High Intensity Focused Ultrasound (HIFU)

The Future of Local Control for Cancer Therapy?

Techniques and Challenges

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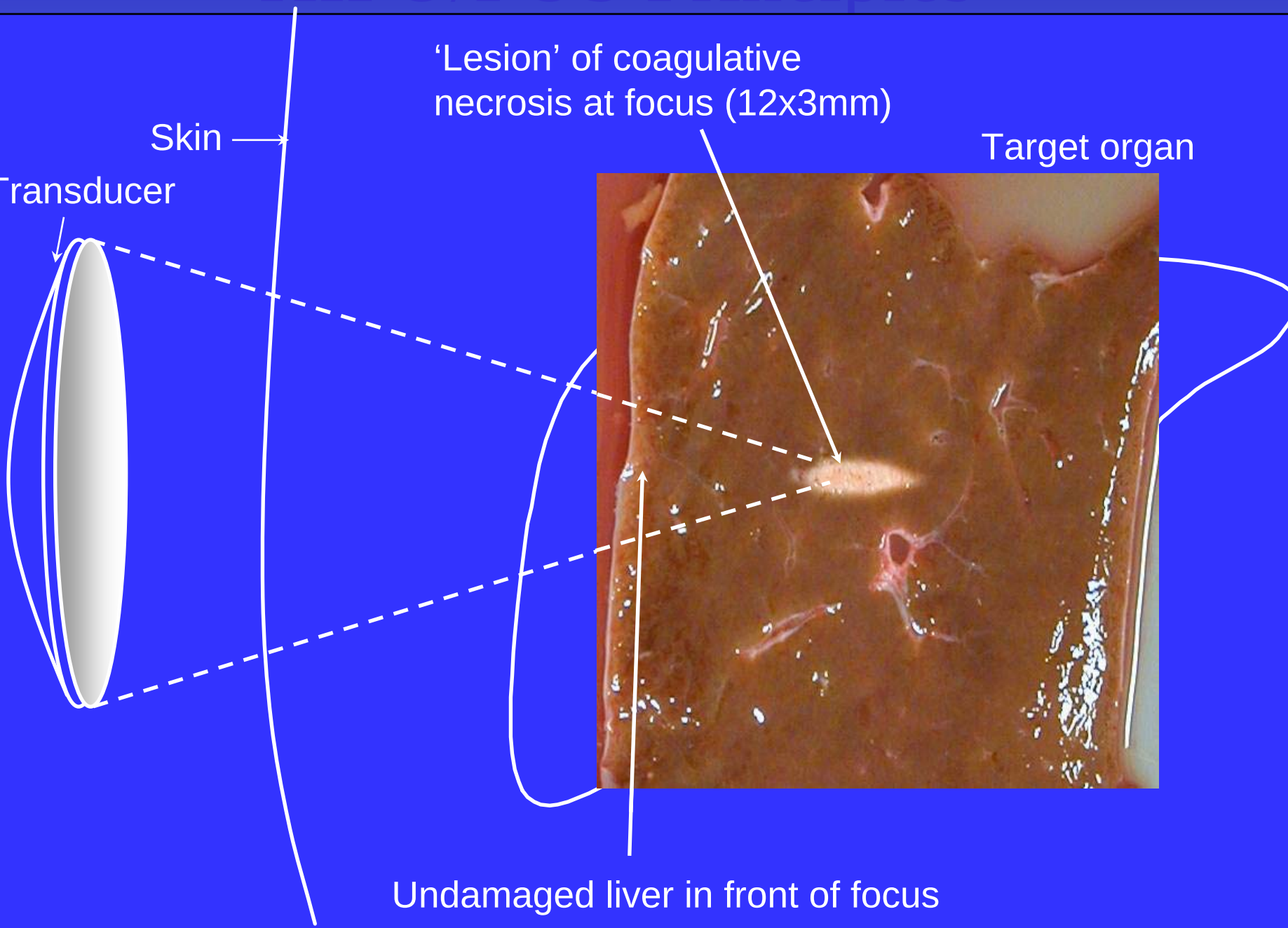
INTENSITY RANGES

