* Electrical Stimulating Currents

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* Physiologic Response To Electrical Current
* Creating muscle contraction through nerve or muscle stimulation
* Stimulating sensory nerves to help in treating pain
* Creating an electrical field in biologic tissues to stimulate or alter the healing process
* Physiologic Response To Electrical Current
* Creating an electrical field on the skin surface to drive ions beneficial to the healing process into or through the skin
* Physiologic Response To Electrical Current
* As electricity moves through the body's conductive medium, changes in the physiologic functioning can occur at various levels
  + Cellular
  + Tissue
  + Segmental
  + Systematic
* Effects at Cellular Level
* Excitation of nerve cells
* Changes in cell membrane permeability
* Protein synthesis
* Stimulation of fibrobloast, osteoblast
* Modification of microcirculation
* Effects at Tissue Level
* Skeletal muscle contraction
* Smooth muscle contraction
* Tissue regeneration
* Effects at Segmental Level
* Modification of joint mobility
* Muscle pumping action to change circulation and lymphatic activity
* Alteration of the microvascular system not associated with muscle pumping
* Increased movement of charged proteins into the lymphatic channels
* Effects at Segmental Level
* Transcutaneous electrical stimulation cannot directly stimulate lymph smooth muscle, or the autonomic nervous system without also stimulating a motor nerve
* Systematic Effects
* Analgesic effects as endongenous pain suppressors are released and act at different levels to control pain
* Analgesic effects from the stimulation of certain neurotransmitters to control neural activity in the presence of pain stimuli
* Physiologic Response To Electrical Current
* Effects may be *direct* or *indirect*
  + Direct effects occur along lines of current flow and under electrodes
  + Indirect effects occur remote to area of current flow and are usually the result of stimulating a natural physiologic event to occur
* Muscle and Nerve Responses
* Excitability dependent on cell membrane's *voltage sensitive permeability* 
  + Produces unequal distribution of charged ions on each side of the membrane
    - creates a potential difference between the charge of the interior of cell and exterior of cell
* Potential difference is known as *resting potential* because cell tries to maintain electrochemical gradient as its normal homeostatic environment
* Muscle and Nerve Responses
* Using active transport mechanism-cell continually moves Na+ from inside cell to outside and balances this positive charge movement by moving K+ to the inside
  + Produces an electrical gradient with + charges outside and - charges inside
* Nerve Depolarization
* To create transmission of an impulse in nerve, resting membrane potential must be reduced below threshold level
* Changes in membrane's permeability may then occur creating an *action potential* that propagates impulse along nerve in both directions causing *depolarization* of membrane
* Nerve Depolarization
* Stimulus must have adequate intensity and last long enough to equal or exceed membrane's basic threshold for excitation
* Stimulus must alter membrane so that a number of ions are pushed across membrane exceeding ability of the active transport pumps to maintain the resting potentials thus forcing membrane to depolarize resulting in an action potential
* Depolarization Propagation
* Difference in electrical potential between depolarized region and neighboring inactive regions causes the current to flow from depolarized region intercellular material to the inactive membrane
* Depolarization Propagation
* Current also flows through extracellular materials, back to the depolarized area, and finally into cell again
* Makes depolarization self propagating as process is repeated all along fiber in each direction from depolarization site.
