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Ultrasound and Phonophoresis

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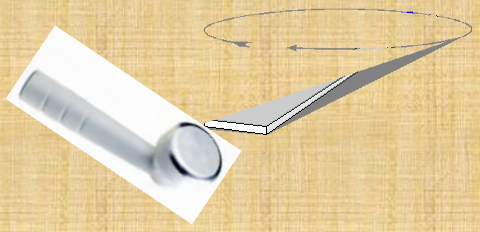
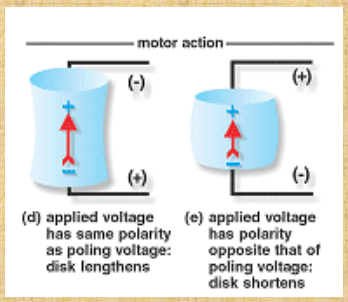
Content

- Ultrasound physics
- Physiological response
  - Thermal
  - Non-Thermal
- Phonophoresis
- Evidence
- Clinical applications

Physics of US

- Reverse piezoelectric effect
- US waves generated and transmitted
  - Doesn't travel through air
- Collimation
- Attenuation in tissues



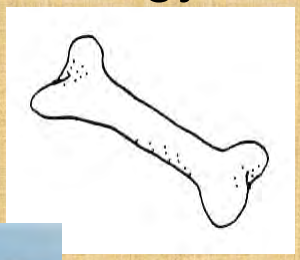


Collimation depth and energy

- Depends on frequency
  - 1 MHz – 4 cm deep
  - 3 MHz – 2-3 cm deep
- Note that 3 MHz delivers 3X the energy for a given period of time

Absorption of US energy

- Blood – 3%
- Fat – 13%
- Muscle – 24%
- Skin – 39%
- Tendon – 59%
- Cartilage – 68%
- Bone – 96%



Other nerd stuff

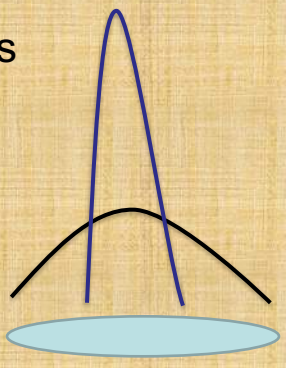
- Ultrasound calibration
- Beam non-uniformity ratio
- Refraction of energy
- Continuous vs pulsed US
- ERA

Calibration

- Underwater balance system
- Calibrates actual output to displayed output
- Should be done every 6-12 months
- Patient injury scenario

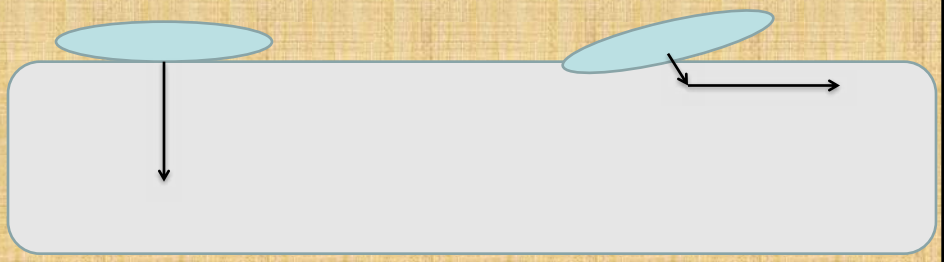
Beam nonuniformity ratio

- BNR
- Gives ratio of peak intensity/average intensity
- 6:1 or less



Refraction of energy

- US energy can bend like light
- Need to apply perpendicular to skin



Continuous vs. pulsed US

- Continuous US
  - Thermal and non-thermal effect
- Pulsed US
  - Non-thermal effect
  - Literature is very poor

Physiological effects

- Thermal
  - Increased molecular kinetic energy
  - 1° C – increase metabolic rate
  - 2-3 °C – reduce muscle spasm and increase blood flow
  - 4 °C – increase tissue extensibility

