In-vivo Magnetization Transfer Imaging of Mouse Lungs using a Zero Echo Time Sequence at 4.7 T – initial Experience.

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Introduction: Several recent publications demonstrated that magnetization transfer (MT) increases in chronic tissue alterations such as fibrosis[1-3]. In MT measurements, the degree of exchange between the macromolecular "bound" proton pool and the pool of "free" water molecules is measured. Typically, an off-resonance pre-pulse, which excites the macromolecular pool, is applied within a conventional imaging sequence resulting in signal attenuation depending on the degree of MT within a certain tissue. Lung magnetic resonance imaging (MRI), however, is hampered by the low spin-density and the fast signal decay due to microscopic magnetic field inhomogeneities between tissue-air interfaces of the alveoli. In this investigation, we apply zero echo time (ZTE) imaging[4] providing sufficient signal yield of lung tissue to measure pulmonary MT in-vivo.

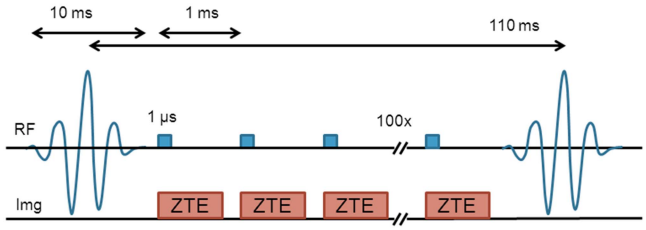

Figure 1: Pulse diagram of the used ZTE sequence with interleaved MT preparation pulse.

Materials and Methods: Two C57BL/10 mice underwent MRI examinations in a small animal MR scanner operating at 4.7 Tesla during isoflurane anaesthesia. Spin excitation and signal reception was performed with a linearly polarized ^{1}H whole-body mouse coil. A 3D ZTE sequence (sequence diagram in Fig. 1) was used with a matrix size of 160, an in-plane resolution 0.31 mm, 80889 radial spokes, and a repetition time TR 1 ms. A Gaussian MT pre-pulse of 10 ms duration and 1.000°, 2.000°, or 3.000° flip angle was applied followed by a train of 100 ZTE imaging readouts. A flip angle of 3.7° of a 1 µs hard pulse was chosen for ZTE imaging. The scan time per 3D volume was 3 m. Off-resonance frequencies of the MT prepulse were varied between 2.000 Hz and 15.000 Hz. Mean magnetization transfer ratios ($MTR=1-M_{sat}/M_0$) were calculated from region-of-interest analysis, MTR maps were computed on a pixel-by-pixel basis. Furthermore T2* apparent transverse relaxation time of lung tissue was estimated by mono-exponential fitting of signal intensities acquired with ultra-short echo time sequences with 8 different echo times between 50 µs and 5000 µs. To estimate the line width of lung tissue at 4.7 T a Lorentzian distribution of the proton absorption spectral line was assumed.

Results: Experimental MTR values of non-pulmonary tissues obtained with ZTE showed the typical characteristics known from conventional MT sequences with skeletal muscle and white matter showing high experimental MTR values and fatty tissue relatively low experimental MTR values (cp. Fig. 2). Lung tissue showed MTR values between fatty tissue and liver tissue. The apparent T2* relaxation time of lung tissue was 770 ± 10 µs resulting in a line width of 413 ± 6 Hz.

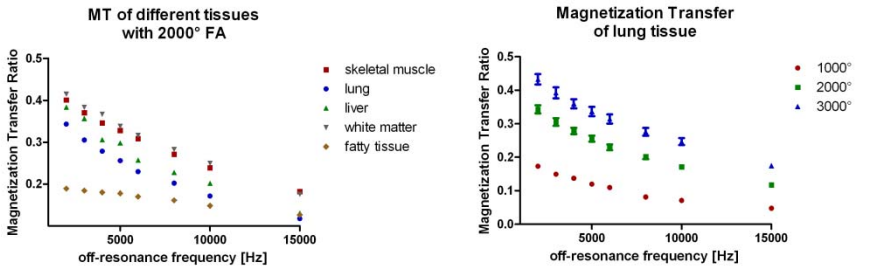

Figure 2: Left: Measured experimental MTR for different tissues. Right: Experimental MTR of lung tissue for different flip angles and offsets of the MT prepulse.

Discussion: Here we present our initial experience with ZTE imaging with a MT preparation pulse applied for pulmonary MT. For tissues which can be imaged with conventional sequences the used technique showed MTR values consistent with literature[5]. The advantage of the chosen approach is that it can provide signal from tissues with fast signal decay such as lung tissue. Furthermore, the 3D data acquisition is fast and the scan time is only increased by 10% with the interleaved preparation scheme. Pulmonary MT might be interesting for assessment of lung fibrosis as it has been shown that MTR values increase in states with increased fibrosis[1-3]. In our study lung tissue showed lower MTR values when compared to other tissues such as skeletal muscle but still considerably higher values than fat, which is known to show only little MT. Therefore we were able to show that measuring MT in the lung in-vivo is feasible. As we measured a line width of around 0.4 kHz for lung tissue, MT preparation pulses with an offset lower than 2-3 kHz might result in a considerable affection of the measured MTR values by direct saturation[6]. However, even when choosing the off-resonance frequency relatively large in the order of 5000 Hz or higher to avoid direct saturation effects, MT of lung tissue remains measurable.

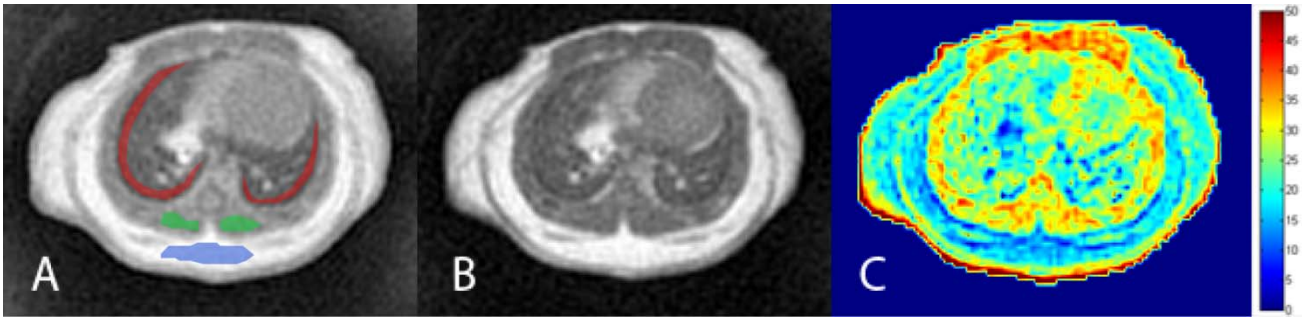

Figure 3: A: ZTE without MT prepulse, note the drawn ROIs for MTR measurement (red: lung, green: muscle, blue: fat), B: ZTE with 2000° MT prepulse at 5kHz offset, C: resulting MTR map (scale 0-50% MTR).

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