Therapeutic Ultrasound: a Research based perspective

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Objectives
Therapeutic Ultrasound

- Discuss a Researched based perspective for the clinical application of US
- Apply research related to dosing US
- Evaluate various coupling media
- Apply Clinical Model for dosing US based on tissue composition and stages of healing
- Discuss indications and contraindications
Past and Present Issues Related to US Research

- Dead animal Models (40 - 45°C range)
- Flawed research methods and designs
- Many US Practice patterns have been based on “Journal of anecdotal medicine”
- Baker KG. Phys Ther July 2001;81:1339-1351

- Problem of placebo vs placebo studies
- Reasonable expectations
Ultrasound

- Sinusoidal wave
- Thermal agent
- Mechanical agent
- Does not fall on electromagnetic spectrum
- Acoustical spectrum (above 20,000 HZ)
- Human ear hears sound between 16,000-20,000
Basic Overview of production of US

- A/C from wall • Piezoelectric crystal • crystal expands and contracts • results in production of sound waves • vibration of molecules within human tissue causes physiologic effects
Essential Terminology

- **Spatial Average Intensity** ("intensity" W/cm²)

- **Spatial Average Temporal Average Intensity** (SATA): describes the net intensity delivered based on the duty cycle selected
e.g. 1.0 W/cm², pulsed 50%, =.5 W/cm²

- **ERA**

- **BNR**
Frequency: Clinical Implications

- Depth of Penetration
  - 1 MHz....................Deep (up to 5 cm)
  - 3 MHz......Superficial (≤ 2.5 cm)

- Efficiency of heating:
  3 MHz heats approx 3 x’s faster than 1 MHz

Application technique

- Size of the treatment area: 2-3 x’s ERA
- Speed of sound head: *4-8 cm per second
- Coupling Issues
  - Air
  - Hair
  - Under water treatment

* Poster presentation NATA 2004 Baltimore
Pulsed US

- Minimizes unwanted heating effects at a given intensity proportional to the duty cycle selected
- SATA intensity is an important consideration in dosing PUS
- Myth: selecting PUS eliminates all heating effects at all intensities
The research question

What is the difference in the extent of tissue heating using the following US parameters?

CUS (3 MHz, .5 w/cm², 10 min)

vs.

PUS (3 MHz, 1.0 w/cm², pulsed 50%, 10 min)

CUS = continuous ultrasound
PUS = pulsed ultrasound
### Results SATA Study

**Gastrocnemius Muscle Temperature (°C) Changes (Mean ± SD) and Rate of Heating per Minute (°C/min) During a 10 minute Ultrasound Application**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Baseline</th>
<th>Peak</th>
<th>Change</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuous</strong></td>
<td>35.5± .9</td>
<td>38.4± .8</td>
<td>2.8± .8</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Pulsed†</strong></td>
<td>35.3± .7</td>
<td>38.1± .6</td>
<td>2.8± .7</td>
<td>0.28</td>
</tr>
</tbody>
</table>

* 0.5 W/cm² intensity, 100% duty cycle, 3 MHz
† 1.0 W/cm² intensity, 50% duty cycle, 3 MHz
Conclusion SATA study

- Pulsed ultrasound can heat
- “Inadvertent overdosing of acute inflammatory conditions is a possibility if low enough duty cycles and spatial average temporal average intensities are not selected”
Pulsed US (Nonthermal)

Physiologic Effects

- Increase macrophage responsiveness
- Increased intracellular calcium synthesis
- Increased skin and cell membrane permeability (greater than CUS)
- Increased protein synthesis by fibroblasts
- Increased early fibroblastic activity leading to accelerated tissue healing
Nonthermal US

- Mechanism of action
- Research on dosing for tissue healing
- Clinical recommendations for dosage
- PUS vs low dose continuous US (0.2 W/cm²)
- PUS advocated for phono
Mild (1º C) to vigorous heating (≥4ºC) is achievable

