VISUALIZATION OF VISCOELASTIC PROPERTIES BY COMBINING US PULSES AND MRI

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Purpose

Ultrasound (US) and MRI are two highly sophisticated non-destructive methods which make it possible to visualize the inner parts of the body. Contrasts between tissues in the MRI measurement are based on the physical parameters T1, T2, T2*, and the proton density, which can be modified by the application of contrast agents. The corresponding parameter in the US measurement is the sound impedance. The aim of our studies is it to combine the two methods and introduce US as a tool to generate contrasts in an MRI picture between tissues and liquids with differing viscoelastic properties. Therefore an US setup that does not affect the imaging of the MR scanner has been developed. The US emitter had to be shielded electromagnetically in order to avoid crosstalk within the MRI coils.

Method

In order to apply US to a sample during an MRI measurement, some kind of synchronisation between the MRI sequence and the application of the US pulses has to be achieved. A simple antenna makes it possible to visualize the rf-pulses of the sequence on an oscilloscope. These signals can be used to trigger the US emitter and place the US pulses at any desired time in the MRI sequence.

Once coupled into the sample, a damping of the US wave along the path of propagation occurs which corresponds to a decrease of the acoustic radiation pressure along the direction of propagation. This pressure gradient leads to a force on each volume element along the path of the US beam. In a liquid, this results in a movement of the molecules along the US path in the direction of propagation of the US. This movement dies away when the US-pulse is over and reestablishes with the next pulse. When a piece of tissue is placed in the US path, the decrease of the acoustic radiation pressure leads to a quasi-statical displacement of the irradiated parts of the tissue in the direction of the propagating sound wave for the duration of the US pulse. This displacement depends on the viscoelastic properties and the of the tissue and the amplitude and absorption of the US. When the pulse stops, the restoring forces in the tissue make it return to its original position. A diffusion sensitive sequence, which is sensitive to movements in the direction of propagation, is able to visualize the sound path in a liquid (fig. 1) and the displacement of the tissue.

All measurements were performed with the standard eight channel head coil on an 1.5T SIEMENS AVANTO scanner at the research center LIFE & BRAIN in Bonn, Germany. During a diffusion-weighted EPI sequence (EPI2D_DIFF_RO), US was irradiated into several liquids (water, glycerine, ethanol) for 30ms at a frequency of 9.41MHz with a maximum excess pressure of about 1 Bar. The US pulse was applied after the first of the two 180° pulses which guaranteed an overlap with the diffusion gradient. For the measurements on tissue, an US lens with a resonance frequency of 4.77MHz was constructed and a simple GRE sequence (Te=12.1ms, Tr=123ms) was used.

Results

Figure 1 shows a setup, where the US beam was deflected by a sheet of glass in a water sample. Only if the direction of the diffusion gradients is aligned with the direction of the sound propagation, the US beam is visible in the MR image as a region with lower signal.

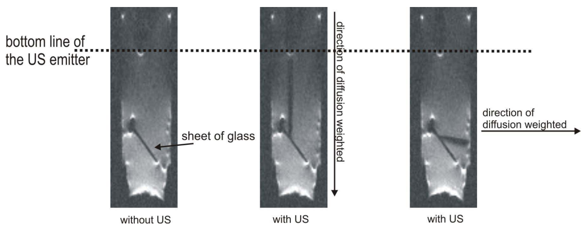

Figure 1: Deflection of the US beam at a sheet of glass. At the top of the pictures a rod made of acrylic glass is visible which serves as a wave guide for the US. The US transducer itself is not visible in the picture. The container has a height of 8cm. (Parameters: Te=155ms, Tr=5700ms; US: Duration=30ms, Voltage=-6dBm).

The measurements on different liquids show a difference in the US effect depending on the properties of the liquid. In water the diminishment of the signal is visible as a straight path, whereas in glycerine a much shorter but wider region is affected by the US. This is due to much higher damping of the US wave in Glycerine. The acoustic radiation pressure is therefore stronger, but only existent in a very short region. This region is wider than in water because of higher friction between the glycerine molecules which corresponds to a higher momentum transfer.

In a piece of pork neck the US effect also becomes visible as a black spot. Only in this region, the piece of pork neck was displaced during the US pulse. The strength of this displacement depends on the viscoelastic properties of the tissue.

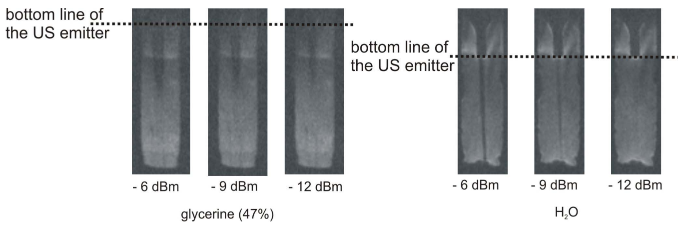

Figure 2: US beam in a 47% glycerine (viscosity=6mPas) mixture and in water (viscosity=1mPas) at different US amplitudes. An amplitude of –6dBm corresponds to an excess pressure in water of about 1 Pa. (Parameters: Te=106ms, Tr=3500ms, US: Duration=30ms).

Conclusion

The combination of US pulses and MRI creates contrasts concerning the viscoelastic properties of liquids and tissue. The spatial resolution of this method is only limited by the resolution of the scanner, since the US wavelength is in the order of magnitude of 100mue.