Lehman- APMR – 48:662-666,1967

Physiological effects

- Non-thermal
  - Microstreaming
  - Cavitation
  - Mast cell degranulation

Physiological effects

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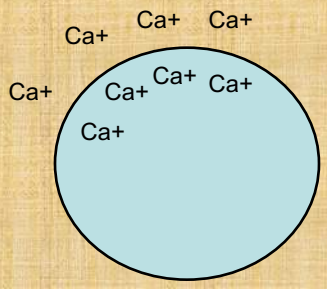
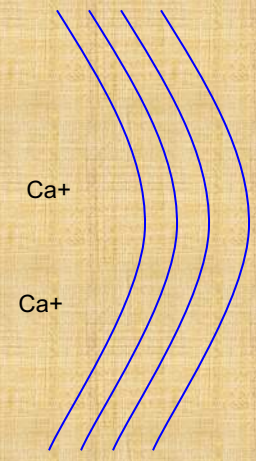
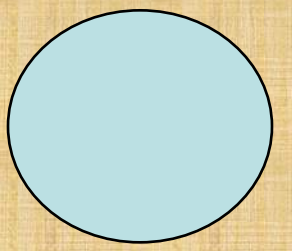


Streaming



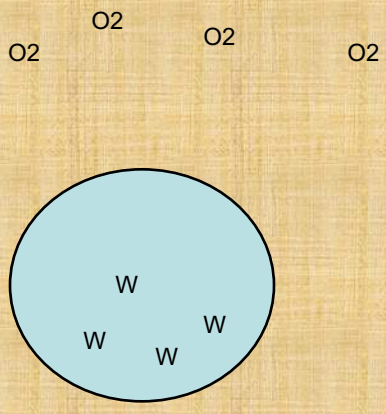


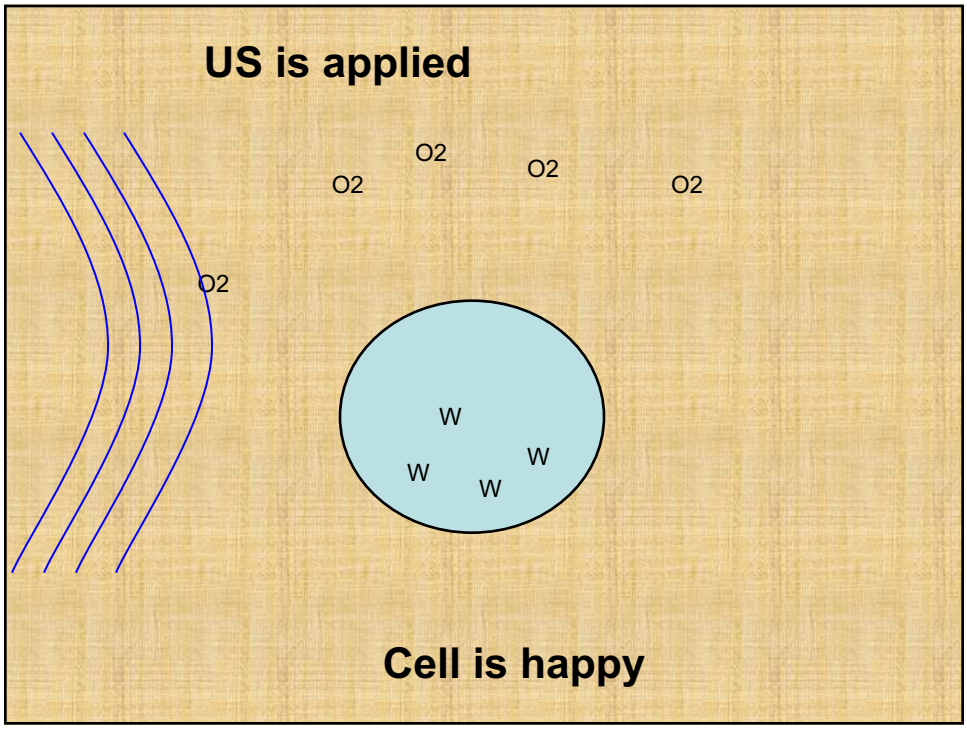
Cavitation

- Formation of gas bubbles
- Oscillation of these bubbles
- Opens spaces in cell membrane

Overall non-thermal effects

- Increase permeability of cell membranes
  - Oxygen, good ions in
  - Waste products out





