MR-microimaging on a 7T whole-body scanner featuring ultrashort detection times and magnetization transfer contrast

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Introduction

The composition and morphological structure of semi-solid tissue components or implants (e.g. cornea, dermis, calcified cartilage, horn substance, teeth and plastics) cannot be imaged by standard MR methods, since the mobility of signaling molecules is highly reduced. This in turn results in a strong MR signal (line) broadening and a significant reduction of T2 times (<1 ms). Using standard pulse sequences, a rapid decay of the MR signal occurs making a detection nearly impossible. This tissue dependent restriction requires the application of special pulse sequences designed for the detection of ultra-short echo times (UTE, TE_{min} = 0.07 ms). Another approach to assess motional restricted protons is magnetization transfer (MT). MT imaging is clinically more established because it is readily available on clinical scanners. MT is based on the polarization transfer via dipolar coupling and chemical exchange between a pool of bound protons and the protons associated to the tissue water [1]. Until now, pulse sequences for very short detection times were only available on special MR microscopy systems or within research on human MR scanners with reduced spatial resolution. In this work we present first images acquired with a UTE pulse sequence with integrated MT contrast on a custom designed MR-microscopy insert for a 7T scanner providing a novel tissue contrast.

Materials and methods

In the UTE sequences, immediately after the RF-excitation the spatial information within the FID is frequency encoded and acquired. 3D-rastering results in a number of radial profiles, which fill the 3-dimesional polar k-space in a spiral manner. The image is than regridded to a Cartesian coordinate system and reconstructed [4]. For achieving MT contrast, a saturation RF pulse precedes the excitation RF pulse. High spatial resolution imaging is achieved using strong gradients and very sensitive detector coils. The specific gradient insert features a maximum gradient strength of 750 mT/m. It was placed on the patient layer into the bore of a high-field whole-body scanner. With this system, a lateral resolution better than 50 microns is possible for turbo-spin echo sequences [2]. In order to investigate the contrast in magnetization transfer weighted imaging, a fully adjustable saturation pulse was placed at spectral positions between 500 Hz to 1.5 kHz off-resonant. For each offset –frequency, the pulse amplitude was varied (10-60 V). MT induced signal reduction was evaluated on cross-linked BSA phantoms (bovine serum albumin, 0.18/0.26/0.30 wt.-%) and biological samples to demonstrate the practical applicability of the sequence ex vivo.

Results

The relative signal intensity of homogeneous BSA phantoms was correlated with the frequency offset and amplitude of the MT saturation pulse. At low frequency offsets (500 Hz) and high amplitudes (60 V), the signal could be reduced by 20-40%. Less BSA concentration corresponds to less MT effects and consequently to a higher signal intensity. The subtraction of UTE images with and without a saturation pulse provides new contrast. However, in comparison to a TSE sequence, the spatial resolution is limited (approx. 128 µm isometrically at best). Additionally, the liability of the UTE sequence regarding imperfect gradient performances can lead to further image artifacts [3].

Conclusion

UTE sequences allow very short detection times down to 0.07 ms and - in combination with strong micro-imaging gradients - resolutions which are not possible on a clinical MR scanner. The combination of UTE imaging with a MT technique can provide a new contrast within tissues with short T2 times remaining invisible for conventional MRI. The currently available UTE imaging part of the MT-weighing pulse sequence exhibits also specific artifacts caused by an imperfect gradient timing performance. However, these imperfections can be minimized by correction terms within the reconstruction algorithm [3].

References

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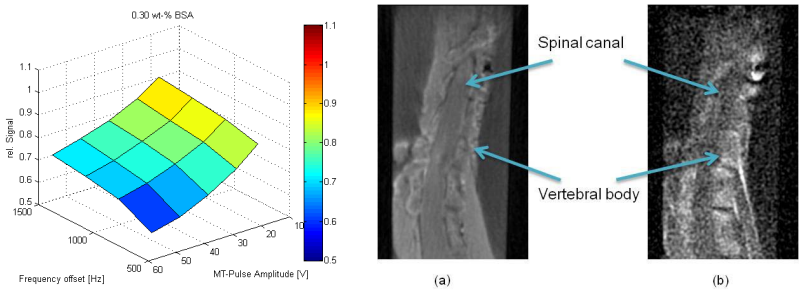

Figure 1: **Left:** Relative signal intensity of a BSA phantom (0.3 wt.-%) as a function of frequency offset and amplitude of the MT-pulse.
Right: UTE image of a rat's backbone ex vivo (paraplegia animal model) with TE=0.07 ms:**(a)** image without MT-weighing, **(b)** difference image between MT-weighted and non-weighted UTE-slice featuring a 300 Hz off-res. saturation pulse.
An increased contrast for the regions around the vertebral bodys can be noticed.