Ultrasound Guided HIFU Ablation (USgFUS)

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Honestly, if there was a virtual prostate exam, don't you think I'd want to be the first to know?“
Multi-Functional HIFU Probe
“See, Treat, and Track”
Most HIFU systems deliver a series of discrete ablations or “shots”

Each shot is delivered in 3 seconds

3 - 6 second pause after shot allows for imaging and tissue cooling

Staggered pattern of shot dispersion allows cooling of tissue

Probe cooled with chilled water
It is possible to deliver heat continuously, moving the focal point over volume of tissue to be ablated.

Tissue back to surface of the probe is destroyed eliminating need for probe cooling and pauses for cooling.

Elimination of “active” cooling results in a more efficient treatment delivery (3 – 6x).
Sonatherm
Integrated Imaging/Therapy

Sonatherm Laparoscopic Probe Tip
• Three (3) distinct operating crystals (one imaging and two therapy)
• Robotic scanning of transducers for volumetric imaging & ablation
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focal Length:</td>
<td>35 mm</td>
</tr>
<tr>
<td>Lesion Depth:</td>
<td>30 mm (maximum)</td>
</tr>
<tr>
<td>Lesion L/W:</td>
<td>30 x 7 mm (maximum)</td>
</tr>
<tr>
<td>Imaging f:</td>
<td>6.5 MHz</td>
</tr>
<tr>
<td>Therapy f:</td>
<td>4 MHz</td>
</tr>
<tr>
<td>Max Output:</td>
<td>35 watts</td>
</tr>
<tr>
<td>Lesion Shape:</td>
<td>Sector</td>
</tr>
<tr>
<td>Treatment Times:</td>
<td>10 min for 12 cc lesion (2 cm x 2 cm x 3 cm)</td>
</tr>
<tr>
<td></td>
<td>30 min for 35 cc lesion</td>
</tr>
<tr>
<td></td>
<td>(Sonablate = 180 min)</td>
</tr>
</tbody>
</table>
Sonatherm
Ex-Vivo
Role of US
HIFU Ablation

- **Image Fusion for localization and targeting**
- Treatment Planning
- Treatment Delivery
- Temperature Monitoring
- Tissue Typing
IMAGE FUSION

SmartTarget

University College London (UCL), United Kingdom

UCL Centre for Medical Image Computing
UCL Department of Medical Physics & Bioengineering
UCL Division of Surgery & Interventional Science
• **Automatic, deformable image registration/fusion**
  - Compensates for shape changes due to ultrasound probe pressure and gland swelling

• **Accuracy**
  - Error of 2.4mm
  - >90% hit rate for a 0.5cc spherical tumour

• **Simple workflow**
  - Minimal user interaction during a surgical procedure

• **Versatility**
  - Configurable for use with biopsy and all minimally-invasive therapies including HIFU

*Patent Pending*
Sonablate® New Software Development

3D Deformable Model

- Volumetric model
- Deformation aspects
- Statistical shape analysis
- 3D organ models

SmartTarget

Courtesy of Professor Mark Emberton, M.D., University College London
1. MR Analysis & Contouring
2. Deformable Model Generation
3. Acquire 3D TRUS Image
4. Register Model to 3D TRUS Image
5. Targeted Therapy Planning & Delivery

Before Procedure (Steps 1-3)

During Procedure (Steps 4-5)

4a. Load 3D US volume file
4b. Load Deformable Model
4c. Define Volume Points in US Image
4d. Register Model to 3D US Image
4e. Export Tumor Data File
IMAGE FUSION
Sonaplan

Export image volume to SmartTarget
Mark positions on prostate capsule
Register MRI to US with SmartTarget

IMAGE FUSION
Sonaplan
Role of US Imaging

HIFU Ablation

- Image Fusion for localization and targeting
- **Treatment Planning**
- Treatment Delivery
- Temperature Monitoring
- Tissue Typing
Import structures into SonaPlan
IMAGE FUSION
Sonaplan

View of target on planning screen
IMAGE FUSION
Sonaplan

Outline with desired margin
IMAGE FUSION
Sonaplan
Complete treatment plan
US-based Planning
Role of US
HIFU Ablation

- Image Fusion for localization and targeting
- Treatment Planning
- Treatment Delivery
- Temperature Monitoring
- Tissue Typing
Sonatherm Treatment

Image update during HIFU
Sonatherm Treatment

Image update during HIFU
Sonatherm Treatment

Image update during HIFU
Sonatherm Treatment

Ablation Complete
Role of US
HIFU Ablation

- Image Fusion for localization and targeting
- Treatment Planning
- Treatment Delivery
- **Temperature Monitoring**
- Tissue Typing
MR thermometry for continuous temperature feedback

\[ y = -0.008x - 0.0005 \]

\[ R^2 = 0.9958 \]
INCREASED ATTENUATION DUE TO TISSUE TEMPERATURE ELEVATION

Attenuation Coefficient Vs temperature for Dog Muscle, Liver, and Kidney Tissue In Vitro

Temperature Change Monitoring (T C M)

Temperature Change Monitoring (TCM)

- Spectral analysis on RF backscattered (pulse-echo) ultrasound signals acquired before and immediately following HIFU exposure
- Analysis generates energy spectra of signals
- Difference used as estimator for changes in tissue temperature

<table>
<thead>
<tr>
<th>TCM Zones</th>
<th>Average Temperature Difference between Calculated (linear fitted) and Measured (°C)</th>
<th>Standard Deviation Difference between Calculated (linear fitted) and Measured (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Yellow</td>
<td>5.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Orange</td>
<td>7.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

*Patented Not Cleared For Use*
Temperature Change Monitoring (T C M)
Temperature Change Monitoring (T C M)

Clinical Example of Second “Pass“ with HIFU

Replacing “Greens“ with “Yellow/Orange“

First Pass

Second Pass
Role of US
HIFU Ablation

- Treatment Planning
- Image Fusion for localization and targeting
- Treatment Delivery
- Temperature Monitoring
- Tissue Typing
“Well, yes, we could fix it in Photoshop, but your arm would still be broken.”
Use of Ultrasound Pulse-Echo (RF) data for Quantitative Features Analysis

Parametric Image
Display of PCa in Real Time
Histology of the same prostate
Anterior Tumor: 3-D Image (base view)
Use of Ultrasound for Anatomic Feature Analysis

Detrusor Muscle

Transitional epithelium

Adventitia
USgFUS

Complementary to Existing Approaches

"Judging by your X-rays, I'd say you've been exposed to too much radiation."

"Hi, I'll be performing your surgery tomorrow."
Final Thoughts
Cost of Health Care