Effects on muscle

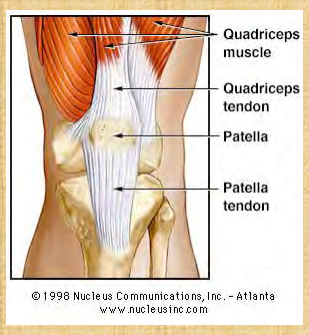
- Draper 1995 – JOSPT 22:142-150
- Thermistors inserted into triceps of healthy individuals
- Measured at depths of 0.8 cm and 1.6 cm
- Temperature increase the same at both depths
- Treatment area kept to 2 x ERA
- * = temperature increase 0.5 degrees
- ** = painful

Effects on muscle

	Intensity	T2.5	T5.0	T7.5	T10
1MHz	0.5	*	*	*	0.5°C
	1.0	*	1.0°C	1.25°C	1.0°C
	1.5	1.0°C	1.75°C	2.5°C	1.0°C
	2.0	1.25°C	2.25°C	3.25°C	1.0°C
3MHz	0.5	0.75°C	1.5°C	2.0°C	1.0°C
	1.0	2.5°C	3.5°C	5.0°C	5.75°C
	1.5	2.75°C	5.0°C	**	**
	2.0	4.0°C	**	**	**

Connective tissue effects

- Higher collagen content = more heat absorbed
- Relative avascularity
- Chan et al 1998, J Athl Training 33:130-135
- Healthy patellar tendons
- 3 MHz at 1.0 W/cm^2
- 4 minute treatment



Connective tissue effects

- Average temperature increase 8°C
- Return to baseline after 20 minutes
  - However 4°C increase (necessary for increased collagen extensibility) was lost after 4 minutes post treatment
- When 4 x ERA
  - Average temperature increase 5°C
  - Lasted 15 minutes
  - However 4°C increase (necessary for increased collagen extensibility) was lost after 2 minutes post treatment
  - “window of post US treatment”

Joint pain

- Ozegenel et al 2009. Ultrasound med biol.
- Double blind placebo-controlled
- Continuous US at 1 MHz, 1.0 W/cm2 x 5 minutes
- Measured pain scale
- Real US superior to sham US

Circulatory effects

- Theory is that the body wants to “ship away” the new heat and maintain homeostasis – thus vasodilation
- Not supported by the literature at all
- Small changes in circulation if small area treated
- Perhaps non-thermal mediated as well
  - Histamine release from mast cells

Wound healing

- Byl et al – Achives PMR1992
- Pig model for wound
- 20% duty cycle, 1 MHz, 0.5 watts/cm^2
- 5 minute treatment time
- Intensity increased at day 4 and 5 to 1.5 watts/cm^2

Wound healing continued

- US treated wounds were smaller, higher breaking strength
- Greater collagen deposition
- Lower dose more effective

Neurologic effects

- Sensory NCV shown to increase with therapeutic thermal doses of US
- Currier et al APMR 59:181-85, 1978
- Lehmann et al APMR 39:560, 1958 showed increased pain thresholds

Rationale for using US in different phases of healing

- Inflammatory phase
  - Stimulate release of growth factors
  - Promote angiogenesis
  - Use an anti-inflammatory medication with phonophoresis

Rationale continued

- Proliferative phase
  - Angiogenesis promoted
  - Increased activity of fibroblasts

Rationale continued

- Remodeling phase
  - Elevate tissue temperature
  - Increase tissue extensibility

In vitro research

- Increased activity of fibroblasts
  - Harvey et al Rheum Rhabil 14:237, 1975
- Increased collagen synthesis
  - Ramirez et al Med Sci Sports Ex 29:326-332, 1997
- Increased calcium uptake in cultured fibroblasts
  - Mortimer et al US Med Biol 16:261-69, 1980

In vitro muscle

- Rantanen et al Am J Sports Med 27:54-59, 1999
  - Injured rat gastrocnemius
  - 3 days post injury, US at 20% duty cycle, 3 MHz, 1.5 W/cm^2 for 6 minutes
  - Treated for 2 days
  - 10 days post injury, significant increase in myogenic precursor cells and fibroblasts

