Intra-luminal phased-array applicator of therapeutic ultrasound for MRI-controlled treatment of oesophageal tumors

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Objective. To develop an intra-luminal, cylindrical, phased-array applicator of therapeutic ultrasound for thermal ablation of oesophageal or rectal tumours, compatible with real-time MRI monitoring of the treatment (anatomy and thermal dose assessment).

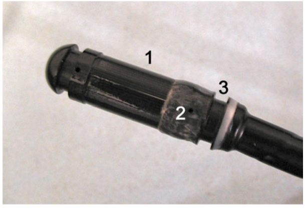

Fig 1. MR compatible phased-array ultrasound applicator:
1. active part ;
2. water circulating orifice;

3.shoulder for balloon fixation.

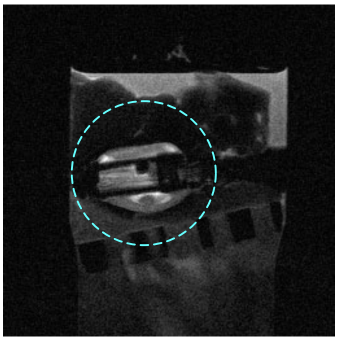

Fig.2. T2w image of the device, (longitudinal plane). Note the water balloon inflated around the applicator.

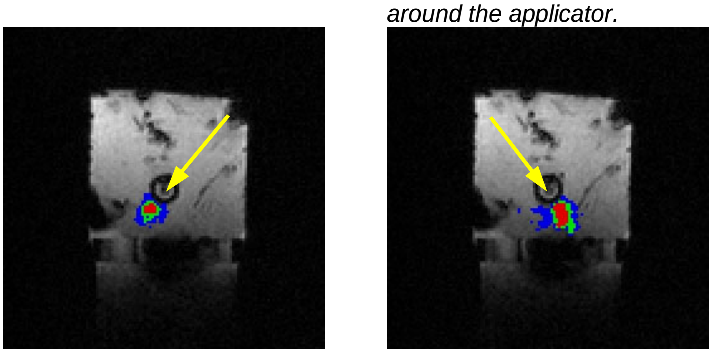

Fig.3. MR temperature maps in a transverse plane during two successive sonications of 60s along orthogonal directions – electronic rotation of the beam (left: 15 W/cm^2 ; right: 20 W/cm^2). Color map: red above 15°C, green 10 to 15 °C, blue 5 to 10 °C.

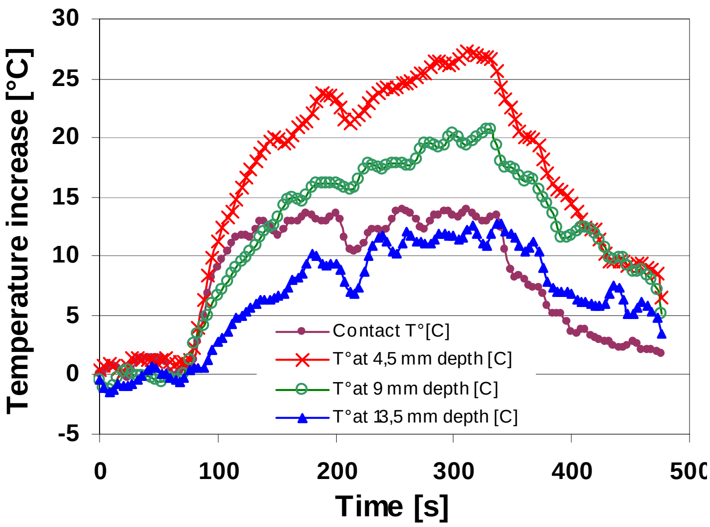

Figure 4. Temperature time course for 2 successive sonications along the same direction; 20 W/cm^2 , 90 sec each, 20 s waiting delay. Four locations on the beam path are considered.

Introduction. New curative and palliative treatments must be proposed in order to respond to the long-term bad prognosis of oesophageal cancers. Local applicators of high intensity ultrasound under MRI temperature monitoring and feed-back control may provide such new therapeutic tool. Versatility of phased-array design provides significant advantages for accurate and fast treatment of sectorial tumors (1,2).

Materials and methods. The applicator (4.6 MHz operating frequency) has a cylindrical geometry (10 mm diameter) and consists of 64 independent (15 mm length, 0.45 mm width) adjacent elements laid out on the cylinder surface as shown on Figure 1.
Acoustic plane waves can be generated using eight adjacent elements with appropriate phase law. Electronic rotation of the ultrasonic beam is possible upon user-defined selection of the eight active elements on the applicator. Simultaneous emission of multiple acoustic beams is also available. A water-circulating latex balloon is positioned around the active part of the applicator. This allows efficient cooling of the device, together with cooling of the superficial layers of tissue in contact to the balloon.
Ex-vivo experiments were performed on a Philips Intera 1.5 T clinical scanner using fresh meat samples. PRF based MR-temperature maps were acquired orthogonal to the applicator axis, using a segmented EPI gradient echo sequence (TR=250ms, TE=16ms, flip 35°, 3 slices, voxel size 1 x 1 x 5 mm^3, 4.0 sec/volume) and on-line displayed using Thermoguide software (I.G.T. SA, Pessac, France). Driving electronics worked outside the Faraday cage and signals were filtered when passing though the cage. Impedance matching unit was installed inside the Faraday cage at approximately 2 m from the applicator.

Results and discussion. No magnetic susceptibility artifacts were noticed. Electromagnetic interferences on the MRI scanner have been completely eliminated for the plane-wave mode (Fig.3). Equivalent lethal thermal dose has been delivered up to 12 mm depth. Note that effective ablation depth can be modulated as a function of the applied power level and the duration of sonication. The cooling effect of the circulating water balloon on the superficial layer of tissue is visible on Figure 4.

Conclusion. Excellent passive and active MR compatibility was demonstrated. Further experiments will be performed in vivo.

References

1. Melodelima et al, *Physics in Medicine and Biology*, 2002;47(23):4191-4203.
2. Melodelima et al, *Ultrasonics,* 2004;42(1-9):937-942.