

Two treatment strategies using a therapy / imaging rotating transducer

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Introduction

Interstitial high-intensity ultrasound therapy :
Miniature transducer brought in contact with deep-seated tumors.
External imaging for monitoring and guiding the treatment can be difficult.



Aim

Add an imaging function to the therapy probe for guiding and monitoring :
A dual mode transducer was designed and built.
Two strategies for combining therapy and real time imaging were tested in vitro.

Transducer :

-11 MHz, 2.5x7.5 mm², cylindrically focused at 10 mm in its short dimension (fig. 1).
-Optimized piezocomposite, acoustic matching layer and electrical matching circuit.
=> good therapy and imaging capabilities :

-64 % transmit efficiency was measured at 11 MHz. Intensities up to 30 W/cm² could be emitted continuously.
-Size of the -6 dB point spread function at 10 mm : 0.2 mm x 0.5 mm (fig. 3). Lateral resolution <1 mm in ROI.

Driving system for imaging and therapy (fig. 4) :

- The transducer was rotated by a motor through a 1.2 m flexible shaft (fig. 2).
- Therapeutic excitation was provided by a signal generator and an amplifier.
- An ultrasound pulser/receiver was used for imaging. Acquired data were transferred to a computer for processing.
- A mechanical relay (switching time : 5 ms) was used to switch from therapy to imaging.
- Switching was synchronized either on the position of the motor or on a periodic trigger provided by the computer.
- Therapy was inhibited during imaging periods.

Material

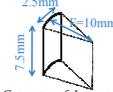


Fig 1. Geometry of the transducer

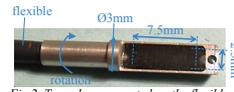


Fig 2. Transducer mounted on the flexible

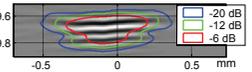


Fig 3. Point spread function at focal distance

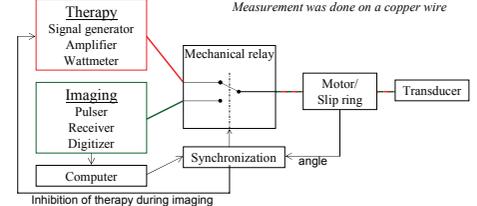
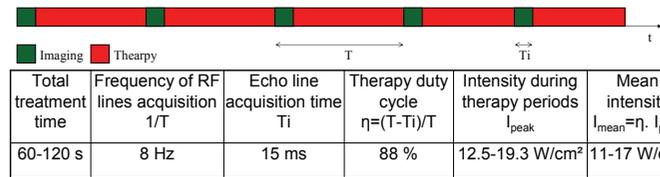


Fig 4. Driving system

Methods : Description of the two treatment strategies

Still transducer :

- The transducer did not move during the formation of thermal lesions
- Therapy was periodically interrupted in order to acquire RF lines (see timeline below)

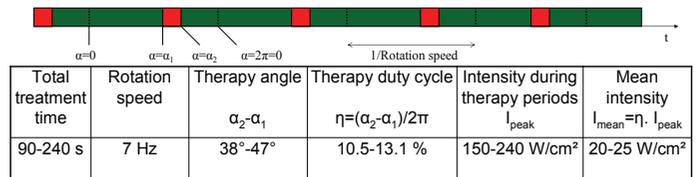


- B-mode images can be built before and after therapy.
- Standard M-Mode images were displayed on-line during the treatment
- 1D strain images were calculated after the treatment

Experiments were conducted in vitro on degassed pig liver samples at ambient temperature.

Fast rotating transducer :

- The transducer rotated continuously as in conventional endo-echography
- Imaging was interrupted over a small angle (α₁ to α₂) in order to perform therapy :

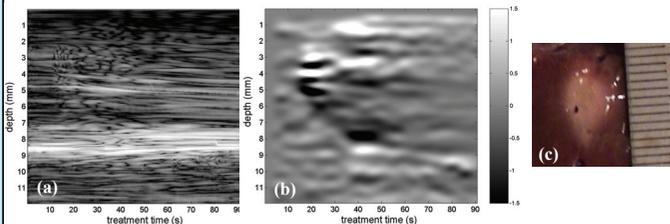


- One rotation over 7 was done without therapy in order to obtain images over 360°
- B mode images were displayed on-line during treatment
- 2D strain images were computed after the treatment

Results

Still transducer :

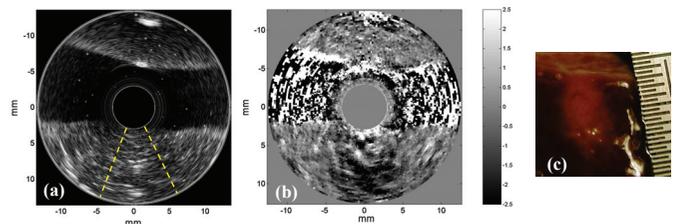
- Up to 9 mm deep lesions were obtained.
- Changes in the speckle pattern were observed on M-mode images during treatments in most cases (19/24) where a lesion was induced.
- Apparent strain was visible on the strain images when a lesion was induced.



(a) M-mode image during a still transducer treatment with I_{mean}=17 W/cm²; 120 s. The transducer was on the top of the image. Changes in speckle occurred after 20 s. (b) Corresponding strain rate image (%/s). After 20 s, expansion appeared near the transducer, and contraction further away. (c) Corresponding picture of the liver sample after treatment.

Fast rotating transducer :

- Up to 8 mm deep elementary lesions were obtained.
- No change was observed during treatment on standard B-mode images.
- Apparent strain was visible in the targeted zone on the strain images.



(a) B-mode image during a fast rotating transducer treatment with I_{mean}=25 W/cm²; 240 s. Dotted lines show the heated zone. No change was seen during treatment. (b) Cumulated strain over the first 30 seconds (%). An expansion zone appeared near the transducer, and a contraction zone further away. (c) Corresponding picture of the liver sample after treatment.

Discussion and conclusion

- Up to 8 mm deep elementary lesions have been obtained with both methods.

-Deeper lesions would have been obtained at lower frequencies for both methods. The intensity of the field emitted by a transducer decreases as e^{-αr}, where r is the axial distance and α is the attenuation, proportional to frequency.
-The fast-rotating strategy required a greater sollicitation of the transducer for obtaining similar lesions. Fast rotation induces an additional 1/r decrease in heat deposition. Moreover treatment was done over a larger sector, thus a higher mean intensity is needed to reach the same depth. Very high peak intensity required for this method does not damage the transducer since the switching speed is fast enough to average the self-heating of the transducer.

- Standard echo images were displayed during therapy. Strain images were calculated.

-Real time B-mode images were necessary for positioning the probe but were not always reliable for monitoring the treatment. Strain images seemed to be an interesting alternative. An objective criteria for assessing the spatial extent of the lesions from strain images has to be found.

-1D images obtained with the still transducer can be used for monitoring the treatment. Although the temporal resolution is poorer, 2D images obtained with the fast rotating transducer provide more spatial information and may be easier to read.