More in vitro muscle

- Karnes et al APMR 83:1-4, 2002
  - Contraction induced muscle injury in rat model
  - 1 MHz US underwater at 0.5 W/cm^2 for 5 minutes daily
  - Significantly increased force production compared to controls

In vitro nerve healing

- Crisci et al US Med Biol 28:1335-1341, 2002
  - Rat model sciatic nerve injury
  - Increased quantity of nerve fibers regenerating, increased myelinization, increased diameter of nerve fibers, increased Schwann cell activity
  - US at 1.5 MHz, 16mW/cm^2

In Vitro tendon/ligament

- Frieder et al JOSPT 10:39-46, 1988
  - Achilles tendon rupture in rats
  - Treated for 3 weeks with US at 1.5 W/cm^2
  - Greater tensile strength, more parallel, dense collagen fibers
  - Not seen with just 2 weeks of treatment
  - US every other day for 3 minutes
  - Another study showed no effect if 1 week went by before treatment began

In Vitro tendon/ligament

- Takakura et al J US Med 21:283-288, 2002
  - Rat MCL model
  - Pulsed US at 1.5 MHz daily for 12 days
  - Superior tensile strength compared to controls

Bone healing with US

- Parameters
  - 20% duty cycle
  - 1.5 MHz
  - 30 mW/cm^2
  - 20 minutes

Bone healing

- Kristiansen 1997, JBJS
- 60 patients with distal radius fracture
- Treatment started within 7 days of fracture
- 20 minutes daily for 10 weeks
- Time to union
  - 61 days (US)
  - 98 days (placebo)

Other conducting media

- Underwater
  - 40-60% less heating than gel
- Balloon
  - 50% energy loss in transmission
- Gel pads
  - Equivalent to US gel

Apply these to humans

- Sadly, few well done controlled trials
- It is prudent to approximate the treatment protocols from animal studies
- Low intensity or pulsed US soon after injury
- Frequent treatments

Contraindications

- Eyes/testes – fluid
- Cardiac pacemaker – ion flux
- Pregnancy –WIDC (when in doubt…)
- Active bleeding or infection
- Tumor/ malignancy
- DVT
- Epiphyseal plate of growing bone (???)

Precautions

- Plastic implants
- Metal – reflects US energy

Appropriate use of US

- Heating of the tissues prior to soft tissue mobilization or stretching
- Perform stretching/tissue mobilization or exercise within the “stretching window”
- Introduction of medication through Phonophoresis

Appropriate use of US

- Research has shown that at least 4-6 treatments are needed for full effect
- If no effect by 6 treatments, try something else
- If patient is improving and US appears to be part of this (used properly), continued use of US is prudent

Application nuggets of wisdom

- Treatment area = 1.5 to 2 times ERA
- Keep applicator moving 4 cm/sec
- Don't fret short removal of applicator from skin – you won't break the crystal
- Applicator perpendicular
- Patient should feel gentle warmth

QUIZ

- 20 applications of US with patient not improving
- 8 applications of US with ROM of shoulder increasing by 45°, resulting in increased functional use of UE to perform overhead ADLs
- 6 applications of US and patient has not shown measurable functional gains – should document that it's time to try something else

Phonophoresis

- Medication delivery through the skin
- Changes permeability of the skin and cells
- Passive diffusion

Optimize your phono

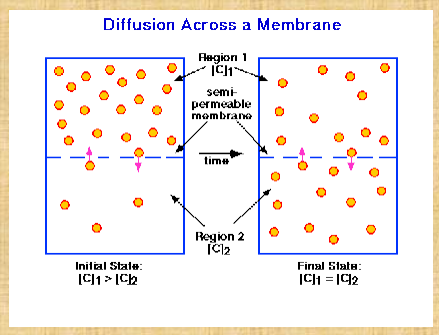
- Good transmission medium
  - Cortisone impregnated gels – POOR
  - Salicylate preparations – POOR
  - Lidex (corticosteroid) – GOOD
  - Theragesic cream – GOOD
  - Betamethasone in US gel - GOOD