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

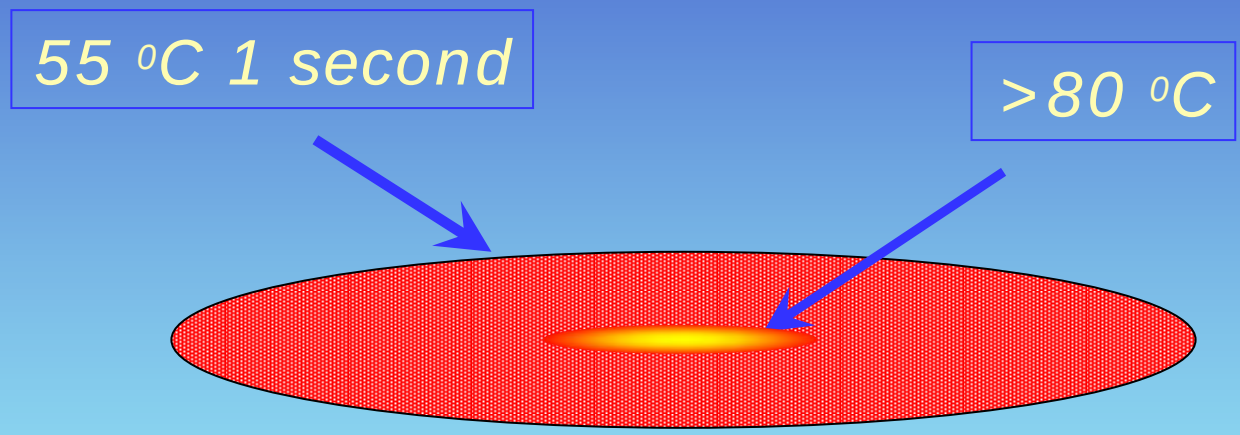
Therapy US: 0.1-3.5 Wcm^{-2}

Surgical US: 800 -1500 Wcm^{-2}

HIFU/FUS Principles



Heating for tissue destruction

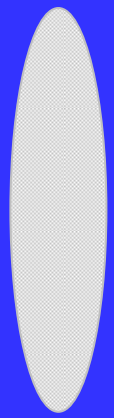


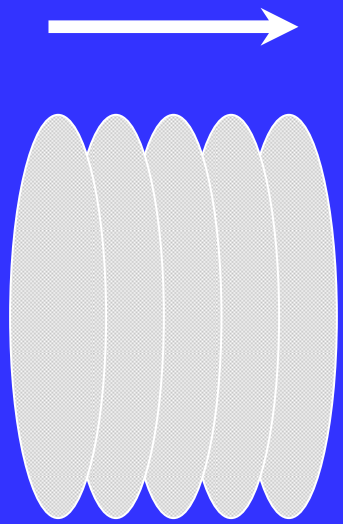
Energy is deposited fast enough for cooling by thermal conduction & blood perfusion to be insignificant

