-350 microseconds); may be labeled as pulse width
- Recognize that as pulse duration is shortened, a greater amplitude will be required to produce the same strength of muscle contraction

Parameters for NMES (continued)

- **Frequency:** sufficient to produce a smooth tetanic contraction (usually between 35-50 pulses per second)
- **Duty cycle:** usually expressed as on time/off time with 1:5 ratio to start (may decrease off time as patient progresses)
- **Ramp time:** used to make the onset of stimulation more comfortable (1-4 seconds often recommended)
- **Treatment time:** usually a minimum of 10 contractions (would take about 10 minutes based on typical on/off times)

Transcutaneous Electrical Nerve Stimulation (TENS)

Widely used for **pain management**

(through gate control theory or endogenous opiate pain control theory)

Commonly used modes of TENS:

- Conventional
- Acupuncture-like

Other modes of TENS:

- Brief intense
- Noxious

Conventional TENS

- High frequency (30-150 pulses per second)
- Short pulse duration (50-100 microseconds)
- Low current amplitude (sensory response only)
- Electrodes placed over the painful area
- Pain relief is during use (often used to relieve pain during ADLs); based on **gate control theory**
- Treatment time dependent on duration of activity

Acupuncture-like TENS

- Low frequency (2-4 pulses per second)
- Long pulse duration (100-300 microseconds)
- Moderate current amplitude (sufficient to generate muscle twitching)
- Electrodes placed over acupuncture or trigger points
- Pain relief may last several hours after stimulation; based on **endogenous opiate pain control theory**
- Treatment time usually 20-45 minutes

Interferential Current (IFC)

- Combines two medium frequency alternating (biphasic) currents (of slightly different frequencies) to interfere with one another (e.g., one current at 4000 Hz and other at 4100 Hz = beat frequency of 100 Hz)
- Delivered through two sets of electrodes from separate channels of the same stimulator
- Often more comfortable to patients since a low amplitude current is delivered through the skin and a higher amplitude current is delivered to deeper tissues
- Commonly used for pain relief, increased circulation or edema reduction

Iontophoresis

- Process by which ions are introduced into the body through the skin by means of **continuous direct current**
- Based on theory that **like charges repel**, resulting in ions in a solution of similar charge moving away from the electrical source and into the body
- **Dosing is measured in milliamp minutes (mA-min)**, with typical dose ranges from 40-80 mA-min
- **Current amplitude (typically 1.0-4.0 mA)** should be adjusted to be comfortable for the patient

Preventing skin irritation or burns (Iontophoresis)

- Increasing the size of the cathode relative to the anode
- Decreasing the current density
- Increasing the space between the electrodes

- **Monitor patient every 3-5 minutes** during Rx to ensure no signs of skin irritation or burns under the electrode

Ions used with Iontophoresis

Dexamethasone (for inflammation): negative (-)

Acetic acid (for calcific deposits): negative (-)

Calcium chloride (for scar tissue): negative (-)

Salicylates (for muscle and joint pain): negative (-)

Lidocaine (for analgesia): positive (+)

Magnesium sulfate (for muscle spasms): positive (+)

Zinc oxide (for dermal ulcers): positive (+)

E-Stim Contraindications

- Cardiac arrhythmia
- Cardiac pacemaker
- Malignancy
- Osteomyelitis
- Over carotid sinus
- Over a pregnant uterus
- Phlebitis
- Seizure disorders

Practice Question #1

A physical therapist assistant prepares to perform neuromuscular electrical stimulation (NMES) for a patient with weak quadriceps. Which of the following parameters **MOST** directly affects the depth of NMES?

1) Frequency of the current
2) Distance between electrodes
3) Intensity of the current
4) Duration of the pulses

Practice Question #2

A patient is treated using pulsed ultrasound. Which of the following parameters **BEST** represents the on/off time for one pulse period with a 25% duty cycle?

1) 1 msec on; 1 msec off
2) 1 msec on; 2 msec off
3) 1 msec on; 3 msec off
4) 1 msec on; 4 msec off

Practice Question #3

Which of the following actions by the physical therapist would be the **MOST** helpful to minimize the risk of a burn when using iontophoresis?

1) Decrease the space between the electrodes
2) Increase the intensity of the current
3) Increase the size of the cathode relative to the anode
4) Decrease the moisture of the electrodes

Practice Question #4

A patient presents with a stage 3 pressure injury with signs of delayed healing. The physical therapist decides to add electrical stimulation to the plan of care to promote tissue repair. Which type of electrical current would **BEST** promote the therapist’s objective?

1) High-volt monophasic pulsed current
2) Low-volt biphasic pulsed current
3) Medium-frequency interferential current
4) Continuous low-amplitude direct current

Practice Question #5

A physical therapist reviews the parameters related to pain control theories when using transcutaneous electrical nerve stimulation (TENS). When comparing sensory stimulation to motor stimulation, the therapist should recognize that sensory stimulation requires which of the following parameters?

1) Longer phase duration
2) Higher frequency
3) Stronger amplitude
4) Longer off time in the duty cycle

Conclusion

- Increased your confidence with basic terminology and principles associated with US and E-stim
- Improved your understanding of clinical decision-making and appropriate parameters when using US and E-stim

Questions?

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