Second International Symposium on Therapeutic Ultrasound

Applied Physics Laboratory, University of Washington
29 July — 1 August 2002  Seattle, Washington USA

Washington Athletic Club
6th & Madison, Seattle, WA

Deadline for receipt of Abstracts is 1 May 2002.
Review the preliminary list of accepted abstracts.
Go directly to online submission, or visit the Technical Program page to learn more.
You may also register online, or visit the Registration page for more information.

Sponsored by:
Telemedicine and Advanced Technology Research Center,
U.S. Army Medical Research and Materiel Command
Vesna already showed this slide
And this one too....
The KIA problem (posed by Col. Satava at DARPA in 1994): 50% of combat casualty mortality results from exsanguination.

OBJECTIVE: Construct a portable, ultrasound-guided acoustic hemostasis device that could be used near the battlefield to reduce mortality from severe blood loss.

Ultrasound scanners can detect and locate internal bleeding.

HIFU can stop bleeding.
The application of hand-held-HIFU to punctured and lacerated vessels can induce hemostasis without occlusion.
Cinematographic comparisons between Electrocautery and Acoustocautery
Cinephotographic illustrations of acoustocautery

Lung

Spleen
Acoustic Hemostasis is a unique technology that has been shown to be an effective means of hemorrhage control.
HIFU can be used for tissue ablation and bloodless resection
UST: The SonoStat 400

Control Module

Transducer and Probe

Disposable cones
Modeling: Acoustic field and lesion generation

Acoustic field generation

Lesion in turkey tissue

Computed lesions
HIFU generates high temperatures only on surface of blood vessels and not in interior.
Demonstration of Image-guided Transcutaneous Acoustic Hemostasis
Successful technology spin-off: THERUS, INC.

1. Successful human trials in Germany (approximately 60 patients)
2. Clinical trials underway with patients in US
3. Boston Scientific has $150 million option to purchase THERUS
Therus Corporation
SoundSeal™ Noninvasive Hemostasis System

Disposable Patient Interface (DPI)

Applicator

Mobile Generator
Grades II and III liver injuries
Demonstration of image-guided transcutaneous venous occlusion

Both vein and artery patent

Vein is now occluded
Esophageal and Gastric Varices

- Dilated veins on the mucosal surface of the esophagus and stomach
- Bleeding from varices is a major cause of morbidity and mortality in patients with cirrhosis
- Varices develop due to portal hypertension
Current Methods of Endoscopic Therapy for Varices

- Band ligation
  - Highly effective in arresting active bleeding esophageal varices
  - Minimal complications
    - Mucosal ulceration
    - Pain
    - Risk of re-bleeding
  - Limitations:
    - High rate of recurrence (50%)
    - Requires multiple sessions

• 18 vessels lacerated
• Treated in 5 second intervals until bleeding stopped
• 3 vessels were given a sham treatment (ultrasound off)
• 3 animals in the treatment group were sacrificed at each time point (0, 2, 7, 14, 28 days)
Histology

A. Normal Day 0

B. Day 0

C. Day 2

D. Day 7

E. Day 14

F. Day 28
Adverse Effects

7 days after treatment

28 days after treatment
Experimental Setup

- Driving Electronics
- Water-filled Cone
- Auricular Vein
- Agar Gel
- Sound Absorbing Material

US Propagation

- Proximal Surface
- Distal Surface
# Conditions for Cavitation-Occlusion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1.17 MHz</td>
</tr>
<tr>
<td>Peak negative pressure</td>
<td>1, 3, 6.5, 9 MPa</td>
</tr>
<tr>
<td>Pulse length</td>
<td>500 cycles</td>
</tr>
<tr>
<td>Pulse repetition frequency (PRF)</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Duty factor</td>
<td>0.042%</td>
</tr>
<tr>
<td>Exposure duration</td>
<td>120 seconds</td>
</tr>
</tbody>
</table>
1 MPa, 120 s

Low Mag

High Mag

-UCA

+UCA
3 MPa, 120 s

Low Mag

High Mag

- UCA

+ UCA
6.5 MPa, 120 s

Low Mag

- UCA

High Mag

+ UCA
9 MPa, 120 s

Low Mag

High Mag

-UCA

+UCA
IC Dose Measurements/PCD

- RMS Amplitude in Specific Window
  Center \( f_c = \frac{(f_3 + f_4)}{2} \)
  Window Width: 0.2 MHz

- FFT Amplitude (V)
- Frequency (MHz)
- RMS of FFT (V)
- Time (min)
SEM
Intravascular Thrombus
Demonstration of image-guided transcutaneous HIFU surgery

QuickTime™ and a decompressor are needed to see this picture.
LONG EXPOSURE HIFU: HYPERECHOIC SPOT CORRESPONDS TO A LESION
HIFU Lesion Development with and without overpressure

Ambient pressure only

Approximately 10 MPa overpressure

Vera Khokhlova, et al.
Numerical modeling

Waveform distortion

Nonlinear enhanced absorption

Shock formation distance
Circular scans in liver (Simulation and ex vivo measurements)

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.
Circular scans in liver (ex vivo measurements)
Circular scans in liver (Simulation and ex vivo validation)

<table>
<thead>
<tr>
<th>Track</th>
<th>Simulation</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.20</td>
<td>0.37 ± 0.09</td>
</tr>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.48 ± 0.11</td>
</tr>
<tr>
<td>3</td>
<td>0.60</td>
<td>0.64 ± 0.14</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
<td>1.22 ± 0.19</td>
</tr>
</tbody>
</table>
Circular scans in liver (Simulation and ex vivo validation)

No pre-focal lesion

Well-defined circular lesions at focus
Lesion imaging in tissue gel phantom

QuickTime™ and a Cinepak decompressor are needed to see this picture.
Cavitation *in vivo*--ESWL

QuickTime™ and a Video decompressor are needed to see this picture.
Hyperechoic region histology: Results

0 hour
- Intra/extra-cellular cavities
- Ruptured cells

$I_{SATP} = 4390 \text{ W/cm}^2$
$t = 31.25 \text{ ms}$
Numerical modeling

Waveform distortion

Nonlinear enhanced absorption
Lesion stripes--different velocity
Same acoustic energy

212 mV, 2 mm/s

519 mV, 6 mm/s
Temperature at the HIFU focus can be monitored in real time.
Transducer Array