IN VIVO QUADRUPOLAR SPLITTING OF POTASSIUM (^{39}K) MR SPECTRA IN HUMAN THIGH MUSCLE

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TARGET AUDIENCE physicists and physicians interested in non-proton MR

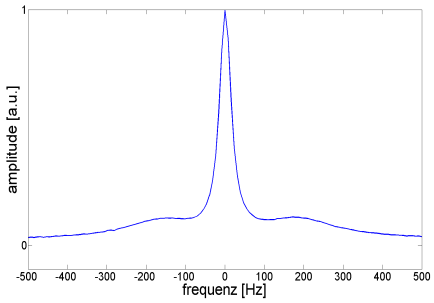

Fig 1a: *in vivo* potassium spectrum of human thigh muscle (zoomed in)

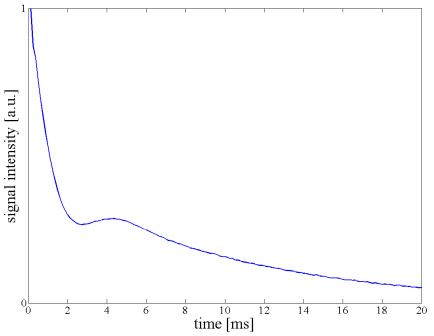

Fig 1b: Corresponding FID of potassium in thigh muscle

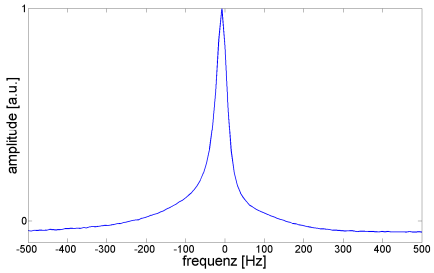

Fig. 2: Potassium spectrum of rotated thigh muscle

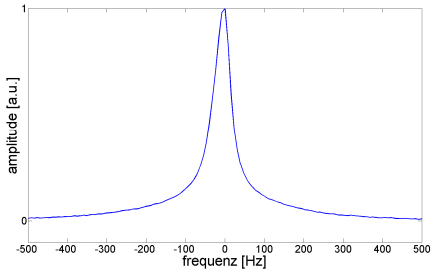

Fig. 3: Potassium spectrum of human head

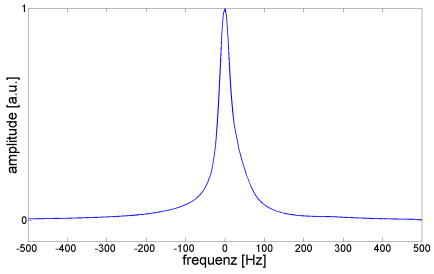

Fig. 4: Sodium spectrum of human thigh muscle

PURPOSE Potassium ions are of fundamental importance for the physiology of living organisms. Ultra high field MRI-systems allow *in vivo* measurements of ^{39}K MR signal[1, 2]. In human thigh muscle oscillations in the T_2^* decay of the MR-signal were observed[1]. The aim of this study was to investigate the origin of these oscillations.

METHODS For all measurements a 7 T whole body MRI scanner (MAGNETOM 7T, Siemens AG, Erlangen, Germany) was used. The ^{39}K MR-Signal was acquired with a custom-built, circularly polarized birdcage coil tuned to 14 MHz whereas the sodium (^{23}Na) signal was detected with a commercially available, double-tuned (^{1}H and ^{23}Na) coil (RAPID Biomedical GmbH, Rimpar, Germany).
Before each measurement a global flip angle calibration was performed. A healthy volunteer (27, f) was examined with a conventional FID sequence (repetition time T_R = 290 ms, bandwidth BW = 2000 Hz, base resolution = 1024, flip angle = 90°, *nex.* = 4000, readout duration T_{RO} = 256ms) to acquire all presented spectra. In Fig. 1a the *in vivo* ^{39}K spectra of a human thigh oriented parallel to the static magnetic field (B_0) is shown. Then, the coil including the thigh was rotated with respect to B_0 by an angle of approx. 35° (spectra shown in fig. 2). Due to the bore diameter it was not possible to reach a larger angle between the thigh and the B_0 field. Further, in this configuration we were partly able to compensate for the lowered B_1 field efficiency by a higher reference voltage. Additionally, an *in vivo* ^{39}K spectrum of the volunteer's head (fig. 3) was acquired. For comparison we also acquired a sodium (^{23}Na) spectrum (repetition time TR = 290 ms, bandwidth BW = 2000 Hz, base resolution = 512, flip angle = 90°, *nex.* = 2000, readout duration T_{RO} = 256ms) of the human thigh aligned to B_0 (fig. 4). Similar to the potassium measurements no shim was done beforehand. Phase correction of all spectra was performed with jMRUI[4]. The AMARES algorithm[3] implemented in the evaluation software was used for quantitative analysis.