* Depolarization Effects
* As nerve impulse reaches effector organ or another nerve cell, impulse is transferred between the two at a motor end plate or a synapse
* Depolarization Effects
* At this junction, a transmitter substance is released from nerve
* Transmitter substance causes the other excitable tissue to discharge causing a *twitch muscle contraction*
* Strength - Duration Curves
* Represents The Threshold for Depolarization of a Nerve Fiber
* Muscle and nerve respond in an *all-or-none* fashion and there is no gradation of response
* Strength - Duration Curves
* Shape of the curve relates intensity of electrical stimulus (strength) and length of time (duration) necessary to cause the tissue to depolarize
* Strength - Duration Curves
* *Rheobase* describes minimum intensity of current necessary to cause tissue excitation when applied for a maximum duration
* Strength - Duration Curves
* *Chronaxie* describes length of time (duration) required for a current of twice the intensity of the rheobase current to produce tissue excitation
* Strength - Duration Curves
  + Aß sensory, motor, Aδ sensory, and C pain nerve fibers
  + Durations of several electrical stimulators are indicated along the lower axis
  + Corresponding intensities would be necessary to create a depolarizing stimulus for any of the nerve fibers
* Effects of Changing Current Parameters
* Alternating versus direct current
* Tissue impedance
* Current density
* Frequency of wave or pulse
* Intensity of wave or pulse
* Duration of wave or pulse
* Polarity of electrodes
* Electrode placement
* Alternating vs. Direct Current
* Nerve doesn’t know the difference between AC and DC
* With continuous direct current a muscle contraction would occur only when the current intensity rose to a stimulus threshold
* Alternating vs. Direct Current
* Once the membrane repolarized, another change in the current intensity would be needed to force another depolarization and contraction
* Alternating vs. Direct Current
* Biggest difference in effects of alternating and direct currents is ability of direct current to cause chemical changes
* Chemical effects from using direct current usually occur only when stimulus is continuous and is applied over a period of time
* Tissue Impedance
* Impedance -resistance of the tissue to the passage of electrical current.
* Bone and fat are high-impedance tissues; nerve and muscle are low-impedance
* If a low-impedance tissue is located under a large amount of high-impedance tissue current will never become high enough to cause a depolarization
* Current Density
* Current Density- - Refers To The Volume Of Current In The Tissues
* Highest At Surface And Diminishes In Deeper Tissue
* Altering Current Density
* Change The Spacing Of Electrodes
  + Moving Further Apart Increases Current Density In Deeper Tissues
* Active vs. Dispersive Electrodes
* Changing The Size Of The Electrode
* Active Electrode Is The Smaller of The Two
  + Current Density Is Greater
* Dispersive Electrode Is The Larger
  + Current Density Is Less
  + Frequency (CPS, PPS, Hz)
* Effects the type of muscle contraction
* Effects the mechanism of pain modulation
* Intensity
* Increasing the intensity of the electrical stimulus causes the current to reach deeper into the tissue
* Recruitment of Nerve Fibers
* A stimulus pulse at a duration-intensity just above threshold will excite the closest and largest fibers
* Recruitment of Nerve Fibers
* Increasing the intensity will excite smaller fibers and fibers farther away. C, Increasing the duration will also excite smaller fibers and fibers farther away.
* Duration
* We also can stimulate more nerve fibers with the same intensity current by increasing the length of time (duration) that an adequate stimulus is available to depolarize the membranes
* Polarity
* Anode
  + Positive Electrode With Lowest Concentration of Electrons
* Cathode
  + Negative Electrode With Greatest Concentration of Electrons
* Polarity Switch Designates One Electrode As Positive and One As Negative
  + Polarity
* With AC Current and Interrupted DC Current Polarity Is Not Critical
* Select Negative Polarity For Muscle Contraction
  + Facilitates Membrane Depolarization
  + Usually Considered More Comfortable
* Negative Electrode Is Usually Positioned Distally
* Polarity With Continuous DC Current
* Important Consideration When Using Iontophoresis
* Positive Pole
  + Attracts - Ions
  + Acidic Reaction
  + Hardening of Tissues
  + Decreased Nerve Irritability
  + Negative Pole
  + Attracts + Ions
  + Alkaline Reaction
  + Softening of Tissues