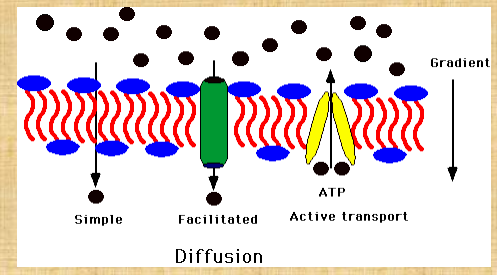
Optimize your phono 2

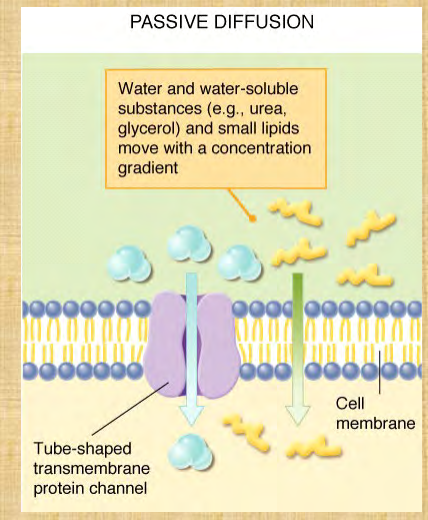
- The skin should be pretreated with heat, US, moistening, shaving
  - Hydration
  - Denude stratum corneum
  - Dilate hair follicles
  - Thin skin

Optimize your phono 3

- Position your patient to maximize circulation during the treatment
  - Max local absorption in 2-4 hours
  - Max systemic absorption in 12 hours
  - Maintain hydration of tissues







Optimize your phono 4

- An occlusive dressing that seals the area should be applied after treatment
  - Medication is still in the tissues after the treatment
  - Evaporation
  - Passive diffusion
  - Hair follicles dilated up to 2-4 hours after treatment

Optimize your phono 5

- Intensity of 1.5 W/cm^2 to capture thermal and non-thermal effects of US
  - Oscillates particles .018um
  - Following the research

Optimize your phono 6

- Low intensity US for acute injuries
  - 0.5 W/cm^2 instead of pulsed US
  - Seems to oscillate particles better

Case study 1

- 70 y.o. patient with knee OA and lacking 15 degrees of extension
- US could be used in posterior knee to decrease stiffness and increase tissue extensibility
- Parameters:

Case study #2

- Patient with right shoulder calcific tendonitis
- US can increase tissue extensibility and increase resorbtion of the calcium deposits
- Parameters:

US evidence

- Systematic review in 2001
  - 35 RCT's
  - 10 used acceptable methods, measures
  - Only 2 of 10 showed positive results compared to placebo
  - Poor methodology of US studies

US evidence

- Grade I evidence for positive effects in
  - CTS – Ebenbichler 1998
  - Shoulder pain – Munting 1978
  - Calcific tendonitis - Ebenbichler 1999
  - Elbow epicndylitis – Binder 1985
  - Wounds – multiple
- Seems to be stuck still at the animal model stage of research

Grade II and III evidence for

- Osteoarthritis
- Myofascial pain
- CTS
- Adhesive capsulitis
- Shoulder pain
- Subacromial bursitis
- Calcific tendonitis
- RSD pain
- Biceps tendonitis
- Plantar warts
- Plantar fascitis
- Elbow epicondylitis

PHTH 523 – EBP2

Therapeutic Ultrasound – Effectiveness studies from

Physical Therapy 2001; 81:1339-1350

Background

- US is one of the most frequently used physical modalities (Nussbaum 1992)
- Early reviews
  - Gam et al (1995) – methodological flaws, no effect of US
  - Heijden et al (1997) – not effective
- Lack of blinding, control groups, info on parameters

Inclusion criteria

- Adequate controls
  - Placebo treatments
  - Randomized group allocation
- Adequate blinding
  - Observers
  - Subjects
  - Treating therapists

Inclusion criteria

- Adequate description of treatment variables
  - Output
  - Time
  - Calibration of US machine
- Meaningful outcome measures
- Adequate sample size
- Acceptable statistical analysis of results

Methods

- Examined only RCTs
- Search strategy
  - 1975-1999
  - Clinical databases (no PEDRO, PubMed)
  - 35 RCTs (seems low to me)
  - Only used studies on real impairments
  - Didn't use studies with multiple interventions
  - Didn't use duplicated results
  - Finally 27 RCTs

Filter #1 - controls

- Subjects randomly allocated to groups
- High alleged placebo effect (gate??)
- **Rejected** Callam et al (1987)
  - Chronic leg ulcers
  - 56 subjects standard care
  - 52 subjects standard care + weekly pulsed US
  - 20% faster healing in US group

Wait a minizzle

Is it fair to reject this study??

