* Therapeutic Ultrasound

 Inaudible , acoustic vibrations of high frequency that produce either thermal or non-thermal physiologic effects

* Ultrasound Is Acoustic Energy
* Relies on molecular collision for transmission
* Collisions cause molecule displacement and a wave of vibration
* Transverse vs. Longitudinal Waves
* Longitudinal Wave
* Displacement is in the direction of wave propagation
* Travels in both liquids and solids (Soft tissue)
* Transverse vs. Longitudinal Waves
* Transverse Wave
* Displacement is perpendicular to direction of propagation
* Travels only in solids (Bone)

* Frequency Of Wave Transmission
* Audible sound = 16-20 kHz
* Ultrasound > 20 kHz
* Therapeutic Ultrasound = 0.75-3 MHz (1,000,000 cycles/sec)
* Lower frequencies have greater depth of penetration
* Higher frequencies more superficial absorption
* Velocity Of Transmission
* Directly related to tissue density (the higher the density the greater the velocity)
* At 1 MHz ultrasound travels through soft tissue at 1540 m/sec
* Attenuation
* Decrease in energy intensity
* Decrease is due to absorption, dispersion, or scattering resulting from reflection and refraction
* Penetration vs. Absorption
* Inverse relationship
* Absorption increases as frequency increases
* Tissues high in water content decrease absorption
* Tissues high in protein content increase absorption
* Highest absorption rate in bone, nerve, muscle, fat
* Ultrasound At Tissue Interfaces
* Some energy scatters due to reflection and refraction
* Acoustic impedance (tissue density X speed of transmission) determines the amount reflected vs. transmitted
* The most energy will the transmitted if the acoustic impedance is the same
* The larger the difference in acoustic impedance the more energy reflected
* Reflection vs. Transmission
* Transducer to air - Completely reflected
* Through fat - Transmitted
* Muscle/Fat Interface - Reflected and refracted
* Soft tissue/Bone Interface - Reflected
* Creates “standing waves” or “hot spots”
* Therapeutic Ultrasound Generators

High frequency electrical generator connected through an oscillator circuit and a transformer via a coaxial cable to a transducer housed within an applicator