  + Increased Nerve Irritability
* Electrode Placement
* Electrodes may be placed:
  + On or around the painful area
  + Over specific dermatomes, myotomes, or sclerotomes that correspond to the painful area
  + Close to spinal cord segment that innervates an area that is painful
  + Over sites where peripheral nerves that innervate the painful area becomes superficial and can be easily stimulated
* Electrode Placement
* Electrodes may be placed:
  + Over superficial vascular structures
  + Over trigger point locations
  + Over acupuncture points
  + In a criss-cross pattern around the point to be stimulated so the area to be treated is central to the location of the electrodes
* If treatment is not working- change placement
* Therapeutic Uses of Electrically Induced Muscle Contraction
* Muscle reeducation
* Muscle pump contractions
* Retardation of atrophy
* Muscle strengthening
* Increasing range of motion
* Reducing Edema
* Muscle Re-Education
* Muscular inhibition after surgery or injury is primary indication
* A muscle contraction usually can be forced by electrically stimulating the muscle
* Patient feels the muscle contract, sees the muscle contract, and can attempt to duplicate this muscular response
* Muscle Re-Education Protocol
* Current intensity must be adequate for muscle contraction but comfortable
* Pulse duration must be set as close as possible to the duration needed for chronaxie of the tissue to be stimulated
* Pulses per second should be high enough to give a tetanic contraction (20 to 40 pps)
* Muscle Re-Education Protocol
* Interrupted or surged current must be used
* High-voltage pulsed or medium-frequency alternating current may be most effective
* On time should be 1 to 2 seconds
* Off time should be 4 to 10 seconds
* Total treatment time should be about 15 minutes, repeated several times daily
* Muscle Re-Education Protocol
* Patient should be instructed to allow just the electricity to make the muscle contract, feeling and seeing the response desired
* Next, patient should alternate voluntary muscle contractions with current-induced contractions
* Muscle Pump Contractions
* Used to duplicate the regular muscle contractions that help stimulate circulation by pumping fluid and blood through venous and lymphatic channels back to the heart
* Can help in reestablishing proper circulatory pattern while keeping injured part protected
* Muscle Pump Contractions
* Current intensity must be high enough to provide a strong, comfortable muscle contraction
* Pulse duration should be set as close as possible to the duration needed for chronaxie of the motor nerve to be stimulated if not preset
* Muscle Pump Contractions
* Pulses per second should be at beginning of tetany range (20 pps).
* Interrupted or surged current must be used
* On time should be 5 to 10 seconds.
* Off time should be 5 to 10 seconds.
* The part to be treated should be elevated
* Total treatment time should be 20 to 30 minutesrepeated two to five times daily
* 8. The athlete should be instructed to allow the electricity to make the muscles contract. Active range of motion may be encouraged at the same time if it is not contraindicated.
* 9. 10. High-voltage pulsed or medium-frequency alternating current may be most effective.32,39,94,97,111 (See Fig. 5-20).
* 11. Use this protocol in addition to the normal I.C.E. for best effect.41,88
* Muscle Pump Contractions
* High-voltage pulsed or medium-frequency alternating current may be most effective
* Athlete should be instructed to allow the electricity to make the muscles contract.
* Active range of motion may be encouraged at the same time if it is not contraindicated
* Retardation of Atrophy
* Electrical stimulation reproduces physical and chemical events associated with normal voluntary muscle contraction and helps to maintain normal muscle function
* Retardation of Atrophy
* Current intensity should be as high as can be tolerated
* Contraction should be capable of moving the limb through the antigravity range or of achieving 25% or more of the normal maximum voluntary isometric contraction (MVIC) torque for the muscle
* Retardation of Atrophy
* Pulse duration should be set as close as possible to the duration needed for chronaxie of the motor nerve to be stimulated
* Pulses per second should be in the tetany range (20 to 85 pps)
* Interrupted or surge type current should be used
* Medium-frequency alternating current stimulator is the machine of choice
* Retardation of Atrophy
* On time should be between 6 and 15 seconds
* Off time should be at least one minute preferably two minutes.