Filter #2 - Blinding

- Assessor, subjects, users
- Difficult to blind subjects
- Rejected Bradnock et al (1990)
  - Used .45MHz and 1 MHz US on in vitro solution
  - Showed increase in fibroblast and osteoblast proliferation
  - Showed increase in collagen production
- **Even though it was in vitro, another positive study bites the dust**

Filter #2

•**Even though it was in vitro, another positive study bites the dust**

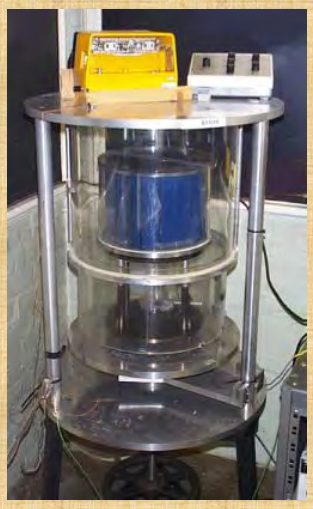
Filter #3 – Treatment Variables

- Should provide information on all treatment parameters, calibration
- Rejected a number of studies due to lack of calibration of the device
- Rejected Creates 1987 (didn't even find Creates 1991) "inadequate details"
  - Perineal pain post childbirth – positive outcomes
- Rejected Haker 1991 – lateral epicondylitis

Haker et al 1991

- "The output of the machines were controlled every day on a simple underwater radiation balance"
- 10 treatments total, followed up in 3 months and 12 months, no significant difference between groups
- ***Weak – evaluated too late***
- Weak #2 – should not have been rejected

Force balance



US force causes motion in a carefully calibrated teeter-totter, the amount of motion is correlated with the power of the US

Filter #4- Outcome measures

- All measures had at least face validity
- Measures such as area tracings, pain scale, grip strength were all OK

Filter #5 – Sample size

- Power analysis – based on effect size (*d*)
  - *d* = (Mean1 – Mean2)/(std dev)
  - Use this d in a table based on alpha (accepted error) and probability of detecting difference (usually 80%)
  - Estimated d at 0.80, this is a very big effect

Rejected by filter #5

- Downing 1986 – sub acromial bursitis – 20 total subjects – no effects
- Gam 1998 – myofascial pain and trigger points – 20 or 18 per group
  - One group US, ex, massage
  - One group sham US, ex, massage
  - One control group, no intervention
  - First 2 groups improved
- McDiamid 1985 – pressure ulcers , improvement in healing (#s not found)

Filter #6 – Data analysis

- Rejected study if they thought wrong stats were used
- Dyson 1976 – Venous ulcers – too large of variance at start of treatment – should have normalized start data
  - Final size/start size

Venous ulcer

Rejected by filter #6

- Roche et al 1984 – venous ulcers –
  - Didn't show equality of groups before treatment – it probably was there however
  - Significant effects of US
- Binder 1985 – lateral epicondylitis
  - Randomly allocated
  - Positive effects

Overall

- 10 studies left, only 2 showed positive effects
- Newer RCTs (PEDRO)
  - Ebenbichler 1999 – CTS – positive – 45 subjects
  - Ebenbichler 1999 – shoulder calcific tendonitis – 54 subjects - improvements
- Cochrane review 2002 – beneficial for RA

Further studies

- Power analysis for numbers (30 per group is good ballpark)
- Calibrate the durned machine and report it
- Report every parameter
- Include a sham US group
- Blind at least the assessor
- Use a sensitive outcomes measure (i.e. quality of life scales, etc.)

Questions?

- Thank you!
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