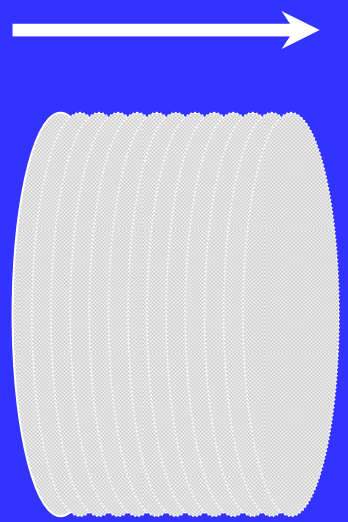
Single

Array

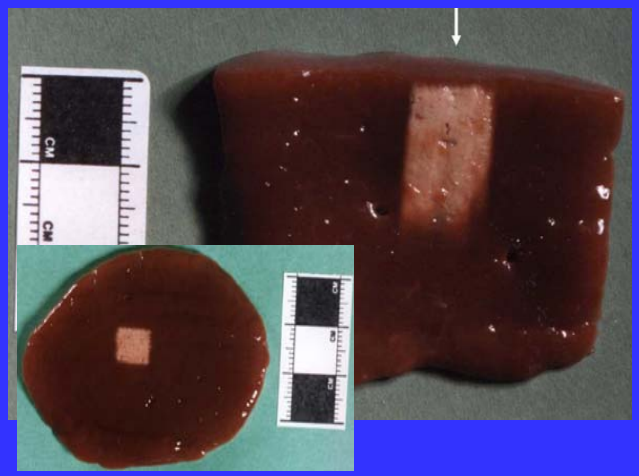
Scanned track







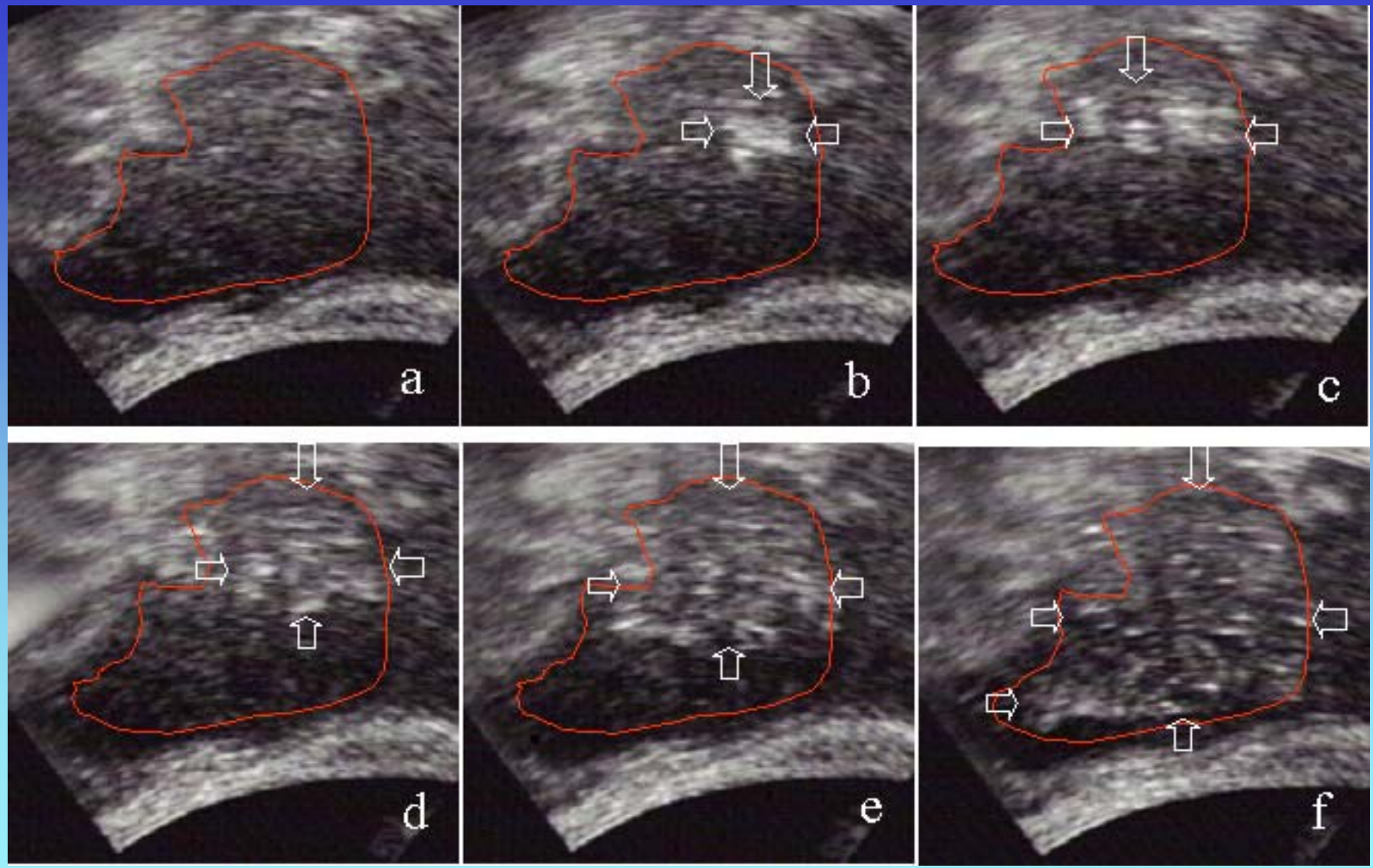
Net result:



