Radiation force imaging and HIFU therapy monitoring in phantom gels by means of high resolution MR-Elastography – In vivo application to the rat brain

B. Larrat[1], R. Sinkus[1], M. Pernot[1], J-F. Aubry[1], M. Tanter[1], and M. Fink[1]

[1]Laboratoire Ondes et Acoustique, ESPCI-CNRS-Univ Paris 7-INSERM, Paris, France

Background and motivation

High field magnetic resonance elastography has the ability to measure 3D displacement fields with sensitivity down to some hundreds of nanometers. It is also able to assess the mechanical properties of living tissues. Therefore, this technique is of first choice in order to non invasively monitor the high intensity focused ultrasound therapy. This latter application is emerging rapidly and need to be coupled to a reliable imaging tool to locate the targeted area and to control the effective necrosis of tissues.

Material and methods

In this study, an MR-compatible prefocused ultrasonic monoelement (Imasonic, France) operating at 4MHz was used to generate a radiation force induced displacement inside phantom gels. In order to check the position of the focal point, this displacement was accurately localized via a motion sensitized MR sequence. A reference high resolution elastography acquisition was performed. Then, the ultrasound transducer was turned into HIFU mode by increasing the sent power. Finally, MR elastography was repeated so that to verify the stiffening of the area of interest. T2-weighted standard anatomy scans were also acquired. All the experiments were performed in a 7T small animal MRI scanner (Pharmascan, Bruker, Germany).

As previously published, the MR-elastography experiment consisted in a monochromatic mechanical excitation synchronized with an acquisition of the displacement field at one time step during the vibration cycle. This acquisition was repeated for 8 equally-spaced times so that to cover one full mechanical excitation period. A 3D local inversion algorithm was then applied in order to reconstruct the maps of the complex shear modulus with an isotropic resolution of 500µm.

For the animal tests, rats were anaesthetized with isoflurane (3% of volume for induction and 1% for the rest of the acquisition time). They were placed in supine position so that to ensure a proper coupling for both a low frequency vibrating piezoelectric plate (Piezosystems, USA) and the ultrasonic transducer. The total duration of the protocol was around 2h30.

Results

A dedicated motion sensitized MR sequence was developed to image radiation force induced displacements. It allows the detection of very small motion so that limit the sent energy (Fig 1 – a). The proposed HIFU protocol was successfully performed in phantoms (Fig 1 – b and c). A significant increase of stiffness was observed at the exact location of the focal spot after the HIFU treatment.

Using the same protocol, *in vivo* rat experiments showed no penetration of the US beam inside the skull (Fig 1 – d and e).

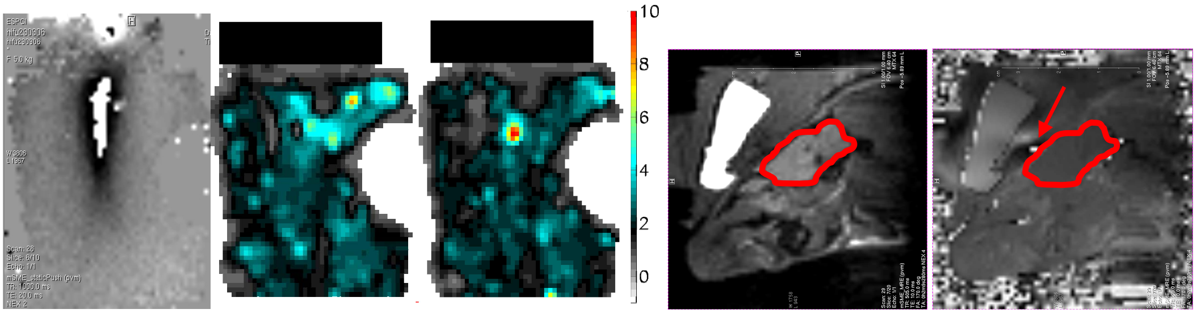

Figure 1: The radiation force induced displacement in a gel creates phase wraps in the MR phase image (a). The elasticity maps (in kPa) pre (b) and post (c) HIFU treatment are calculated from the 200Hz MR-Elastography acquisition. For phantom images, the position of the HIFU transducer corresponds to the black rectangle whereas the beam is sent from left to right for rat experiments (images d and e). Magnitude image (d) and corresponding phase image (e) with the same manually segmented brain region. The maximum displacement spot remains at the surface of the skull (arrow).

Discussion

In this study, the ability of monitoring an HIFU therapy with MR-elastography was demonstrated in phantoms. A single positioning of the targeted object was needed to sequentially visualize the focal point of the HIFU transducer, burn at that location and measure the mechanical properties before and after the treatment.

However, preliminary *in vivo* tests in the rat brain showed no proper penetration of the HIFU beam inside the skull. This was due to a small aperture angle of the transducer and a relatively high operating frequency. Therefore, further tests are being prepared with new transducers.