Overhauser Enhanced MR Elastography

Najat Salameh[1,2], Mathieu Sarracanie[2,3], Brandon D. Armstrong[2,3], Arnaud Comment[1,2], and Matthew S. Rosen[2,3]

[1]Institut de Physique des Systèmes Biologiques, EPFL, Lausanne, Switzerland. 1015

[2]Martinos Center for Biomedical Imaging, 13 149th St. Suite 2301, Boston, MA. 02129

[3]Department of Physics, Harvard University, 17 Oxford St. Cambridge, MA. 02138

MGH/HST Athinoula A. Martinos Center for Biomedical Imaging

MASSACHUSETTS GENERAL HOSPITAL

HST Harvard-MIT Health Sciences & Technology

Introduction

MR elastography (MRE) is a powerful non-invasive tool that can be used to assess the mechanical properties of living tissues. It has shown its potential for the diagnosis of chronic liver diseases and breast cancer.

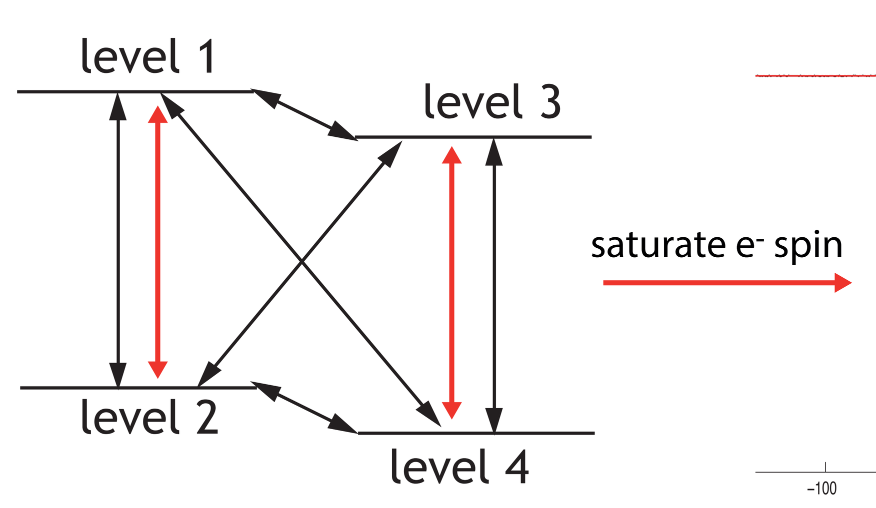
However this technique suffers from major limitations: the number of motion encoding gradients (MEG) used to increase the sequence sensitivity adds up to the initial sequence TR and is restricted by the intrinsic T2's of the targeted tissues. This leads to limited SNR compensated by higher number of averages (NA), leading in turn to longer acquisition times. This drawback hinders its routine use by radiologists. **The aim of the present study is to show the feasibility of enhancing the signal via the Overhauser effect to shorten MRE acquisition times.**

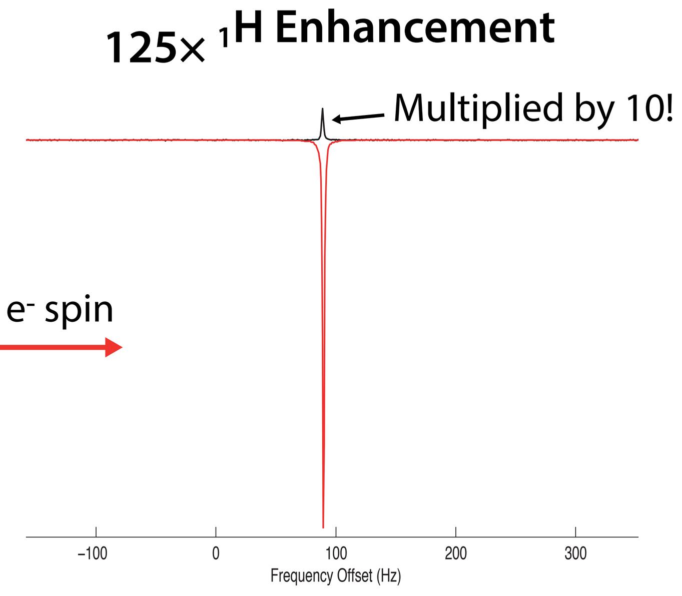
Material and methods

MRE was performed on a custom-built MRI scanner consisting of a bi-planar **6.5 mT electromagnet** with bi-planar gradients [1].