Extent of heat build up depends on:
- Frequency
- Intensity
- Duration of treatment
- Tissue composition
Clinical Example of Pearls and Pitfalls of Dosing US

- US to Piriformis Muscle for Deep Heating using 1.5 W/cm² at 1 MHz
- Note: A 4 deg Celsius net increase or a total tissue temp increase ≥ 40 deg Celsius is needed to optimize tissue extensibility
  
  

- How long should we sonate?
“The Answer”

- 1.5 W/cm² at a freq of 1 MHz generates a heating rate of .3°C/min (Draper et al. JOSPT. 1995;22:142-150)
- .3°C X 5 min = 1.5°C
- .3°C X 7 min = 2.1°C
- .3°C X 9 min = 2.7°C
- .3°C X 12 min = 3.6°C
- .3°C X 13 min = 3.9°C

- Heating rate (°C/min) from Draper et al JOSPT 1995.
Clinical Model for Dosing CUS
Considerations

- Stage of tissue healing
- Desired goal of treatment
- Depth of Target tissue
- Target tissue composition
- Tendon study (Chan et al JAT 33:2; 1998)
- Mild, moderate, vigorous heating
- Equipment (heating rates vary)
- 40 deg C threshold vs Net increase of 4 deg C
- Pt perception at 40 deg C (Merrick JOSPT, July 2003)
Clinical Dosing Model for vigorous heating

- The 4 classifications
- Deep muscle
- Superficial muscle
- Deep tendon/ligament
- Superficial tendon/ligament

Heating rate data for muscle from Draper et al JOSPT 1995.
Clinical Model for Dosing US

Vigorous Heating

- **Deep Muscle (3-5 cm deep)**
  - Duty Cycle: 100% (continuous)
  - Frequency: 1 MHz
  - Intensity: 1.5 W/cm²
  - Heating Rate: .3°C/min
  - Time: 13 min (13 min x .3°C/min = 3.9°C)

- Heating rate calculations may vary based on manufacturer (Merrick JOSPT July 2003)
Clinical Model for Dosing US
Vigorous Heating

- **Superficial Muscle (≤ 2.5 cm)**
  - Duty Cycle: 100% (continuous)
  - Frequency: 3 MHz
  - Intensity: .5 W/cm² – 1.0 W/cm²
  - Heating Rate .3° C/min - .6° C/min
  - Time: 13 min at .5 W/cm² (.3 x 13=3.9°C)
    7 min at 1.0 W/cm² (.6 x 7=4.2°C)

- Caution: 3 MHz heats 3x’s greater than 1 MHz
  patient feedback over rules all dosage calculations
Clinical Model for Dosing US

Vigorous Heating

- **Superficial Tendon/Ligament (≤2.5 cm)**
  - Duty Cycle: 100% (continuous)
  - Frequency: 3 MHz
  - Intensity: .5 W/cm² – 1.0 W/cm²
  - Time: 7 min at .5 W/cm²
    - 4-5 min at 1.0 W/cm²
  - Rationale: superficial tendon heats 3.45 faster than muscle than mm.
    (Chan et al. J Athl Train. 1998;33:130-135)
Clinical Model for Dosing US

Vigorous Heating

- **Deep Tendon/Ligament (3-5 cm deep)**
  - Duty Cycle: 100% (continuous)
  - Frequency: 1 MHz
  - Intensity: 1.5 W/cm²
  - Time: 10 min
  - Rationale: Collagen rich tissue such as tendon heats 3.45 x’s faster than mm. However, some US is absorbed in superficial tissue prior to reaching deep tissue.
Clinical Recommendations for the Use of Pulsed US

- *Pulsed US - Superficial Tissue (≤2.5 cm)*
  - Duty Cycle: 20%
  - Frequency: 3 MHz
  - ≤ .5 W/cm²
  - Time: 7 min
  - Rationale……..
Clinical Recommendations for Pulsed US