IMAGING
for treatment monitoring

- Diagnostic Ultrasound
- MRI

Monitoring and Assessing Tumour Response



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

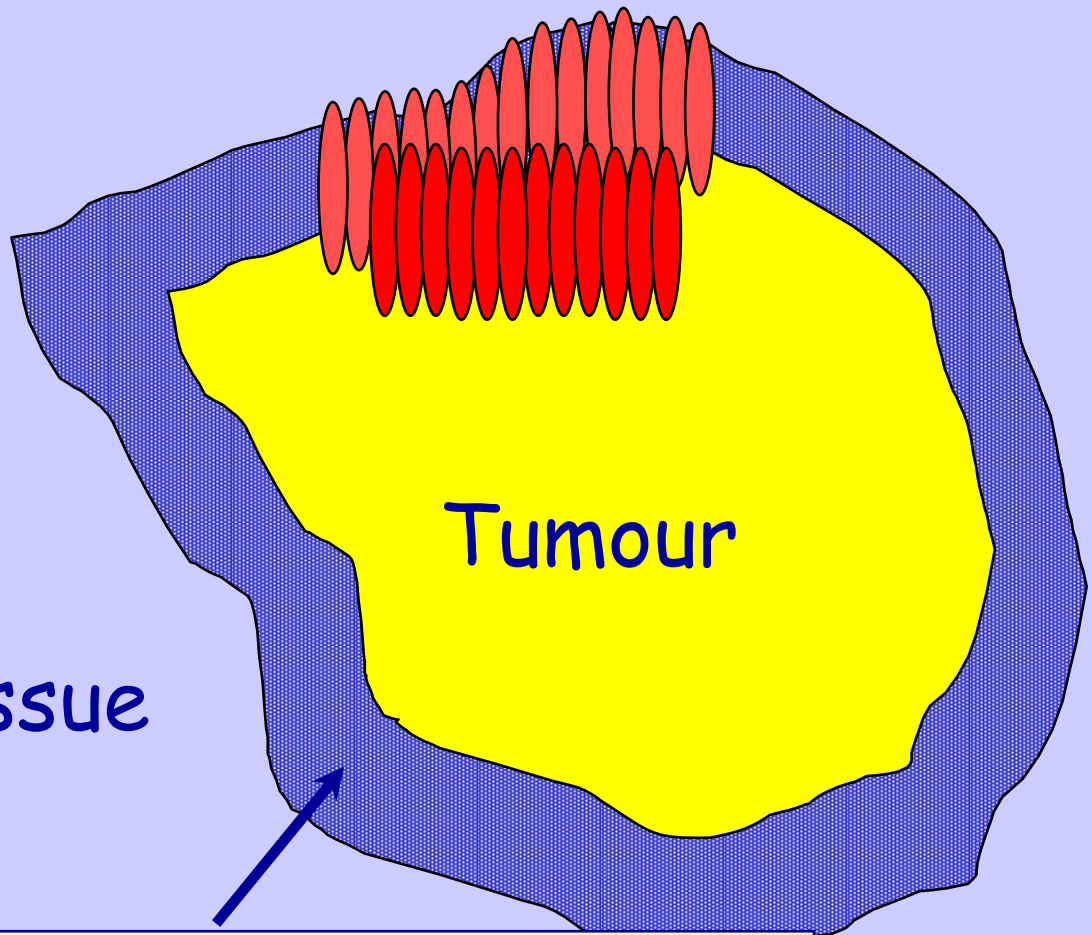
Wu F *et al* 2004 Ann. Surg. Oncology 11: 1061-1069