* Muscle should be given some resistance, either gravity or external resistance provided by the addition of weights or by fixing the joint so that the contraction becomes isometric
* Retardation of Atrophy
* Patient can be instructed to work with electrically induced contraction, but voluntary effort is not necessary
* Total treatment time should be 15 to 20 minutes, or enough time to allow a minimum of 10 contractions
* Treatment can be repeated two times daily
* Muscle Strengthening
* Current intensity should make muscle develop 60% of torque developed in a maximum voluntary isometric contraction (MVIC)
* Pulse duration should be set as close as possible to the duration needed for chronaxie of the motor nerve to be stimulated
* Muscle Strengthening
* Pulses per second should be in the tetany range (20 –85 pps)
* Surged or interrupted current with a gradual ramp to peak intensity most effective
* On time should be 10-15 seconds
* Off time should be 50 seconds to 2 minutes
* Medium-frequency alternating current stimulator is machine of choice
* Muscle Strengthening
* Muscle is given an isometric contraction torque equal to or greater than 25% of the MVIC torque
* Patient instructed to work with the electrically induced contraction, but voluntary effort is not necessary
* Total treatment should mimick normal active resistive training protocols of 3 sets of 10 contractions
* Increasing Range of Motion
* Electrically stimulating a muscle contraction pulls joint through limited range
* Continued contraction of muscle group over extended time appears to make contracted joint and muscle tissue modify and lengthen
* Increasing Range of Motion
* Current intensity must be of sufficient intensity and duration to make muscle contract strongly enough to move the body part through antigravity range
* Pulse duration should be set as close as possible to the duration needed for chronaxie of the motor nerve to be stimulated
* Increasing Range of Motion
* Pulses per second should be at the beginning of the tetany range (20 to 30 pps)
* Interrupted or surged current should be used
* On time should be between 15 and 20 secs
* Off time should be equal to or greater than on time, fatigue is a big consideration
* High-voltage pulsed or medium-frequency alternating current stimulators are suggested
* The stimulated muscle group should be antagonistic to the joint contracture and the athlete should be positioned so the joint will be moved to the limits of the available range.
* 8. The athlete is passive in this treatment and does not work with the electrical contraction.
* 9. Total treatment time should be 90 minutes daily. This can be broken into three 30-minute treatments.
* 10..
* Increasing Range of Motion
* Stimulated muscle group should be antagonistic to joint contracture and patient should be positioned so joint will be moved to the limits of available range
* Patient is passive in treatment and does not work with electrical contraction
* Total treatment time should be 90 minutes daily broken into 3 x 30-minute treatments
* Reducing Edema
* Sensory level direct current used as a driving force to make charged plasma protein ions in interstitial spaces move in the direction of oppositely charged electrode
* Reducing Edema
* Current intensity should be (30V-50V) or 10% less than needed to produce a visible muscle contraction
* Preset short duration interrupted DC currents with high pulse frequencies (120 pps) on high voltage equipment are effective
* Reducing Edema
* Distal electrode should be negative
* Treatment should begin immediately after injury
* Thirty minute treatment showed good control of volume for 4 to 5 hours
* High voltage pulsed generators are effective, low voltage generators are not effective
* Stimulating Denervated Muscle
* Electrical currents may be used to produce a muscle contraction in denervated muscle
* Denervated muscle has lost its peripheral nerve supply
* Purpose for electrically stimulating denervated muscle is to help minimize the extent of atrophy while the nerve is regenerating
* Stimulating Denervated Muscle
* Muscle fibers experience a decrease in size, diameter and weight of the individual muscle fibers
* There is a decrease in amount of tension which can be generated and an increase in the time required for contraction
* Stimulating Denervated Muscle
* Degenerative changes progress until muscle is reinnervated by axons regenerating across site of lesion
* If reinnervation does not occur within 2 years fibrous connective tissue replaces contractile elements and recovery of muscle function is not possible
* Stimulating Denervated Muscle
* A current with an asymmetric, biphasic (faradic)waveform pulse duration **<** 1 ms may be used during the first 2 weeks
* After 2 weeks, either an interrupted DC square wave or a progressive DC exponential wave with long pulse duration **>** 10 ms, or a AC sine wave with frequency **<** 10 Hz will produce a twitch contraction
* Stimulating Denervated Muscle
* Length of pulse should be as short as possible but long enough to elicit a contraction
* Current waveform should have pulse duration **=** or **>** than chronaxie of denervated muscle
* Amplitude of current along with pulse duration must be sufficient to stimulate a denervated muscle with a prolonged chronaxie while producing a moderately strong contraction of muscle fibers
* Stimulating Denervated Muscle
* Pause between stimuli should be 4 to 5 times longer (about 3-6 seconds) than stimulus duration to minimize fatigue
* Either a monopolar or bipolar electrode setup can be used with small diameter active electrode placed over most electrically active point
* Stimulation should begin immediately using 3 sets of 5 -20 repetitions 3 x per day
* Therapeutic Uses of Electrical Stimulation of Sensory Nerves
* Gate Control Theory
* Descending Pain Control
* Opiate Pain Control
* Gate Control Theory
* Current intensity adjusted to tolerance but should not cause muscular contraction
* Pulse duration should be 75 -150 µsec or maximum possible
* Pulses per second should be 80-125 or as high as possible
* A transcutaneous electrical stimulator waveform should be used
* Gate Control Theory
* Continuous on time should be used
* Total treatment time should correspond to fluctuations in pain;
  + Unit should be left on until pain is no longer perceived, turned off, then restarted when pain begins again
* Should have positive result in 30 min. if not reposition electrodes
* Descending Pain Control  
  (Central Biasing)
* Current intensity should be very high, approaching noxious level
* Pulse duration should be 10 msec.
