THERAPEUTIC ULTRASOUND

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Therapeutic Ultrasound

- Ultrasound is a form of MECHANICAL energy
- Mechanical vibration at increasing frequencies is known as sound energy.
- Below 16Hz, these vibrations are not recognizable as sound
- The normal human sound range is from 16Hz to something approaching 15-20,000 Hz

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- Beyond this upper limit, the mechanical vibration is known as ULTRASOUND.
- The frequencies used in therapy are typically between 1.0 and 3.0 MHz
- 1MHz = 1 million cycles per second

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- As the energy within the sound wave is passed to the material, it will cause oscillation of the particles of that material.
- Any increase in the molecular vibration in the tissue can result in heat generation, and ultrasound (US) can be used to produce thermal changes in the tissues

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Ultrasound

- all sound is produced by the vibration of a membrane
- Ultrasound (> 20,000 Hz) is produced by the vibration of synthetic crystals
- The crystal contracts and expands when exposed to alternating electric current
- These oscillations of the crystal produce pressure waves = ultrasound waves.

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Indications

1. Decrease pain and muscle spasm
2. Increase extensibility of collagen
3. Increase blood flow
4. Increase metabolic rate
5. Increase tissue healing
6. Organization of healing tissues

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Precautions

- Over analgesic areas
- Myositis ossificans ?
- Fibrotic myopathy ?
- Plastic and metal implants
- Over the carotid sinus
- Over a pregnant uterus

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Contraindications

- Over the heart
- Over the cordal spine
- Over epiphyseal area of growing bones
- Infected areas
- Bleeding areas
- Neoplasms
- Thrombophlebitis

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Important Parameters You Should Know

1. Frequency – 1 MHz and 3 MHz
2. Mode - continuous and pulsed
3. Intensity
4. Sound head size
5. Treatment time
6. Coupling agent

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Frequency

- 3MHz ultrasound is absorbed more rapidly in the tissues, and therefore is considered to be most appropriate for superficial lesions
- So, if the target tissue is within 2-3cm of the skin surface, 3MHz treatments will be effective

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Frequency

- 1MHz energy is absorbed less rapidly with progression through the tissues, and can therefore be more effective at greater depth.
- treatments to deeper tissues will be more effectively achieved with 1MHz ultrasound (up to 5 cm depth)

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Ultrasound Frequencies

1 MHz penetrates deeper (2-5 cm)
3 MHz heats superficial structures to a greater degree (0-3 cm)

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Ultrasound

Continuous or Pulsed

- Both produce thermal and non-thermal effects.
- The pulsed US produces predominantly non-thermal effects as the average energy is much lower.
- In continuous US the heating effect is greater.

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Pulse Ratio

- The pulse ratio determines the concentration of the energy on a time basis.
- The pulse ratio determines the proportion of time that the machine is ON compared with the OFF time

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Mode Pulse Ratio Duty Cycle

• Continuous	100%
• Pulsed	
o 1:1	50%
o 1:2	33%
o 1:3	25%
o 1:4	20%
o 1:9	10%

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Pulse Ratio

- A pulse ratio of 1:1 for example means that the machine delivers one 'unit' of ultrasound followed by an equal duration during which no energy is delivered. The machine duty cycle is therefore 50%.
- A machine pulsed at a ratio of 1:4 will deliver one unit of ultrasound followed by 4 units of rest, therefore the machine is on for 20% of the time.

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- It is suggested that pulse ratios of 1:4 are best suited to the treatment of acute lesions
- reducing this as the tissue moves towards the chronic state moving through 1:3 and 1:2 to end
- up with 1:1 or continuous modes

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- The state of the tissue determines the pulse ratio rather than the onset of the lesion.
- tissue reactivity is the key.
- If the tissue behaves in an acute manner on assessment, then the lesion is effectively treated with an 'acute' dose.
- If it behaves as a chronic, less responsive tissue, then treat with a 'chronic' dose

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Continuous vs. Pulsed Ultrasound

Continuous – maximal heating

50% pulsed – mild heating

20% pulsed – non-thermal or mechanical effects without much heating

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Ultrasound

Intensity

How much energy is delivered per unit area

The higher the intensity the greater the heating

Expressed in Watts or Watts/cm^2

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Ultrasound Treatment Intensity

- Intensity of ultrasound required at the target tissue will vary with the tissue state
- The more acute the lesion, the smaller the 'strength' of the ultrasound that is required to achieve/maintain the tissue excitement.
- The more chronic the tissue state, the less sensitive, and the greater the intensity required at the lesion in order to instigate a physiological response.

