All-in-one interventional MR elastography (MRE) system dedicated to MR-guided percutaneous procedures

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TARGET AUDIENCE – Magnetic Resonance Elastography / Interventional MRI

PURPOSE – MRI-guidance is increasingly used in percutaneous procedures such as biopsies or thermal tumor therapies. MRI guidance is particularly helpful to visualize the procedure in real time. However, some tumors remain difficult to precisely delineate during the procedure without contrast agent injection in real-time acquisitions. Magnetic Resonance Elastography (MRE) is a non-invasive method that allows to measure mechanical properties of soft tissues[1]. It requires a mechanical driver that generates a shear wave inside the tissue, a specific MR pulse sequence including MRE motion-sensitizing gradients, and an inverse problem solver that computes the elastogram from wave images. Based on the fact that mechanical properties of tumors differ from healthy tissues[2], this work aims at providing an elasticity map of tissues in real-time during MR-guided percutaneous procedures. In this feasibility study, an all-in-one MRE system specifically adapted to MRI-guided percutaneous procedures is developed and tested in a heterogeneous gel phantom.

METHODS – Adapting MRE to interventional MRI sets new specifications. A compact and ergonomic actuator is designed to answer the space and aseptic constraints: a piezoelectric actuator makes an MRI-compatible needle vibrate inside the tissue directly within the region of interest. The stimulation can vary from 50 Hz to 150 Hz with typical motion amplitude of 100 µm. A fast interactive motion encoding sequence is developed (Fig. 1.b). A motion sensitizing gradient is added to a multi-slice real-time spoiled gradient echo sequence, that allows to interactively change the acquired slice position and orientation during the acquisition[3]. Fractional encoding[4] is used to minimize the echo time increase; hence the vibration period equals the inter-echo space. An online inverse problem solver was implemented for real-time elastogram reconstruction. Based on the local frequency estimation algorithm[5], this solver version requires 2 phase images (0° and 180° phase shift) as input to reconstruct an elastogram. Experiments are carried out on a 1.5T interventional MRI system (MAGNETOM Aera, Siemens, Germany) with a 4-channel flex coil and the spine coil. The protocol is tested on a phantom made of two halves with different gelatin concentrations (5% /10%). Relevant acquisition parameters for an excitation frequency of 80 Hz include: encoding frequency 120 Hz, TE/TR 9.71/12.5 ms, matrix 128×112, partial Fourier 6/8, field of view 250×250 mm, slice thickness 10 mm, flip angle 10° and image acquisition time 1.075 s.

RESULTS – The excitation device generates a shear wave inside the phantom without resulting in significant artifacts on phase images (Fig. 1.c). As expected given the phantom design, two regions with different wavelengths are clearly visible on the phase images acquired with the real-time MRE-sequence. The total acquisition time, 2.15 s for 2 phase images, meets the real-time interventional MRI requirements. From these images, the image processing algorithm was able to reconstruct an elastogram showing 2 distinct regions in terms of mechanical properties (Fig. 1.d).

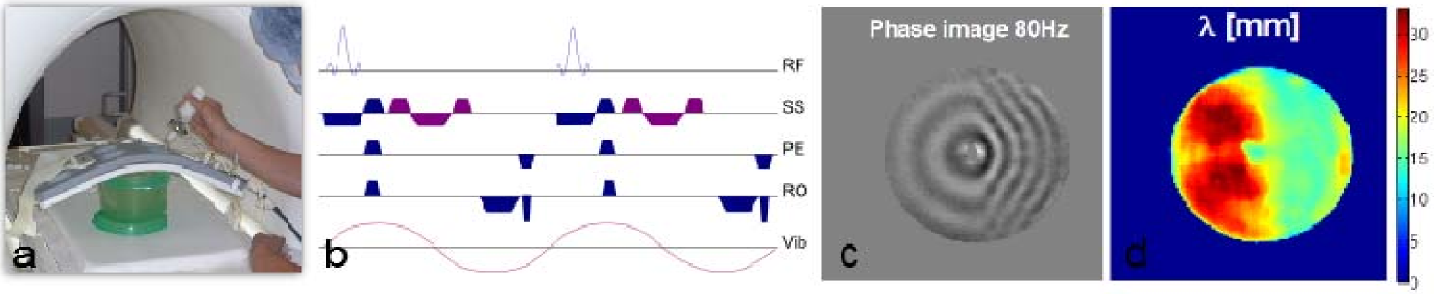

Figure 1: (a) View of the experimental setup with hand-held needle actuation piezoelectric device. (b) Chronogram of the MRE pulse sequence including motion sensitizing gradients (purple) with fractional encoding. (c) Shear waves propagating away from the needle and (d) Elastogram obtained in a gelatin phantom with 2 different concentrations.

CONCLUSION –This study demonstrates the feasibility of interventional MRE in phantoms. Dedicated excitation device, interactive real-time pulse sequence and online reconstruction were implemented. This additional information of elasticity in real-time is expected to help the physician better localize tumors during the needle insertion and the monitoring of thermal therapy procedures.

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