RESULTS The spectrum of the thigh muscle in its natural (0°) orientation is shown in fig 1a and the absolute value of its free induction decay in fig. 1b. The quadrupolar splitting of the ^{39}K peak is clearly visible. Fitting Lorentzian shaped peaks to the measured spectrum via jMRUI with the AMARES algorithm leads to following results: the two side peaks are shifted by +(194 ± 2) Hz and -(170 ± 3) Hz relative to the reference peak at 0 Hz, respectively. The integral in the frequency domain of both peaks is 0.53 ± 0.01 and 0.58 ± 0.02 of the integral of the main peak. This corresponds to the amplitude of the signals in the time domain. The relaxation time constants determined by the linewidth of each fitted peak were $T_{2,\ peak\ 1}^*$ = (9.2 ± 0.1) ms (main peak), $T_{2,\ peak\ 2}^*$ = (1.50 ± 0.05) ms (left small peak) and $T_{2,\ peak\ 3}^*$ = (1.23 ± 0.04) ms (right small peak).
In the ^{39}K spectrum of a human head (Fig. 3) no peak splitting was observed. No satellite peaks in the ^{39}K spectrum of the 35° rotated thigh (Fig. 2) were discernible, but the spectrum stayed slightly asymmetric after phase correction. No quadrupolar splitting was observed in the ^{23}Na spectrum (Fig. 4) of the ordinary (0°) orientated thigh.

DISCUSSION
No quadrupolar splitting of the ^{23}Na signal was observed in human thigh muscle, which is in good agreement to the literature[5]. Contrary to this, the ^{39}K signal was split in the same experimental setup. In the zoomed in FID (fig. 1b) the locations of the first minimum and maximum of overlying oscillations correspond to the ones measured in [1] with an imaging sequence. Opposite to the sodium signal, which is dominated by contributions of the extracellular space, most of the potassium signal accrues from the intracellular space. Here, the electrical field gradient might be different from that in human head, where also no splitting of the ^{39}K signal in the frequency domain was observed.
In addition, the splitting in *in vivo* potassium spectra of thigh muscle seems to be angular dependent, which also fits to the theoretical description of an anisotropy effect. Nevertheless, detailed studies were not possible with the given coil setup.
The given errors result from the fitting. Because the splitting is not symmetric and the T_2^* relaxation time constants lead to different values for the two side peaks, there might also be a systematic error due to field inhomogeneity. Quadrupolar splitting theory predicts an amplitude ratio of 3:4:3 for the triplet peaks. The calculated amplitudes from fitting side peaks are slightly lower. Nevertheless, the fast component of T_2^* decay is in agreement with the in [1] estimated ones.

CONCLUSION We acquired *in vivo* a potassium spectrum of human thigh muscle, which shows quadrupolar splitting and causes the observed oscillations in T_2^* decay.

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REFERENCES [1]Umathum *et al.*, Radiology 2013; [2]Atkinson *et al.*, Magn. Reson. Med. 2013; [3]Vanhamme *et al.*, J. Magn. Reson. 1997; [4]Naressi *et al.*, MAGMA, 2001; [5] Nielles-Vallespin, Dissertation, 2004