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Tissue State	Intensity required at the lesion (W/cm2)
Acute	0.1 - 0.3
Sub Acute	0.2 - 0.5
Chronic	0.3 - 0.8

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Intensity

1.5-2.0 W/cm^2 are generally used for maximal heating in areas with a moderate to large amount of soft tissue

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Ultrasound

Intensity

1.0-1.5 W/cm^2 are generally used for heating areas with a moderate amount of soft tissue

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Ultrasound

Intensity

0.5-1.0 W/cm^2 is generally used for areas where there is relatively little soft tissue

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Ultrasound

Reflection

Interface	**Energy reflected**
water/soft tissue	0.2%
soft tissue/bone	40%

Tissue temperature may increase at tissue interfaces due to reflection.

This is why we use lower intensities over bony areas.

Overheating the periost is painful

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- The following tables indicate the intensity required at the skin surface in order to achieve a particular intensity at depth

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Size of the Lesion

- The greater the size of the lesion, the longer the duration of the ultrasound that will be required in order to achieve a particular effect.
- The most common method is to estimate the number of times which the ultrasound treatment head can be placed over the target tissue

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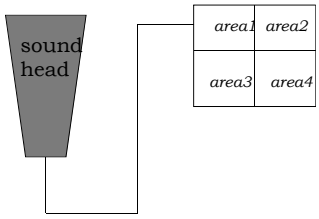
Calculations of treatment time

4 minutes for every sound head that fits in the area



Maximal area of 4X the sound head = Maximal treatment time 16 min.

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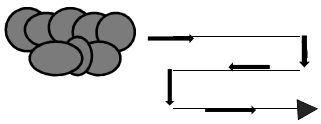
Movement of the Transducer Head

Overlapping circles



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Ultrasound

Thermal effects of ultrasound

1. Increased metabolic rate of tissues
2. Increased blood flow
3. Increased extensibility of collagen tissue (tendon, scars, contracted joint capsule)
4. Decreased pain and spasm

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Summary and Conclusions

3 MHz US heats target tissues to a therapeutic range with the greatest increases in temperature at the 1.0 cm depth

1.5 W/cm2 US heats tissues significantly higher than 1.0 W/cm2 US

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Ultrasound

Mechanical properties of ultrasound

Acoustic Streaming - a unidirectional movement of fluid in the ultrasound field causing a micro massage of the target tissue that increases cell diffusion and membrane permeability which is thought to promote tissue repair

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Non-thermal/Mechanical effects of ultrasound

1. Increased cell diffusion and membrane permeability
2. Increased calcium ion transport
3. Facilitates the inflammatory process in releasing histamine
4. Increased GAG synthesis
5. Increased fibroblast proliferation

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Ultrasound

Wound Management - In review of the literature, there is substantial evidence that supports the use of US in wound healing due to:

- acceleration of the healing process
- improvement of the mechanical properties of the scar that develops at the wound site during the remodeling phase of healing

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Ultrasound

Wound Healing

- Theories as to why the rate of healing may increase are a more rapid recruitment of fibroblasts and endothelial cells to the wound site so that the proliferative and remodeling phases occur more rapidly.
- An increase in GAG metabolism has also been demonstrated which would indicate an increase in metabolic activity.

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Ultrasound

Wound Healing

Accelerates the inflammatory phase of repair and thus accelerates wound healing

Neutrophils and macrophages contain chemo tactic agents and growth factors necessary for the development of the new connective tissue at the site of the injury

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Ultrasound

Wound Healing

Two methods are used for open wounds; the indirect method where US is used around the wound, and the direct method where US is performed directly over the wound through a sterile gel pad that can then be left on as a sterile wound dressing or underwater.

Pulsed US is more commonly utilized.