* Pulses per second should be 80.
* On time should be 30 seconds to 1 minute
* Stimulation should be applied over trigger or acupuncture points
* Descending Pain Control  
  (Central Biasing)
* Selection and number of points used varies according to the part treated.
* Low-frequency,high-intensity generator is stimulator of choice for central biasing
* Should have positive result shortly after treatment begins-if not reposition electrodes
* Opiate Pain Control Theory
* Current intensity should be high, at a noxious level- muscular contraction is acceptable
* Pulse duration should be 200 µsec to 10 msec
* Pulses per second should be 1-5.
* High-voltage pulsed current should be used.
* On time should be 30 to 45 seconds.
* Stimulation should be applied over trigger or acupuncture points
* Opiate Pain Control Theory
* Selection and number of points used varies according to part and condition being treated
* High-voltage pulsed current or a low-frequency, high-intensity machine is best
* Analgesic effect should last for several (6-7) hours
  + If not successful, try expanding the number of stimulation sites
* Clinical Uses of Low-Volt Continuous Direct Current
* Medical Galvinism
* Ionotphoresis
* Medical Galvanism
* Continuous low-volt direct current causes:
  + Polar effects
    - Acid reaction around the positive pole and the alkaline reaction at the negative pole
    - Acidic or alkaline changes can cause severe skin reactions
    - Occur only with low-voltage continuous direct current and are not likely with the high-voltage generators since current duration is too short to cause chemical changes
  + Vasomotor Changes
    - Blood flow increases between the electrodes.
* Medical Galvanism
* Current intensity should be to tolerance
  + - Intensity in the milliamp range.
* Continuous direct current should be used
* Pulses per second should be 0.
* Low-voltage direct current stimulator is the machine of choice.
* Treatment time should be between 15-50 min
* Medical Galvanism
* Equal-sized electrodes are used over gauze that has been soaked in saline solution and lightly squeezed
* Skin should be unbroken
* Skin burns are the greatest hazard of any continuous direct current technique
* Functional Electrical Stimulation
* **FES** utilizes multiple channel electrical stimulators controlled by a microprocessor to recruit muscles in a programmed synergystic sequence that will allow patient to accomplish a specific functional movement pattern
* Multichannel microprocessors may be pre-programmed to execute a variety of specific movement patterns
* Low Intensity Stimulators
* Originally called microcurrent electrical neuromuscular stimulators (MENS)
* *LIS* currents are not substantially different from the currents discussed previously
* LIS generators produce current where intensity is limited to **<**1000 microamps (1 milliamp) while intensity of standard low-voltage equipment can be increased into milliamp range
* Low Intensity Stimulators
* Low intensity stimulation has been used for two major effects:
  + Analgesia of the painful area
  + Biostimulation of the healing process either for enhancing the process or for acceleration of its stages
    - Used to promote wound healing (skin ulcers) and fracture healing (nonunion
* Analgesic Effects of LIS
* LIS is a subsensory current
* As such it does not fit existing models of pain modulation
* Exact mechanism of action has not yet been established
  + - LIS can create or change constant direct current flow of the neural tissues which may have some way of biasing transmission of painful stimulus
    - May also make nerve cell membrane more receptive to neurotransmitters which will block transmission
* Promotion of Wound Healing
* Low intensity stimulators can be used but other generators with intensities adjusted to sub-sensory levels can also be effective
* Current intensity is 200-400 µamp for normal skin and 400-800 µamp for denervated skin
* Long pulse durations or continuous uninterrupted currents can be used
* Promotion of Wound Healing
* Maximum pulse frequency
* Monophasic direct current is best but biphasic direct current is acceptable. A battery powered portable unit is most convenient.