- Pulsed US – Deep Tissue (≥3 cm)
  - Duty Cycle: 20%
  - Frequency: 1 MHz
  - ≤ 0.5 W/cm²
  - Time: 7 min
  - Rationale: ....
Stretching windows

“time period of vigorous heating when tissue will undergo greatest elongation”

- Muscle: 3.3 minute window post sonation
- Tendon/ligament: 5 minute window post sonation
- Clinical implications: begin to put tissue on stretch during the tail end of the treatment, when the tissue is warm and continue stretching or mobilization, or cross friction STM during the first five minutes post treatment

Draper et al. Athl Train. 1995;30:4
Draper et al. Athl Train. 1996;31:139-143
Tendinopathy

- Acute Tendonitis

  V.S.

  - Tendinosis: collagen degeneration with no histological signs of inflammation

- Differences in clinical recommendations for treatment…….
Additive Effect of HP + US

- Hot pack produces peak increase in muscle (gastroc) tissue temperature at 15 minute duration
  (3.4°C at 1 cm, 1.0°C at 3 cm)

- Preheating with hot pack (15 min) prior to 1 MHz CUS at 1.5 W/cm² (10 min) facilitates deep/vigorous heating with 3 minutes less sonation time

Coupling media

- Gel: “gold standard”
- Underwater technique: Heats mm to approximately 50% of the peak temp obtained with gel.¹
- Aquaflex disc: No diff in mm temp increase when compared to gel.²
- Others

All phono preparations are not equal

- Hydrocortisone creams do not transmit Ultrasound effectively\(^1\)
- Theragesic\(^{\text{TM}}\)
- Biofreeze\(^{\text{TM}}\) mixed 1:1 with Aquasonic\(^{\text{TM}}\) gel\(^2\)
- Others

**Exogen Home US Unit**

- Enhanced bone healing of nonunion fractures.
- Unadjustable preset Low intensity PUS parameters
  - 1.5 MHz frequency
  - 20% duty cycle
  - .15 W/cm²
- 20-30 minutes daily
Contraindications

- Cancerous Lesions\textsuperscript{1,2,3,4,5}
- Acute Injury or hemorrhage (thermal)\textsuperscript{1,5}
- Circulatory Insufficiency (thermal)\textsuperscript{1,3,5}
- Deficits in sensation over the area to be treated (thermal)\textsuperscript{1,3,5}
- Methylmethacrylate (cemented joint replacements)\textsuperscript{2,4}
- Over Plastic implants\textsuperscript{1,2}

\textsuperscript{1}=Belanger, \textsuperscript{2}=Cameron, \textsuperscript{3}=Michlovitz \textsuperscript{4}= Denegar, \textsuperscript{5}= Starkey
Contraindications Cont..

- Pacemaker\textsuperscript{1,2,3,4,5}
- Over the heart \textsuperscript{3,4,5}
- Over skin that has been exposed to radiation therapy\textsuperscript{1}
- Over the abdomen low back, or pelvic area during pregnancy\textsuperscript{1,2,3,4,5}
- Implanted neurostimulation systems (medtronic type)\textsuperscript{1}

\textsuperscript{1}=Belanger, 2=Cameron, 3=Michlovitz, 4=Denegar, 5=Starkey
Contraindications Cont..

- Over thrombotic areas (thrombophlebitis/DVT)\textsuperscript{1,2,3,5}
- Over infected lesions\textsuperscript{1,4,5}
- Over the eyes\textsuperscript{1,2,3,4,5}
- Over the reproductive organs\textsuperscript{1,2,3,4,5}
- Directly over the spinal cord after laminectomy\textsuperscript{1,2,4}

1=Belanger, 2= Cameron, 3=Micloivitz, 4 = Deneger , 5=Starkey
A few words about..........

- Metal implants
- Epiphyseal plates
E-mail Josephjag4@aol.com

Thank you

Questions