Overhauser enhancement was performed using an EPR coil tuned to the low energy transition of 140.8 MHz of a nitroxide radical. The ESR coil was placed inside of a 16 cm long solenoid coil used for NMR excitation and detection at 276 kHz [2].

The e^- spin of a nitroxide free radical is strongly coupled to the ^1H nuclear spins of nearby water molecules. Saturation of the e^- spin resonance can transfer part of the 660X larger e^- spin polarization to ^1H nuclear spin polarization.





The Signal enhancement given by [2]:

$$\frac{\langle I_z \rangle}{\langle I_0 \rangle} = E = 1 - \rho f s \frac{|\gamma_S|}{\gamma_I}$$

- ρ is dependent on the local dynamics between the two spins.
- f accounts for 1H relaxation not due to coupling to the electron
- s describes the saturation of e- spin and depends on the applied EPR power

$$\rho = \frac{w_2 - w_0}{w_0 + 2w_1 + w_2}$$

$$f = 1 - \frac{T_1}{T_{10}} \qquad s = \frac{AP}{1 + BP}$$

A 7 % PVA gel containing 5 mM hydroxy-TEMPO dissolved in water (Sigma-Aldrich Co, St. Louis, MO, USA) was obtained after 2 cycles of freezing/thawing at - 20 °C. An acoustic waveguide was placed on top of the gel. A loudspeaker, positioned outside the Faraday cage on the other side of the waveguide, was used to generate **a 103 Hz acoustic wave.**

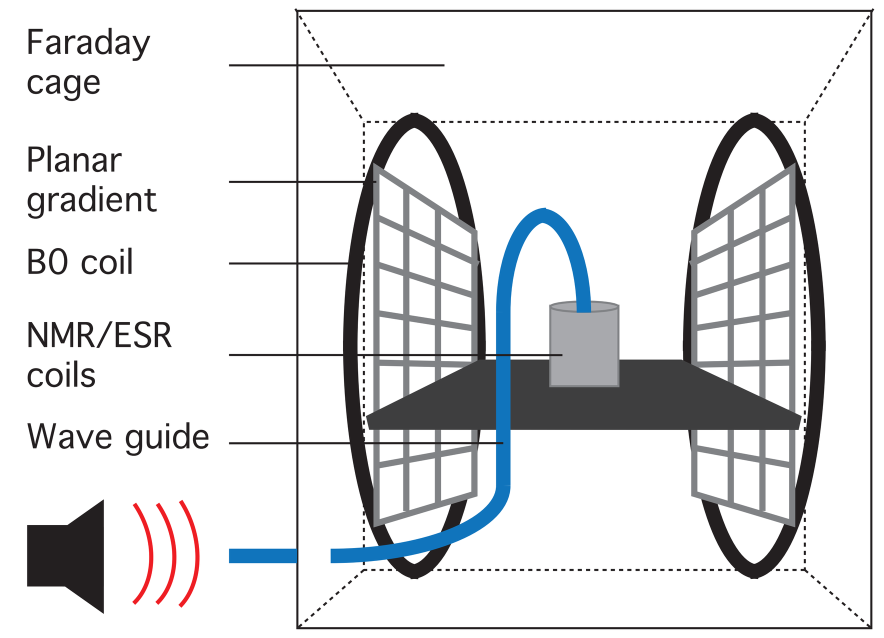


Figure 1: *Set up of the experiment. The phantom was placed inside of the ESR and NMR coils. Acoustic waves are quided through a tube placed on top of the gel.*