* Treatment time 2 hours followed by a 4 hour rest time
* 2-3 treatment bouts per day
* Promotion of Wound Healing
* Negative electrode positioned in the wound area for the first 3 days
* Positive electrode positioned 25 cm proximal to the wound
* After 3 days polarity reversed and positive electrode is positioned in the wound area
* Promotion of Wound Healing
* With infection negative electrode should be left in wound area until the signs of infection are not evident and for 3 more days after infection clears
* If wound size decrease plateaus return the negative electrode to the wound area for 3 days
* Promotion of Fracture Healing
* Current intensity is just perceptible to patient
* Pulse duration is longest duration allowed on unit (100 to 200 msec)
* Pulses per second set at lowest frequency allowed on unit (5 to 10 pps)
* Standard monophasic or biphasic current in TENS units used
* Promotion of Fracture Healing
* Treatment time 30 minutes-1 hour 3-4 x daily
* Negative electrode placed close to but distal to fracture site
* Positive electrode placed proximal to immobilizing device
* Results reassessed at monthly intervals
* Russian Currents
* Deliver medium (2000 -10,000 Hz) frequency polyphasic AC wave form
* Pulse varies from 50-250 µsec; the phase duration is half of the pulse duration or 25-125 µsec
* Two basic waveforms: sine wave or square wave cycles with a fixed intrapulse interval
* Russian Currents
* Sine wave produced in burst mode with 50% duty cycle
* To make intensity of current tolerable it is generated in 50-burst-per-second envelopes with an interburst interval of 10 msec
* Russian Currents
* Dark shaded area represents total current, and light shading indicates total current without the interburst interval
* When generated with burst effect total current is decreased allowing for tolerance of greater current intensity
* Russian Currents
* Higher frequency currents reduce resistance to current flow making wave form comfortable enough to tolerate higher intensities
* As intensity increases more motor nerves are stimulated increasing magnitude of the contraction
* Russian Currents
* Because it is a fast oscillating AC current, as soon as nerve repolarizes it is stimulated again, producing a current that will maximally summate muscle contraction
* Interferential Currents
* Make use of 2 separate generators
* Produce sine waves at different frequencies
* Interferential Currents
* When displayed on an oscilloscope with only one generator the current behaves as previously described
* Interferential Currents
* If a second generator is added the currents may interfere with each other
* If produced in phase if or they originate at same time interference can be summative-amplitudes of the electric wave are combined and increase
* Referred to as *constructive interference*
* Interferential Currents
* If waves are generated out of sync, Generator 1 starts in a positive direction at the same time that Generator 2 starts in a negative direction- waves cancel each other out
* Referred to as *destructive interference*
* Interferential Currents
* If two generators have slightly different frequencies they are out of phase an thus create a *beat* pattern
* Blending of waves caused by constructive and destructive interference patterns called*heterodyne* effect
* Interferential Currents
* When using an interference current
  + Set intensity according to peak
  + Select the frequencies to create a beat frequency corresponding to choices of frequency when using other stimulators
    - 20 to 50 pps for muscle contraction
    - 50 to 120 pps for pain management
    - 1 pps for acustim pain relief
* Interferential Currents
* When electrodes are arranged in a square and interferential currents are passed through a homogeneous medium a predictable pattern of interference will occur
* Interferential Currents
* An electric field is created where two currents cross between lines of electric current flow
* Maximum interference effect takes place near center, with field gradually decreasing in strength as it moves away from center
* Interferential Currents
* Scanning interferential current moves force around while the treatment is taking place enlarging effective treatment area
* Another set of electrodes create a three-dimensional flower effect called a *stereodynamic* effect