

Feasibility of brain MR-Elastography at 1.5 T with a novel wave generator: An animal study

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Introduction

Magnetic Resonance Elastography (MRE) investigates the viscoelastic properties of living tissues while mechanically exciting them. Protected by the meninges and the skull, the brain has remained rather immune to any excitation generated by transducers coupled to the cranial or facial bones [1-3]. Waves quickly vanish inward the human brain and MRE outcomes are obliterated. The challenge persists in rodents despite the smaller dimensions since waves with higher frequencies and lower penetration depth must be accordingly applied to resolve the animal brain structures. In the present study, a new excitation mode is proposed where pressure waves are directly guided into the animal's mouth. Proof of concept and optimization of the technique were initially carried out on gel phantoms at 1.5 T and afterwards the method was applied to *in vivo* rat brains.

Materials and Methods

MRE sequences and pressure wave amplitudes in the mouth cavity were first optimized in a plastic shell half filled with gel. Pressure waves were generated by a loudspeaker MS320 (Ciare, Italy) and guided into the phantom cavity in a 176 cm tube of 2 cm diameter terminated by a reducer to 3 mm (Figure 1A). The resonance frequencies of the system loudspeaker-waveguide-phantom were assessed by a pressure probe positioned at the shell input (Figure 1B). Feasibility and reproducibility of brain MRE *in vivo* were evaluated in seven rats. The rats were anesthetized with an intraperitoneal injection of pentobarbital (CEVA Santé Animale, France) at 45 mg/kg body weight. An alginate hydrogum 5 (Zhermack, Italy) mask was made to properly close the mouth cavity onto the 3 mm tube (Figure 1C). MR images were acquired using a microscopic coil of 47 mm diameter (Philips Medical Systems, The Netherlands).

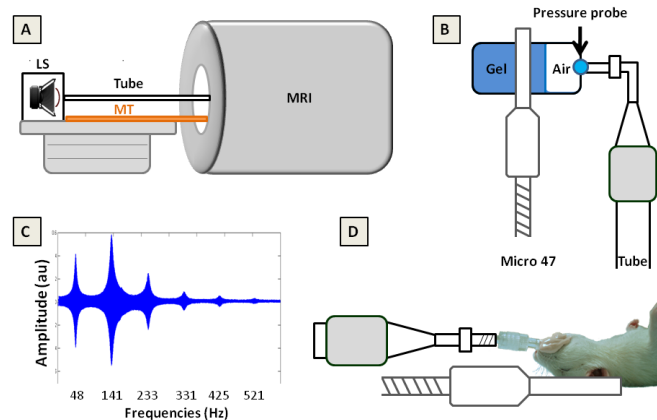


Figure 1: Experimental set up.

(A) Acoustic waves were transmitted from the loudspeaker (LS) to the phantom or the animal via an altuglas[®] tube. Resonance frequencies were assessed with a pressure probe placed at the output cavity entrance on the moving table (MT) (B). (C) Typical spectrum depicting various resonance frequencies measured with the pressure probe. (D) For *in vivo* studies, the rat is placed in supine position with a wave guide in the mouth fixed with an alginate mask.

First, a multi-frequency study (331 Hz, 425 Hz, and 521 Hz) was carried out in one rat in order to determine the best compromise between signal to noise ratio (SNR), wave penetration depth, and spatial resolution. Second, the reproducibility of the technique was evaluated at the selected frequency.

MRE was performed on a 1.5 T Philips Achieva MRI scanner (Philips Medical Systems, The Netherlands). The displacement fields were obtained with a modified echo-planar spin-echo sequence with echo train 5. Motion encoding gradients (MEG) were added before and after the π -pulse. The number of MEG was set to 20 at 331 Hz, 30 at 425 Hz, and 40 at 521 Hz to keep the motion sensitivity constant with frequency.

TE/TR were respectively equal to 85/1027, 98/1884, and 105/2323 ms. The isotropic spatial resolution was reduced with frequency as the wavelength becomes smaller. It was 1.13, 0.75, and 0.63 mm³ at 331, 425, and 521 Hz respectively. Four temporal steps evenly separated in one oscillatory cycle were acquired in the multi-frequency study, and eight in the reproducibility study. MRE parameters expressed after the wavelength as shear dynamic modulus G_D and shear lost modulus G_L were calculated as previously described [4]. Results are expressed in mean +/- standard deviation.

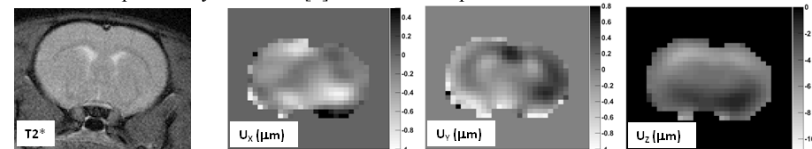


Figure 2: Wave propagation.

T_2 weighted image of a rat brain and total waves at 521 Hz propagating in the x, y, and z-directions throughout the whole brain.

Results

The best compromise in the multi-frequency study was obtained for 521 Hz. Mean SNR was 15 and wave propagation throughout the animal brain could be observed as shown in Figure 2. The mean total amplitude over the whole brain for all rats was $5.2 \pm 0.8 \mu\text{m}$. The mean wavelength was $4.4 \pm 0.1 \text{ mm}$. Shear dynamic modulus maps with corresponding anatomy are shown in Figure 3. $\langle G_D \rangle = 4.3 \pm 0.3 \text{ kPa}$ and $\langle G_L \rangle = 2.3 \pm 0.1 \text{ kPa}$.

Structures are visible in the cerebral parenchyma. Stiffer zones correspond to highly fibrous regions as striatum, decussation of the superior cerebellar peduncle, and corpus callosum (red zones in Figure 3).

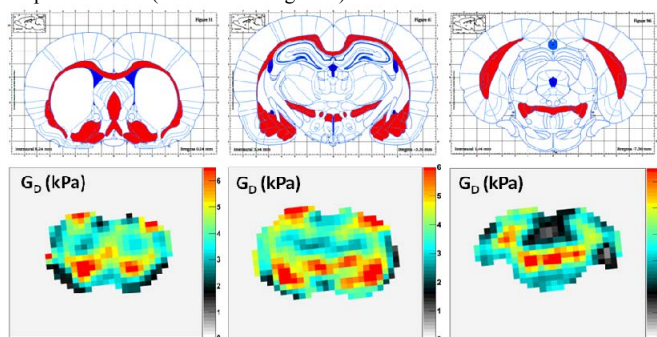


Figure 3: Elasticity maps versus anatomy.

Shear dynamic modulus maps (bottom) can be correlated to anatomical maps (top) from [5].

Discussion

This study showed that MRE in the rat brain is feasible and reproducible with a novel acoustic excitation technique placed in a clinical scanner. Moreover, this technique is sensitive enough to discriminate anatomical structures in the rat brain such that it should allow the measurement of viscoelastic changes, which are expected mainly in cancer or neurodegenerative diseases. This technique also opens new horizons for assessing the consistency of local lesions before surgery or for monitoring thermotherapies.

References:

- [1] Hamhaber *et al.* Acta Biomaterialia **3**:127-137 (2007) [2] Kruse *et al.* NeuroImage **39** 231-237 (2008) [3] Green *et al.* NMR Biomed. **21**:755-764 (2008) [4] Sinkus *et al.* Magn Reson Med **58**:1135-1144 (2007) [5] Paxinos and Watson *The Rat brain in stereotaxic coordinates*