* Ultrasound Generator
* Therapeutic Ultrasound Generator Control Panel
* Timer
* Power meter
* Intensity control ( watts or W/cm2)
* Duty cycle switch (Determines On/Off time)
* Selector switch for continuous or pulsed
* Automatic shutoff if transducer overheats
* Transducer or Applicator
* Matched to individual units and not interchangeable
* Houses a *piezoelectric* crystal
* Quartz
* Lead zirconate or titanate
* Barium titanate
* Nickel cobalt
* Transducer or Applicator
* Crystal converts electrical energy to sound energy through mechanical deformation
* Piezoelectric Effect
* When an alternating current is passed through a crystal it will expand and compress
* Direct Effect - An electrical voltage is generated when the crystal expands and compresses
* Piezoelectric Effect
* Indirect or Reverse Effect - As alternating current reverses polarity the crystal expands and contracts producing ultrasound
* Effective Radiating Area (ERA)
* That portion of the surface of the transducer that actually produces the sound wave
* Should be only slightly smaller than transducer surface
* Frequency of Therapeutic Ultrasound
* Frequency range of therapeutic ultrasound is 0.75 to 3.0 MHz
* Most generators produce either 1.0 or 3.0 MHz
* The Ultrasound Beam
* Depth of penetration is frequency dependent not intensity dependent
* 1 MHz transmitted through superficial layer and absorbed at 3-5 cm
* 3 MHz absorbed superficially at 1-2 cm
* The Ultrasound Beam
* Concentrates energy in a limited area
* Larger head- more collimated beam
* Smaller head- more divergent beam
* Ultrasound Beam
* Near field
* Distribution of energy is nonuniform due to the manner in which waves are generated and differences in acoustic pressure
* Ultrasound Beam
* Point of Maximum Acoustic Intensity
* Waves are indistinguishable and arrive simultaneously
* Ultrasound Beam
* Far Field
* Energy is more evenly distributed and the beam becomes more divergent
* Beam Nonuniformity Ratio (BNR)
* Indicates the amount of variability in intensity within the beam
* Ratio - Highest intensity found in the beam relative to the average intensity of the transducer
* Ideal BNR would be 1:1
* Typical BNR 6:1
* Beam Nonuniformity Ratio (BNR)
* If intensity is 1.5 W/cm2 the peak intensity in the field would be 9 W/cm2
* The lower the BNR the more even the intensity
* Manufacturers must include the BNR on their generators
* Better generators have a low BNR thus provide more even intensity throughout the field
* Pulsed vs. Continuous Ultrasound
* Continuous Ultrasound
* Ultrasound intensity remains constant over time
* Pulsed vs. Continuous Ultrasound
* Pulsed
* Intensity is interrupted thus average intensity of output over time is low
* Pulsed Ultrasound and Duty Cycle
* Duty Cycle (mark space ratio)
* Duration of pulse / Pulse period X 100
* Duty Cycle may be set to 20% or 50%
* Intensity
* Rate at which energy is delivered per unit area
* Spatial Average Intensity - W/cm2
* Power output in watts ERA of transducer in cm2
* Example
* 6 watts = 1.5 W/cm2 4 cm2
* Intensity
* There are no specific guidelines which dictate specific intensities that should be used during treatment
* Recommendation is to use the lowest intensity at the highest frequency which transmits energy to a specific tissue to achieve a desired therapeutic effect
* Physiologic Effects of Ultrasound
* Thermal vs. Non-Thermal Effects
* Thermal effects
* Tissue heating
* Non-Thermal effects
* Tissue repair at the cellular level
* Thermal effects occur whenever the spatial average intensity is > 0.2 W/cm2
* Whenever there is a thermal effect there will always be a non-thermal effect
* Increased collagen extensibility
* Increased blood flow
* Decreased pain
* Reduction of muscle spasm
* Decreased Joint stiffness
* Reduction of chronic inflammation
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* Set at 1.5 W/cm2 with 1MHz ultrasound would require a minimum of 10 minutes to reach vigorous heating
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* Set at 1.5 W/cm2 with 3 MHz ultrasound would require only slightly more than 3 minutes to reach vigorous heating
* Thermal Effects
* Baseline muscle temperature is 36-37°C
* Mild heating
* Increase of 1°C accelerates metabolic rate in tissue
* Moderate heating
* Increase of 2-3°C reduces muscle spasm, pain, chronic inflammation, increases blood flow
* Vigorous heating
* Increase of 3-4°C decreases viscoelastic properties of collagen
* Non-Thermal Effects of Ultrasound
* Increased fibroblastic activity
* Increased protein synthesis
* Tissue regeneration
* Reduction of edema
* Bone healing
* Pain modulation
* Microstreaming
* Unidirectional flow of fluid and tissue components along the cell membrane interface resulting in mechanical pressure waves in an ultrasonic field
* Alters cell membrane permeability to sodium and calcium ions important in the healing process
* Cavitation
* Formation of gas filled bubbles that expand and compress due to pressure changes in fluid
* Stable Cavitation
* Stable cavitation results in an increased fluid flow around these bubbles
* Cavitation
* Unstable Cavitation
* Unstable cavitation results in violent large excursions in bubble volume with collapse creating increased pressure and temperatures that can cause tissue damage
