High Intensity Focused Ultrasound (HIFU)
The Future of Local Control for Cancer Therapy?
Techniques and Challenges

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INTENSITY RANGES

Diagnostic US: 0.01-0.1 Wcm$^{-2}$

Therapy US: 0.1-3.5 Wcm$^{-2}$

Surgical US: 800 - 1500 Wcm$^{-2}$
HIFU/FUS Principles

Transducer

Tumour

Target organ

Skin

Undamaged liver in front of focus

‘Lesion’ of coagulative necrosis at focus (12x3mm)
Heating for tissue destruction

55 °C 1 second

>80 °C

Energy is deposited fast enough for cooling by thermal conduction & blood perfusion to be insignificant
Single  Array  Scanned track

Net result:
IMAGING
for treatment monitoring

- Diagnostic Ultrasound
- MRI
Changes in real-time US images during HIFU procedure for Large human HCC

Imaging HIFU treatments: other methods under investigation

- MRI thermometry
  functional imaging

- US elastography
  radiation force imaging
  temperature imaging
  functional imaging
Tumour + normal tissue margin is treated

Breast: 1-2 cm
Liver: 1-3 cm
Bone: 3-5 cm
Kidney: 1 cm

Surgical resection (normal tissue) margin
Transducers

- Frequencies from 0.5 to 4.0 MHz
- Spatial peak intensities up to 20kWcm\(^{-2}\)
- Focal lengths from 3 to 15 cm
- Many different geometries
- Phased arrays
  - multiple simultaneous foci
Extra-corporeal HIFU
Extracorporeal HIFU Devices

US guided

MRI guided

Haifu

Insightec

Shanghai Aishen

DKFZ Siemens

Minayang

Univ. Bordeaux

China Medical Technologies
HIFU Unit
Churchill Hospital, Oxford
HAIFU ‘JC-Tumor Therapy System’
HIFU in the PROSTATE
Transrectal devices

'Ablatherm' device, EDAP Technomed, France

Sonablate 500, Focus Surgery, USA
Integrated Probe

Therapy:
- Large aperture transducer
- 3 MHz working frequency
- Piezo-composite technology

Imaging:
- 128 elements electronic array
- B&K image processing
- 7.5 MHz:
- Real time imaging
Extracorporeal HIFU

Clinical Trials

Churchill Hospital, Oxford
Endpoints

- Primary
  - Adverse events and variations in clinical laboratory data in first 28 days after treatment

- Secondary
  - Radiological & Histological evaluation
LIVER Cancer
Metastatic colorectal carcinoma

T1 weighted images, 1 minute post IV contrast

Pre-HIFU 12 days post-HIFU
KIDNEY Cancer
Primary renal tumour - not fit for resection

T1W MRI (1min post gadolinium contrast) subtraction films

Pre HIFU 12 days post HIFU
<table>
<thead>
<tr>
<th></th>
<th>Range (mm)</th>
<th>Mean (mm)</th>
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</thead>
<tbody>
<tr>
<td>Size (maximum transverse diameter on US)</td>
<td>17-120</td>
<td>38</td>
</tr>
<tr>
<td>Skin to superficial margin of tumour</td>
<td>14-115</td>
<td>39</td>
</tr>
<tr>
<td>Skin to deep margin of tumour</td>
<td>44-185</td>
<td>71</td>
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</table>
Disadvantages and future challenges of FUS

- Does not travel through air or bone
- Equipment expensive initially
- Treatment is slow
Approaches to reduction of treatment times:

1. New scanning & transducer geometries

2. Tissue modification
Tissue modification:

1. Introduction of gas bubbles
   - contrast agents
   - cavitation bubbles

2. Reduction of vascular perfusion
   - TACE
   - vascular occlusion
Summary:

1. HIFU has already shown great promise in the clinic

2. In order for HIFU to become more widely accepted we need to understand and improve the ultrasonic energy delivery and treatment monitoring
Strengths of FUS

- Non-invasive method of programmed tissue destruction
- High spatial specificity
- Damage is “bloodless”
Strengths of FUS

- Minimal normal tissue toxicity
- Repeatable
- Tissue sparing possible (NVB)
- Salvage treatment
Summer School on

THERAPEUTIC ULTRASOUND

CARGESE, April 10th – 13th 2007

Directors:
Gail ter Haar & Mathias Fink

Organised by:
Jean-François Aubry, Mickaël Tanter

http://www.loa.espci.fr/therapeutic.htm