A ^{1}H and ^{23}Na Two Coil System Optimized for Imaging Mini-Pig Knee Cartilage at a Whole Body 7 Tesla MRI

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Introduction: Investigation of integration and vitality of cartilage transplants as well as the underlying cartilage matrix are important to optimize therapeutic approaches for cartilage damage. By using ultra high field MRI systems (>7T), high isotropic resolution ((>0.3µm)^3) ^{1}H images can be obtained within appropriate coil systems in a reasonable scan time. Especially for cartilage imaging co-registered sodium data (^{23}Na) is used to analyze the cartilage regeneration [1]. Usually imaging of ^{1}H and ^{23}Na is performed with double resonant coil systems. In these systems, at least one of the channels is compromised due to filter circuits and coupling [2], which results in a decreased image resolution or increased scan time.
The aim of this study was to design an SNR optimized coil system for co-registered ^{1}H and ^{23}Na imaging of mini-pig knee cartilage at a whole body 7 Tesla MRI scanner, without the common loss of sensitivity due to a double resonant coil design.

Methods: To avoid SNR losses which are known for double resonant coils, a concept with two optimized single resonant coils was developed. Two solenoid coils *(d = 90 mm, l = 60 mm*) with two turns wound in parallel, were designed (Fig.1). This provided a homogeneous field of view, by keeping the overall conductor length short (Fig 2). The coils were tuned to $f_0(^{1}H)$= 297.15 MHz and $f_o(^{23}Na)$=78.6 MHz. A symmetric matching network and a cable trap, placed at the feed port, provided stable conditions for tuning and matching. A base plate, fitting the patient table's geometry, in combination with an exchangeable sample insert allowed for a reproducible positioning for later co-registration of the ^{1}H and ^{23}Na datasets. Imaging was performed at a Magnetom 7T whole body scanner (Siemens Healthcare, Erlangen Germany). The SNR performance of the two size optimized solenoid coils were compared to a ^{1}H CP birdcage (Invivo Corp., Gainesville, FL, USA) with *d = 270 mm* and *l = 160 mm* and a double resonant ^{1}H^{23}Na CP birdcage coil (Rapid Biomedical GmbH, Rimpar, Germany) with *d = 325 mm and l = 240 mm* which would have been available as alternative setups.

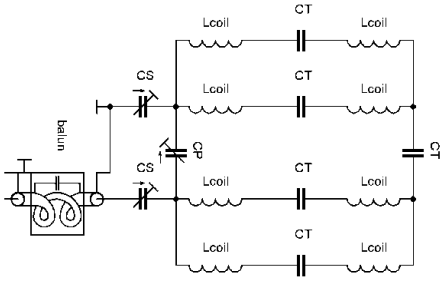

Fig. 1: (a) Schematic of the solenoid coil where two turns were wound in parallel. To reduce E-field effects in the final designs, CT was split into 7 and 3 capacitors for the ^{1}H and the ^{23}Na coil respectively.

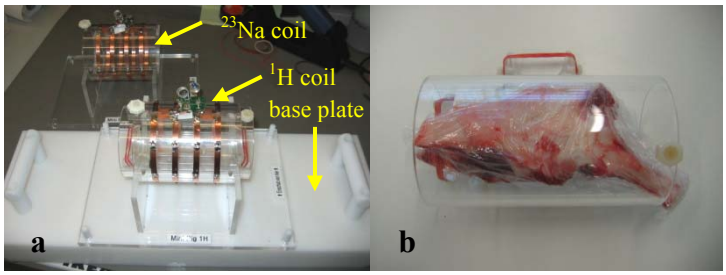

Fig. 2: (a) Final two coil setup with the base plate and (b) the removable insert, in which the knee samples are fixed.

Results and Discussion: The SNR for ^{1}H/ ^{23}Na imaging was increased by a factor of 13/ 3.3 compared to the ^{1}H CP birdcage/ ^{1}H^{23}NA birdcage. These improvements are caused by the optimized geometry and the single resonant features. Due to the removable sample insert, reproducible positioning could be realized. With (250µm)^3 resolution ^{1}H images covering the whole knee sample (T_{acq}=12:54 min), the anatomically, very thin cartilage structure of the mini-pig knees could be resolved in detail (Fig. 3). Complementary ^{23}Na datasets with (1.4mm)^3 resolution were acquired (T_{acq}=15 min) in first ex-vivo studies (Fig.3+4).

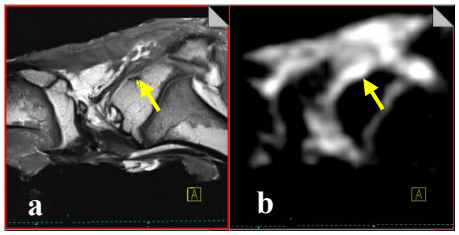

Fig. 3: (a) T1 weighted spin echo (TR/ TE/α=675 ms/ 12 ms/ 90°, 0.3 x 0.3 x 1.2 mm^3) and (b) the co-registered ^{23}Na images (DARP [3], (1.4 mm)^3 isotropic resolution). The arrows mark the provoked cartillage injury (see also Fig. 4).

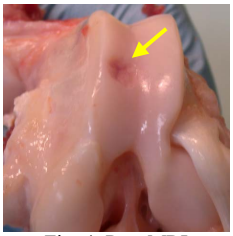

Fig. 4: Post MRI macroscopic analysis of the injured cartilage. The arrow highlights the circumscribed cartilage injury.

Conclusion: We present a two coil SNR optimized coil system for co-registered ^{1}H and ^{23}Na imaging of Mini-Pig knee cartilage at a whole body 7 Tesla MRI that does not show the common loss of sensitivity due to a double resonant coil design.

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References:

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