The **103 Hz acoustic wave excitation was synchronized with a modified 3D gradient echo sequence** (Figure 2). Four motion ecoding gradients (N = 4) were used with the following parameters: matrix 9×65×128, resolution 13.3×1.0×2.4 mm3, TE/TR = 67/87 ms, α = 90 °, **NA = 1.** Six temporal steps evenly distributed over one period (T) were acquired leading to an acquisition time of 278 s per direction. One additional scan was performed without any vibrations in order to have a reference scan for B0 drift correction. **The total phase accumulation** is given by [3]:

$$\Phi = \frac{2\gamma NT(G.\xi)}{\pi} \sin(k.r+\theta)$$

were Φ is the accumulated phase, γ the gyromagnetic ratio, G the gradient vector, ξ the displacement vector, k the wave vector, r the position vector, and θ the phase offset. A total ESR irradiation time of 50ms/TR was used to enhance the NMR signal. **Displacement fields were obtained after phase unwrapping and correction of B0 drift** using Matlab (MathWorks, Natick, MA, USA).

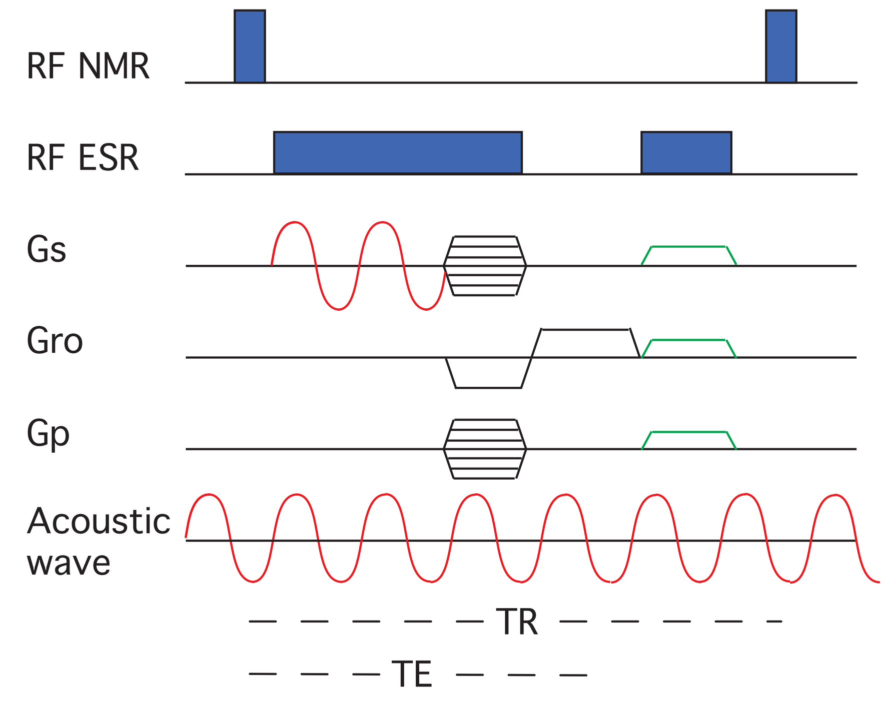


Figure 2: *Diagram of the modified 3D gradient echo sequence used for MR elastography. MEG, as well as the acoustic wave, is shown in red and crushers in green.*

Results and conclusions

An enhancement factor of ~30 was obtained. 3D phase maps were calculated and showed good wave propagation inside the gel (Figure 3).

We had shown for the first time that the Overhauser effect can be used to perform MR elastography at 6.5 mT with sensitivity and acquisition times being equivalent to those using standard spin echo and gradient echo sequences referred in the literature at much higher fields. Furthermore, shorter acquisition times can easily be reached by making use of fast imaging strategies.