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

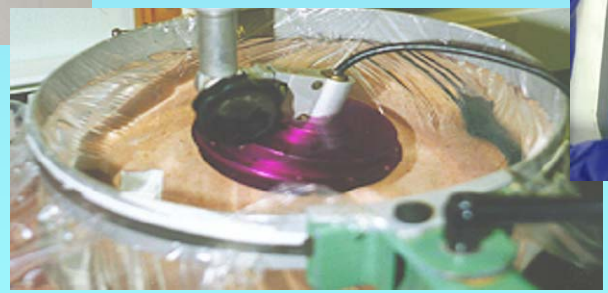
Breast : 1-2 cm
Liver : 1-3 cm
Bone : 3-5 cm
Kidney: 1 cm



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

HIFU Unit
Churchill Hospital, Oxford

HAIFU 'JC-Tumor Therapy System'

HIFU in the PROSTATE

Transrectal devices

CE marked

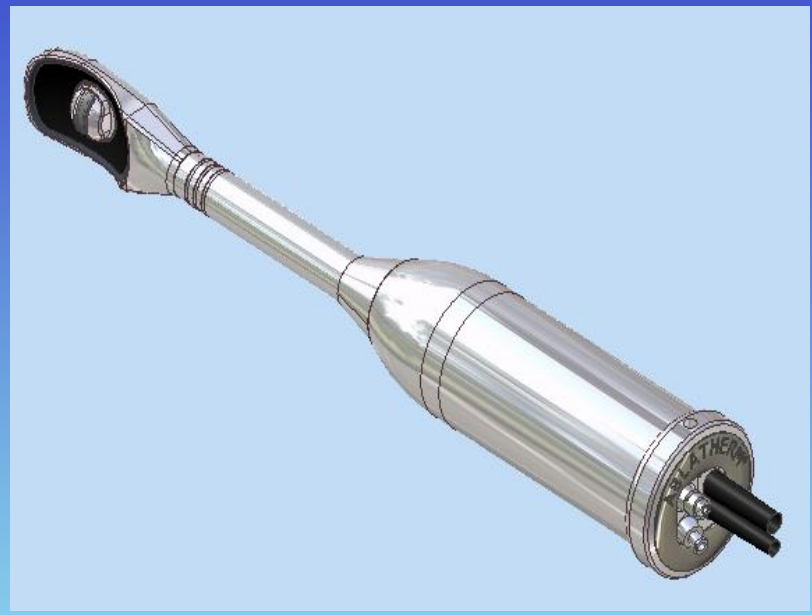
'Ablatherm' device,
EDAP Technomed,
France

Sonablate 500, Focus Surgery,
USA

Integrated Probe

Imaging:

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



Therapy:

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

edap
THE HIFU COMPANY

Extracorporeal HIFU

Clinical Trials

Churchill Hospital, Oxford

Endpoints

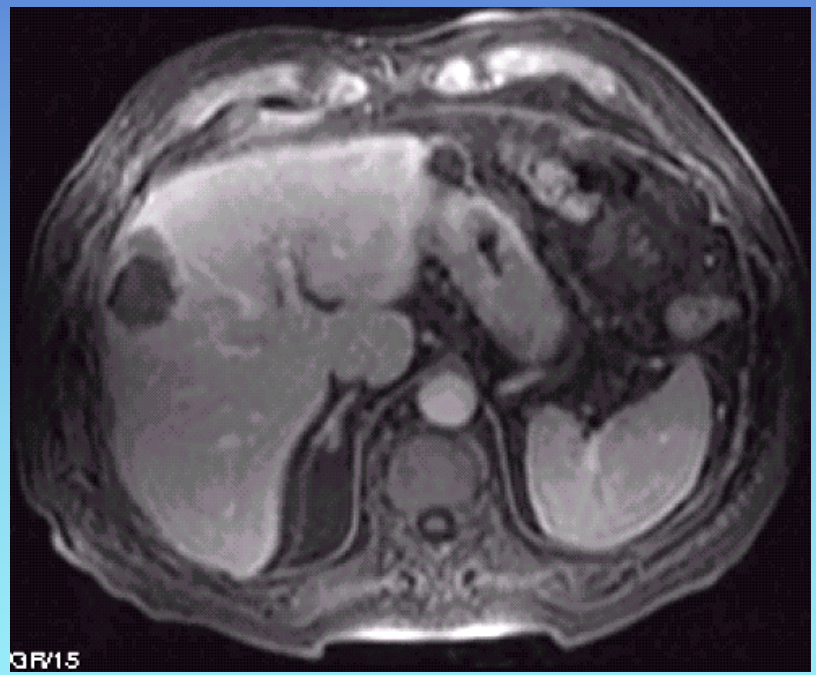
- Primary
  - Adverse events and variations in clinical laboratory data in first 28 days after treatment
- Secondary
  - Radiological & Histological evaluation

