SODIUM *IN VIVO* MEASUREMENT OF T_1 AND T_2* RELAXATION TIMES OF ARTICULAR CARTILAGE AT 7 TESLA

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Introduction/Purpose:

One of the first changes associated with degenerative osteoarthritis (OA) is the loss of proteoglycans (PG) from the articular cartilage. It has been shown on bovine cartilage specimens that the decrease of PG content in cartilage results in the prolongation of sodium T_1 and slow T_2 component (T_{2S}) and in shortening fast T_2 component (T_{2F}) [1]. In this study, we demonstrate the feasibility of *in vivo* sodium relaxation time measurements using spoiled gradient echo sequence (GRE) at 7 Tesla.

Subjects and Methods:

Four volunteers (mean age of 24.8 years, 1 female, 3 males) with no history of pain in the knee were included in this study. All experiments were performed on a 7 Tesla Siemens Magnetom (Siemens, Erlangen, Germany) whole body system. At first the proton images for evaluating articular cartilage in all subjects were acquired with a single loop transmit/receive surface coil. Then sodium measurements were performed using a ^{23}Na-only (78.61 MHz) circularly polarized knee coil. Our sodium protocol consisted of a localizer, a 3D-GRE sequence for choosing the slice with the highest signal in cartilage, a set of low resolution 2D-GRE images for flip angle adjustments and relaxation experiments itself. Flip angle calibration was achieved by varying the RF amplitude in a set of lower resolution sodium images. For measuring the articular cartilage T_1 relaxation times, a saturation recovery spoiled-2D-GRE sequence was employed using the following parameters: TR = 125 ms, TE = 3.62 ms, a bandwidth of 240 Hz/pixel, 90° flip angle, 4.0 x 4.0 mm^2 in-plane resolution, 10 mm slice thickness, 64 averages and six different TI times (9.2, 14, 18, 25, 37 and 117 ms). The measurement time for one TI was 8:32 min. For estimating of cartilage T_2* values, the 2D-GRE multiecho sequence was used with TR = 60 ms, a bandwidth of 240 Hz/pixel, 89° flip angle, 4.0 x 4.0 mm^2 in-plane resolution, 10 mm slice thickness, 128 averages, eight different TE times of 3.62, 8.28, 12.94, 17.60, 22.26, 26.92, 31.58, 36.24 ms and the measurement time of 8:12 min. The whole sodium protocol including adjustments took about 90 minutes. T_1 and T_2* relaxation maps were calculated from intensities of non-interpolated pictures on a pixel-by-pixel basis using a three parameter nonlinear least squares fitting routine written in IDL (Interactive Data Language, Research Systems, Inc., Boulder, CO) (Fig.1,2). For assessing precision of the fitting routine, a corresponding measure of goodness-of-fit (R^2) map was calculated for each T_1 and T_2* map. Accuracy of the relaxation experiments was checked by measuring each subject together with two homogenous agarose-saline phantoms containing 154 mM NaCl solution and 8 or 12% w/w of agarose respectively.

Results:

As previously published [2], fast component of transversal magnetization relaxation (T_{2F}) fell in the range from 0.7 to 2.3 ms. TE of 3.62 ms used in this study caused a signal loss of T_{2F} between 99% and 79%. Therefore, the reported T_2* measurements detect only the slow component of transversal relaxation (T_{2S}*). Cartilage mean T_1 and T_{2S}* times calculated from four subjects yield values of 16.9 ± 2.6 ms and 12.2 ± 2.4 ms (mean ± standard deviation (SD)), respectively (Tab.1,2). Both relaxation times are in good agreement with the published range of T_1 from 14 to 20 ms and T_{2S} from 8 to 12 ms [2]. The SD of relaxation times of cartilage and phantoms are comparable. Since our saline-agarose phantoms are considered to be homogenous, we believe that the range of observed relaxation times of cartilage is also small.

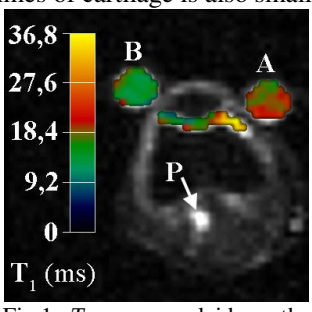

Fig.1. T_1 map overlaid on the sodium image of 1st. volunteer. P = Popliteal artery, A = 8% agarose-saline phantom and B = 12% agarose-saline phantom.

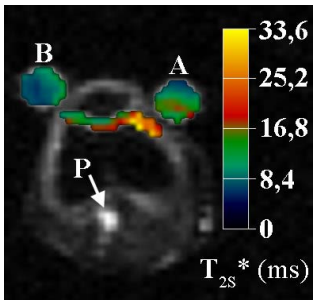

Fig.2. T_{2S}* map overlaid on the sodium image of 1st. volunteer. P = Popliteal artery, A = 8% agarose-saline phantom and B = 12% agarose-saline phantom.

Vol.	Cartilage T_1 (ms)	Cartilage R^2 (-)	8% Phantom T_1 (ms)	8% Phantom R^2 (-)	12% Phantom T_1 (ms)	12% Phantom R^2 (-)
1	16,2 ± 3,8	0,932	19,6 ± 2,4	0,929	15,1 ± 2,4	0,926
2	13,5 ± 3,7	0,921	17,9 ± 5,0	0,934	13,4 ± 2,3	0,907
3	18,9 ± 6,5	0,923	20,4 ± 5,0	0,940	17,9 ± 6,4	0,919
4	18,9 ± 3,4	0,914	24,3 ± 1,8	0,955	18,5 ± 3,0	0,947
Mean	**16,9 ± 2,6**	**0,923**	**20,6 ± 2,7**	**0,940**	**16,2 ± 2,4**	**0,925**

Tab.1. T_1 & R^2 values of cartilage & saline-agarose phantoms (mean±SD).

Vol.	Cartilage T_{2S}* (ms)	Cartilage R^2 (-)	8% Phantom T_{2S}* (ms)	8% Phantom R^2 (-)	12% Phantom T_{2S}* (ms)	12% Phantom R^2 (-)
1	8,9 ± 2,0	0,984	8,3 ± 2,2	0,983	5,8 ± 1,2	0,991
2	13,3 ± 4,0	0,979	13,8 ± 2,9	0,977	10,0 ± 3,8	0,985
3	14,4 ± 3,2	0,979	11,0 ± 4,4	0,988	10,5 ± 4,3	0,980
4	12,3 ± 2,5	0,973	12,8 ± 3,6	0,980	10,4 ± 3,8	0,987
Mean	**12,2 ± 2,4**	**0,979**	**11,5 ± 2,4**	**0,982**	**9,2 ± 2,3**	**0,986**

Tab.2. T_{2S}* & R^2 values of cartilage & saline-agarose phantoms (mean±SD).

Discussion/Conclusion:

In this study we demonstrated that the *in vivo* measurement of sodium relaxation times using a standard GRE sequence is feasible due to a high signal-to-noise ratio of the 7 Tesla scanner. Since the range of relaxation times within healthy volunteers is low and it is proven that the relaxation times change in OA, we can expect that this method will be useful in detecting early stages of OA.

References:

[1] Insko E.K., et al., *Magn Reson Med*, 1999; 41: p. 30-34. [2] Reddy R. et al., *Magn Reson Med*, 1998; 39: p. 697-701.