* Therapeutic benefits are derived only from stable cavitation
* Non-Thermal Effects
* Can be maximized while minimizing the thermal effects by:
* Using a spatial average intensity of 0.1-0.2 W/cm2 with continuous ultrasound
* Setting duty cycle at 20% at 1 W/cm2
* Setting duty cycle at 50% at 0.4 W/cm2
* Techniques of Application
* Frequency of Treatment
* Acute conditions require more treatment over a shorter period of time (2 X/day for 6-8 days)
* Chronic conditions require fewer treatments over a longer period ( alternating days for 10-12 treatments)
* Limit treatments to a total of 14
* Considerations for Determining Treatment Duration
* Size of the area to be treated
* What exactly are you trying to accomplish
* Thermal vs. non-thermal effects
* Intensity of treatment
* Size of the Treatment Area
* Should be 2-3 times larger than the ERA of the crystal in the transducer
* If the area to be treated is larger use shortwave diathermy, superficial hot packs or hot whirlpool
* Ultrasound As A Heating Modality
* Intensity
* Recommendations for specific intensities make little sense
* Ultrasound intensity should be adjusted to patient tolerance
* Increase to the point where there is warmth and then back down until there is general heating
* Intensity
* If you decrease intensity during treatment you should increase treatment duration
* Ultrasound treatments should be temperature dependent not time dependent
* Coupling Methods
* Energy reflection is great at the air-tissue interface
* Purpose is to minimize air and maximize contact with the tissue
* Include gel, water, mineral oil, distilled water, glycerin, analgesic creams
* Gel seems to be the best coupling medium
* Direct Contact
* Transducer should be small enough to treat the injured area
* Gel should be applied liberally
* Heating of gel does not increase the effectiveness of the treatment
* Immersion Technique
* Good for treating irregular surfaces
* A plastic, ceramic, or rubber basin should be used
* Tap water is useful as a coupling medium
* Transducer should move parallel to the surface at .3-5 cm
* Air bubbles should be wiped away
* Bladder technique
* Good for treating irregular surfaces
* Uses a balloon filled with water
* Both sides of the balloon should be liberally coated with gel
* Moving The Transducer
* Stationary technique no longer recommended
* Applicator should be moved at about 4 cm/sec
* Low BNR allows for slower movement
* High BNR may cause cavitation and periosteal irritation
* Ultrasound and Other Modalities
* Cooling the tissues does not facilitate an increase in temperature (Remmington 1994, Draper, 1995)
* Analgesic effects of ice can interfere with perception of heating
* Ultrasound and EMS is effective in treating myofascial trigger points when used in combination with stretching (Girardi, et al. 1984)
* Clinical Applications For Ultrasound
* Ultrasound is recognized clinically as an effective and widely used modality in the treatment of soft tissue and boney lesions
* There is relatively little documented, data-based evidence concerning its efficacy
* Most of the available data-based research is unequivocal
* Soft Tissue Healing and Repair
* During inflammatory stage cavitation and streaming increases transport of calcium across cell membrane releasing histamine
* Histamine stimulate leukocytes to “clean up”
* Stimulates fibroblasts to produce collagen (Dyson, 1985, 1987)
* Scar Tissue and Joint Contracture
* Increased temperature causes an increase in elasticity and a decrease in viscocity of collagen fibers (Ziskin, 1984)
* Increases mobility in mature scar (Gann, 1991)
* Chronic Inflammation
* Few clinical or experimental studies
* Ultrasound does seem to be effective for increasing blood flow for healing and reduction of pain (Downing, 1986)
* Bone Healing
* Ultrasound accelerates fracture repair (Dyson, 1982, Pilla et al., 1990)
* Ultrasound given to an unstable fracture during cartilage formation may cause cartilage proliferation and delay union (Dyson, 1989)
* Ultrasound has no effect on myositis ossificans but may help reduce surrounding inflammation (Ziskin, 1990)
* Ultrasound not effective in detecting stress fractures
* Pain Reduction
* Ultrasound not used specifically for decreasing pain
* Ultrasound may increase threshold for activation of free nerve endings (McDiarmid, 1987)
* Superficial heating may effect gating (Williams et al. 1987)
* Increased nerve conduction velocity creates a counterirritant effect (Kitchen, 1990)
* Placebo Effects
* A number of studies have demonstrated a placebo effect in patients using ultrasound (Lundeberg, 1988, Dyson, 1987, Hashish et al., 1986)
* Phonophoresis
* Ultrasound used to drive topical application of selected medication into the tissues
* Antiinflammatories
* Cortisol
* Salicylates
* Dexamethasone
* Analgesics
* Lidocaine
* Phonophoresis
* Non-thermal effects increase tissue permeability and acoustic pressure drives molecules into the tissue
* Effectiveness of phonophoresis is debatable
* Early studies demonstrated effective penetration (Griffin, 1982, Kleinkort, 1975)
* More recent studies show ineffectiveness (Oziomek et al, 1991, Benson et al., 1989)