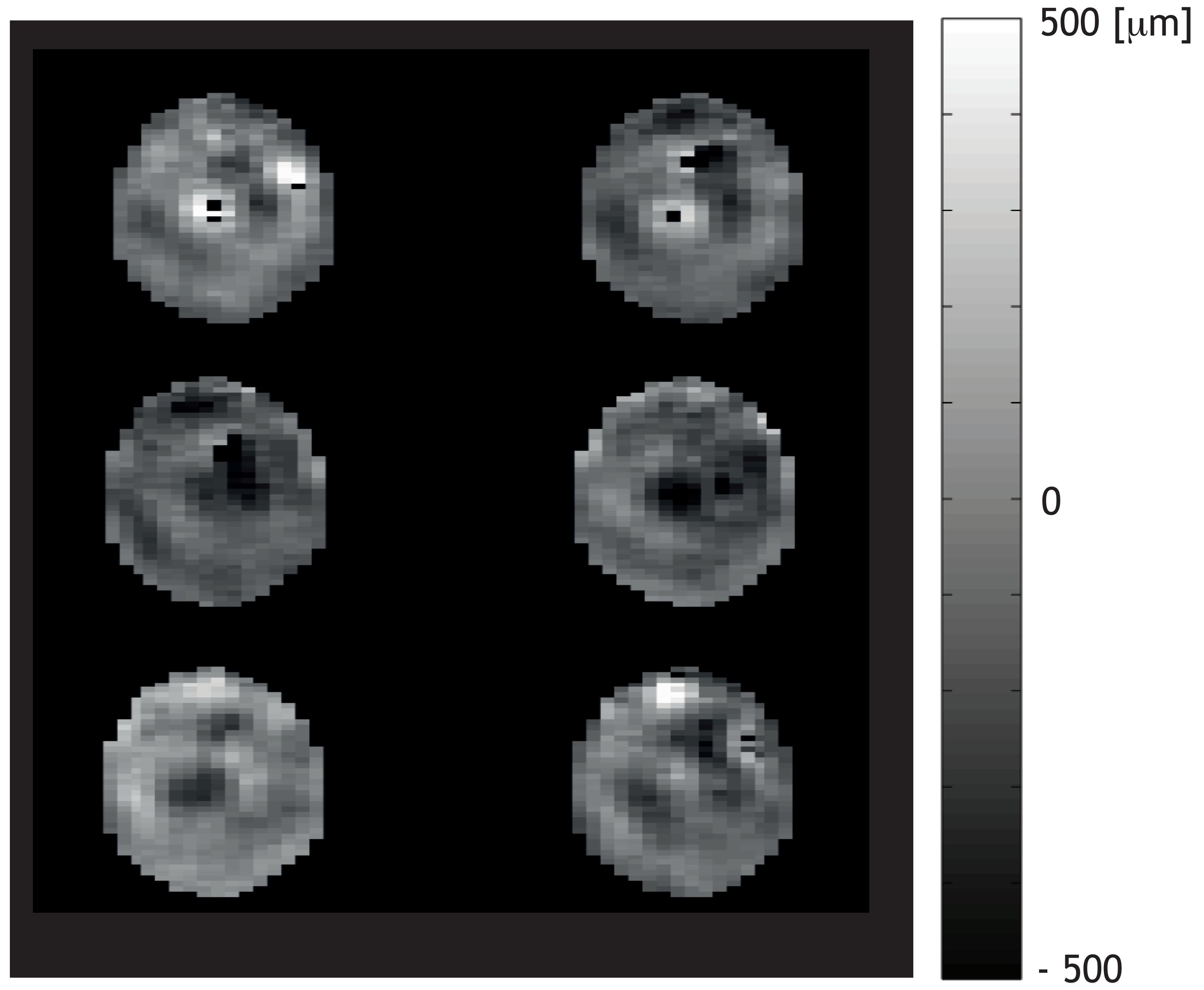


Figure 3: *Total displacement fields after phase unwrapping and drift correction obtained in the readout direc-*

This study opens new perspectives in clinical applications when short T2's of biological tissues constrain the sensitivity of MRE leading to prohibitive acquisition times

This work was supported by the Swiss National Fund (grant #PP00P133562_2)

References - [1] Tsai LL *et al*, JMR 2008 [2] Sarracanie M *et al*, MRM 2013 [3] Mutthupillai R *et al*, Science 1995

Visit our webpage →