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Phonophoresis

- The use of US to enhance the delivery of topically applied medications.
- hydrocortisone (10%)
- ketoprofen (10%)
- dexamethasone
- NSAID gel
- The drug may be used as the coupling agent or added to it depending on its form.

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Phonophoresis

Both thermal and non-thermal effects of US theoretically help to enhance the diffusion of topically applied drugs. Heating from the US increases the kinetic energy in the molecules of the drug as well as the cell membrane, heat also dilates the point of entry such as hair follicles and sweat glands, and increases circulation to the area

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Phonophoresis

The acoustic streaming may also enhance drug diffusion by increasing cell diffusion.

Can use pulsed or continuous but pulsed is much more common as the meds are usually anti-inflammatory

Use of heat/cold prior to phonophoresis

Need to check the drug as a possible contraindication

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Possible Use of Therapeutic Ultrasound

1. Increase extensibility of collagenous tissues to increase ROM
2. Decrease spasm
3. Decrease pain
4. Increased blood flow/metabolic rate to improve healing
5. Calcific tendonitis
6. Phonophoresis

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Calculations Case 1

- **Ultrasound treatment for an acute lesion of the medial collateral ligament of the knee**
- the primary focus of the lesion is determined to be at the central portion of the ligament
- The lesion is superficial, hence a 3MHz frequency would be most appropriate
- The lesion is acute, thus an intensity of 0.2 W/cm2 should be sufficient to treat the lesion

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Calculations Case 1

- There is no need to increase the surface dose to allow for loss of ultrasound at depth
- The lesion is acute, therefore a pulse ratio of 1:4 will be most appropriate
- the target tissue is approximately the same size as the treatment head

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Calculations Case 1

- Working on the principle of 1 minutes worth of ultrasound per treatment head area, the total time taken to treat the lesion will be (1 minute) x (number of times the treatment head fits over the lesion) x (the pulse ratio) which in this instance = (1) x (1) x (5) = 5 minutes.
- The final treatment dose will therefore be
- 3MHz ; 0.2 W/cm2 ; Pulsed 1:4 ; 5 minutes

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Case 2

- Ultrasound treatment of a sub acute lesion of the lateral ligament complex of the elbow and superior radioulnar joint
- the primary focus of the lesion is at the lateral ligament of the elbow joint itself together with the lateral portion of the annular ligament of the superior radioulnar joint

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- The lesion is superficial, a 3MHz frequency would be most appropriate
- The lesion is sub-acute, thus an intensity of 0.4 W/cm2 should be sufficient
- There is no need to increase the surface dose to allow for loss of ultrasound at depth
- The lesion is sub-acute, therefore a pulse ratio of 1:2 will be most appropriate

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- Using the small treatment head the target tissue is approximately twice the size of the treatment head
- Working on the principle of 1 minutes worth of ultrasound per treatment head area, the total time taken to treat the lesion will be (1 minute) x (number of times the treatment head fits over the lesion) x (the pulse ratio) which in this instance = (1) x (2) x (3) = 6 minutes.

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- The final treatment dose will therefore be
- **3MHz ; 0.4 W/cm2 ; Pulsed 1:2 ; 6 minutes**

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Case 3

- Ultrasound treatment of a chronic lesion of the anterior capsule of the shoulder (glenohumeral joint, the primary focus of the lesion is determined to be at the anterior capsule of the glenohumeral joint,
- The lesion is not superficial, a 1MHz frequency would be most appropriate
- The lesion is chronic, an intensity of 0.5 W/cm2 should be sufficient

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- There is a need to increase the surface dose to allow for loss of ultrasound at depth, and using the tables above, it is estimated that the required surface dose will need to be 0.75W/cm2
- The lesion is chronic, therefore a pulse ratio of 1:1 will be most appropriate

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- Using the large treatment head, it is estimated that the target tissue is approximately twice the size of the treatment head
- Working on the principle of 1 minutes worth of ultrasound per treatment head area, the total time taken to treat the lesion will be (1 minute) x (number of times the treatment head fits over the lesion) x (the pulse ratio)

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- this instance = (1) x (2) x (2) = 4 minutes.
- The final treatment dose will therefore be
- **1MHz ; 0.75 W/cm2 ; Pulsed 1:1 ; 4 minutes**

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