Multiparametric therapy study of the goat cartilage after inducing Osteoarthritis

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Introduction: The increase of the life expectancy in western civilizations is accompanied with more musculoskeletal deceases e.g. Osteoarthritis (OA). Accordingly to this trend there is a great need for an early detection and a successful therapy of OA.

The aim of this goat study was to compare Sodium, $T_{1\rho}$ and dGEMRIC measurements for the characterization of cartilage tissue in a diseased joint and the estimation of the GAG content in the cartilage. Furthermore, combining different MRI methods could potentially lead to earlier and clearer diagnoses and to a better characterization of tissue engineering methods. Therefore OA was surgically induced in goats and examined by MRI over a course of 16 weeks. In this work the results of Sodium, $T_{1\rho}$ and dGEMRIC measurements and the correlations between the different techniques are presented.

Materials and Methods: To induce OA medial the meniscus and anterior cruciate ligament (ACL) were surgically removed in 12 goats (6 control; 6 therapy). The weight bearing zones of the femoral condyles were examined healthy, 3 and 16 weeks postoperatively using MRI. Some of the measurements had to be discarded later because of motion artifacts.

An optimized 3D Gradient Echo sequence (TR/ TE = 40/4ms, resolution: 2×4×5mm³, averages: 40) with non-selective excitation and asymmetric readout was applied to acquire a sodium data set of each goat knee with a custom built coil[1]. A 2D gradient echo with spinlock preparation (TR/TE = 990/4.8ms, τ = 1/10/30/60ms, inplane resolution: 0.5×0.5mm^2) was used to determine the $T_{1\rho}$ relaxation time. The T_1 relaxation time was determined with a 2D IRSnapshotFlash method (TR/TE = 9.1/4.8ms, inplane res.: 0.5×0.5mm^2) after injection of the contrast agent (CA) Magnevist (0.2mL/kg). The examined knee was moved manually for 10 minutes after injection. For determining the dGEMRIC index two calculations were performed: dGEMRIC (1) is equal to the mean T_1 value after CA administration and dGEMRIC (2) got calculated via the formula $1/T_{1,post} - 1/T_{1,prae}$. All measurements were performed at a 1.5T system (Magnetom Avanto, Siemens) in combination with a 4+4 channel multifunctional coil array (NORAS MRI products).

Image reconstruction, data fitting and a manually segmentation of the area of contact between femur and tibia was done offline using Matlab R2012b (The Mathworks). The program used for the statistical analysis was PASW Statistics 18 (IBM).

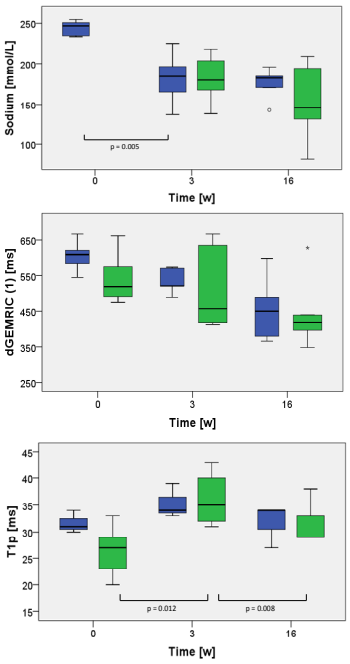

Fig. 1: Sodium, dGEMRIC (1) and $T_{1\rho}$ over the course of 16 weeks (healthy, 3 weeks after defect, 16 weeks later) within the control (blue) and therapy (green) group.

Results: Figure 1 shows the results of all measurements within the control (blue) and therapy (green) groups over the course of 16 weeks after inducing the defect. Sodium and dGEMRIC (1) display a decrease over time in both groups by trend. The decrease in Sodium within the first three weeks is significant. The $T_{1\rho}$ values increase at the beginning and decrease later on. This is significant in the therapy group.

In figure 2 three scatter plots are displayed with dGEMRIC (2), $T_{1\rho}$ and Sodium over dGEMRIC (1). In table 1 the Pearson correlation coefficients and the significant levels are listed. We found a very strong correlation (**) between dGEMRIC (1) & dGEMRIC (2) and moderate correlations (*) between $T_{1\rho}$ & dGEMRIC (1), Sodium & dGEMRIC (1) and $T_{1\rho}$ & dGEMRIC (2).

Methods		r	p
dGEMRIC (2)	dGEMRIC (1)	- 0.867**	< 0.001
$T_{1\rho}$	dGEMRIC (1)	0.548*	0.015
Sodium	dGEMRIC (1)	0.451*	0.012
$T_{1\rho}$	dGEMRIC (2)	0.466*	0.044
Sodium	$T_{1\rho}$	0.249	0.304
Sodium	dGEMRIC (2)	0.226	0.230

Tab. 1: Pearson correlation coefficients and significance levels.

Discussion & Conclusion: All measurements were able to characterize the cartilage after OA. The Sodium and dGEMRIC (1) values show the expected behavior after an OA with a loss of GAG, like it is described in literature for humans[2,3]. The increase of $T_{1\rho}$ at the beginning also corresponds to a degenerating cartilage[4], but the decrease in week 16 is a sign of early changes towards a kind of healing process in the cartilage. This fits well to findings described in literature for humans that $T_{1\rho}$ is sensitive to early cartilage changes[5].

Due to the very strong correlation between both dGEMRIC methods the T_1 measurement before CA application can be dropped in future goat studies, which will lead to a decreased measurement time. This coincides with results for the human cartilage[6].

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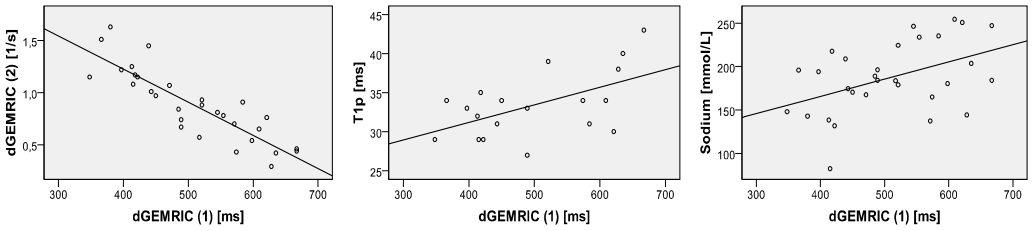

Fig. 2: Scatterplots and linear regression lines of dGEMRIC (2), $T_{1\rho}$ and Sodium over dGEMRIC (1).

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