LIVER Cancer

Metastatic colorectal carcinoma

T1 weighted images, 1 minute post IV contrast

Pre-HIFU

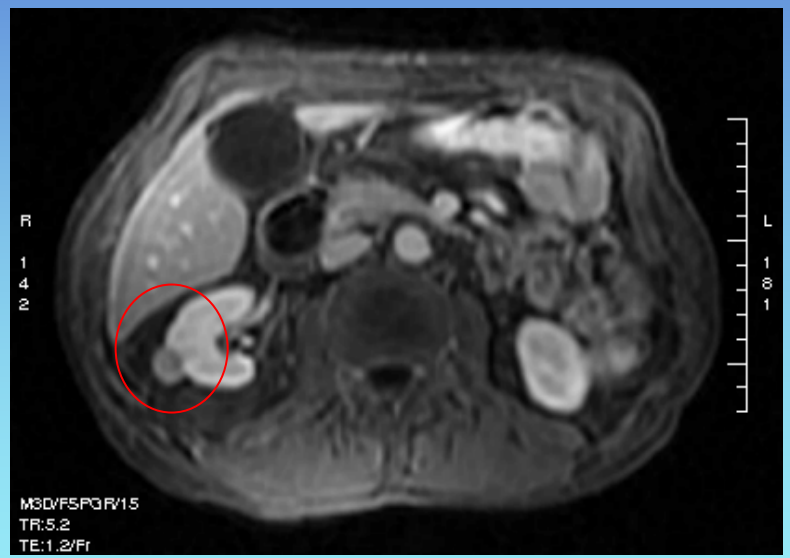


12 days post-HIFU

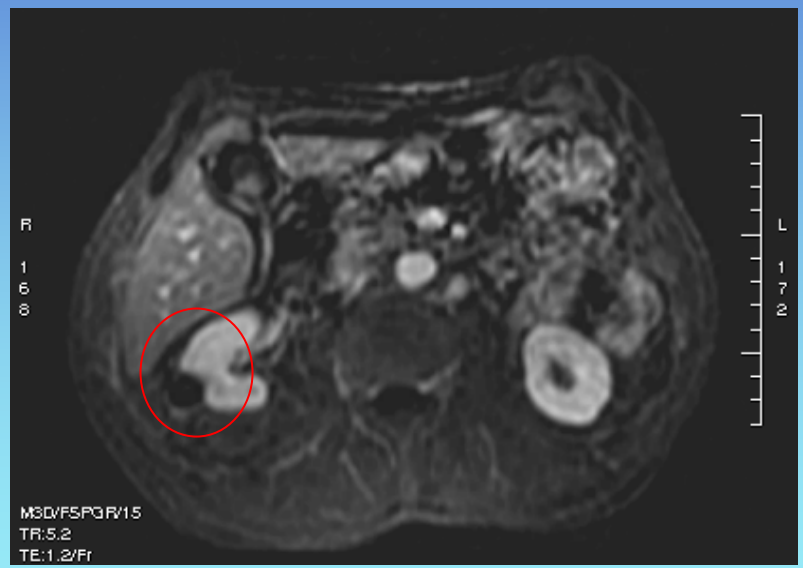
KIDNEY Cancer

Primary renal tumour – not fit for resection

T1W MRI (1min post gadolinium contrast) subtraction films



Pre HIFU



12 days post HIFU

Tumour Characteristics

	Range (mm)	Mean (mm)
Size (maximum transverse diameter on US)	17-120	38
Skin to superficial margin of tumour	14-115	39
Skin to deep margin of tumour	44-185	71

Disadvantages and future challenges of FUS

- Does not travel through air or bone
- Equipment Expensive initially
- Treatment is slow

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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"

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Strengths of FUS

- ⇨ Minimal normal tissue toxicity
- ⇨ Repeatable
- ⇨ Tissue sparing possible (NVB)
- ⇨ Salvage treatment

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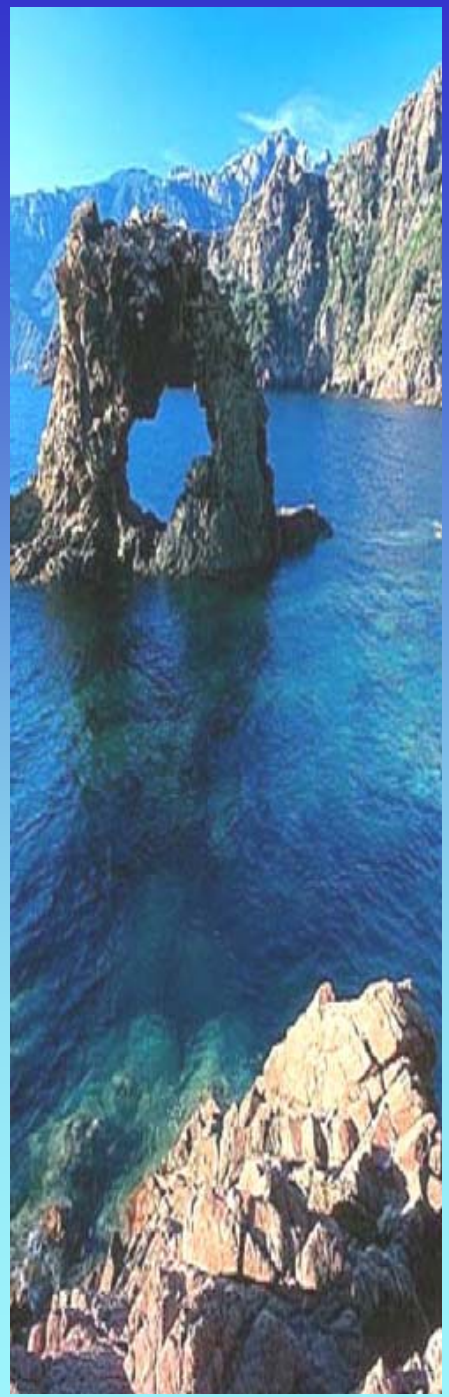

Summer School on

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