SODIUM MR IMAGING OF THE GOAT KNEE AT 1.5T USING A TORO (TRANSMIT-ONLY, RECEIVE-ONLY) COIL AND A 3D UTE SEQUENCE

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Introduction

Sodium is known to be a sensitive MR imaging biomarker for early diagnosis of knee articular cartilage osteoarthritis (OA) [1]. The goat animal model closely matches the human knee anatomy and can be used to mimic the progressive nature of OA and monitor the loss of proteoglycans.
Although sodium imaging has shown promising results for years, sodium MR is still intrinsically challenging because of the low sensitivity of the ^{23}Na nucleus, low in vivo concentrations, fast transverse relaxation times and the requirement for custom, dual tuned RF coils. In this study, we have developed a coil setup which allows, in combination with a 3D UTE sequence, improved sodium imaging at 1.5 T. High quality sodium images of the goat knee are shown.

Methods

Coil design:
The combination of a homogenous transmit coil and local receive surface coils has been shown to deliver optimum SNR [2]. Additionally homogenous excitation is essential for accurate total sodium quantitation (TSC). The usual approach used for human knee cartilage imaging is a quadrature birdcage. Since the goats knee anatomy hinders the use of full volume birdcage designs, a Helmholtz coil pair (11*11 cm, 7 cm spacing) was used to achieve a rather homogenous excitation profile over the U-shaped region of interest (ROI) (see Fig. 1). For low field strengths and coil noise dominated probes sodium SNR is proportional to $B_0^{7/4}$ which makes imaging at 1.5 T challenging. To partly compensate the low field strength, two oval surface coils (5.5*7 cm) driven in quadrature were used for signal reception. Heavy silver plated copper wire was used for the receive coils since it shows considerable SNR gain compared to copper foil [2]. The quadrature coils were decoupled by overlap. Active decoupling is used to detune the receive coils during transmit pulses. A single channel TX/RX 1H surface coil allows anatomic localization of the sodium signal.

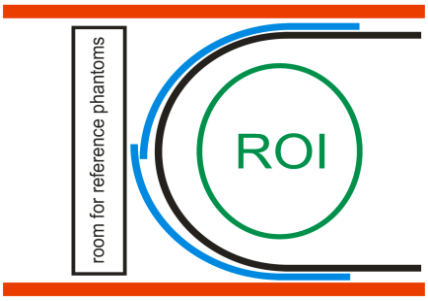

Fig 1: Schematic of the coil (side view): transmit Helmholtz coil (red), receive quadrature coil pair (blue), proton surface coil (black) and the ROI (region of interest) of the goat knee. The coil housing offers room for sodium reference phantoms to allow sodium quantitation in the knee cartilage.

Sequence design and optimization:
A short echo time (TE) is essential for sodium imaging to minimize signal loss due to fast transverse relaxation. In this study short TE was achieved by 3D ultra short echo time (UTE) imaging which allows TE to be as low as ~0.1 ms. The minimum allowed receiver bandwidth (BW) was used to reduce noise. The flip angle was adjusted to the Ernst condition by measuring the sodium signal intensity as a function of the transmitter voltage.

Sodium MRI of the goat knee:
Sodium images of the goat knee were acquired with a 3D UTE sequence with the following parameters: pulse length: 0.2 ms, TR = 40 ms, TE = 0.15 ms, number of projections = 40000, BW = 130 Hz/px, nominal flip angle = 90°, readout points = 64, FOV = 384 mm. Total imaging time was 26:40 min. Hanning filtering was used to reduce the noise of the sodium images.

Results and Discussion

The measured decoupling for the quadrature coils, active decoupling and proton/sodium isolation is >30dB. Fig 2 shows the good quadrature efficiency in the region of interest. The coil was used to image an adult goat's knee. The images of the 0.3 cm isotropic data set (Fig 3) show SNR of about 10-20 in the condyles and allow differentiation of fine cartilage structures.

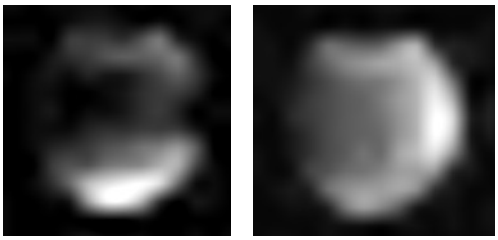

Fig 2: Quadrature efficiency of the receive elements

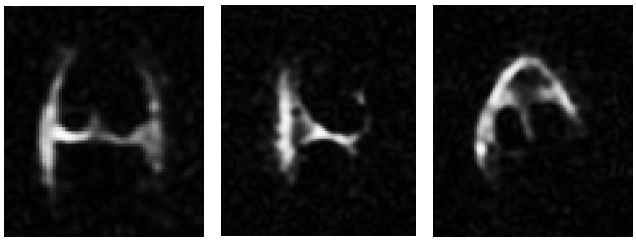

Fig 3: exemplary coronal, sagittal and transversal slices of the 3D sodium data set

Conclusions

The TORO approach and the use of UTE imaging has enabled us to acquire ^{23}Na images with a isotropic resolution of as low as 0.3 cm with high SNR in less than 30 minutes at 1.5 T. Additionally the proposed coil can be equipped with sodium reference phantoms and used for sodium quantitation in the goat knee cartilage.

Acknowledgement:

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References:

[1] Shapiro et al., JMR 142: 24-31 (2000); [2] Barberi et al., MRM 43:284–289 (2000); [3] Doty et al., NMR Biomed 20: 304-325 (2007);