QUANTITATIVE SODIUM MRI IN AN OSTEOARTHRITIS GOAT ANIMAL MODEL: PRELIMINARY RESULTS

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Introduction:

Sodium is known to be a sensitive MR imaging biomarker for early diagnosis of knee articular cartilage osteoarthritis (OA). Several studies have established the feasibility of sodium MRI to assess the progress of knee OA in humans [1,2]. The goat animal model closely matches the human knee anatomy and can be used to mimic the progressive development of OA and monitor the loss of proteoglycans and glycosaminoglycans (GAG). In this study we used quantitative sodium MRI to track the cartilage degradation following an OA inducing surgery.

Material and Methods:

To induce OA in the goat animal model, the medial meniscus of the knee joint was surgically removed in one knee. The therefore altered loading stress on the weight bearing joint leads to degradation of the articular cartilage, subsequently. Proton and sodium MRI was performed on six goats (62 to 75 kg) one to two weeks pre-surgery, 3 and 13 weeks post-surgery on a 1.5 T scanner (Siemens Medical Solutions, Erlangen, Germany). A custom built double resonant U-shaped coil which fits the goat knee was used. The coil consists of a quadrature surface coil for sodium and a single channel surface coil for proton imaging. The image slices were oriented perpendicular to the medial condyle plane with proton localizers. An optimized 3D Gradient Echo sequence (FOV: 128 x 128 x 120 mm³, matrix: 64 × 32 x 24, resolution: 2 x 4 x 5 mm³, TE: 4 ms, Bandwidth: 85 Hz/p, TR: 40 ms, averages: 40) with non-selective excitation and asymmetric readout was used to acquire a sodium 3D data set of each goat knee in 20:30 min. Additionally high resolution proton MRI (Siemens 3D MEDIC, resolution: 0.4 x 0.4 x 0.8 mm³, TE: 25 ms, TR: 48 ms) was performed with an 8 channel receive only array coil (Noras MRI products, Höchberg, Germany). A B_1-map of the sodium coil was acquired with a phase sensitive B_1-mapping method [3] and a NaCl phantom (50 mmol/L). This B_1 map together with fiducial markers, which were attached to the coil, allowed us to retrospectively perform B_1 correction of the sodium in vivo datasets. The B_1 corrected datasets were scaled to sodium concentration maps with agarose phantoms of known concentration [1]. Finally, the maps were corrected for T_1/T_2^* of the goat cartilage and the 75 % water fraction of cartilage. Thus, the resulting scale of the sodium concentration maps is only valid for cartilage.

Results:

The healthy goats show similar mean sodium concentration in the range of 218±42 to 257±68 mmol/L in the medial cartilage region (Fig1). The evaluation of the 3 weeks post-surgery measurements was discarded due to major post-surgical trauma of the knee joints leading to oedema/effusions which compromise a precise data analysis due to partial volume effects. 13 weeks post-surgery, a reliable sodium quantitation is still not possible in most subjects. For those animals, where the sodium concentration is accurately quantifiable (Fig.2) in the weight bearing cartilage region, a significant decrease in the sodium concentration (146±49 to 164±39 mmol/L) could be measured (Fig.1). As known from literature [1], this decrease corresponds to a loss of GAG in the cartilage (Fig.2) and is in the range of advanced OA in humans reported by other researchers [4].
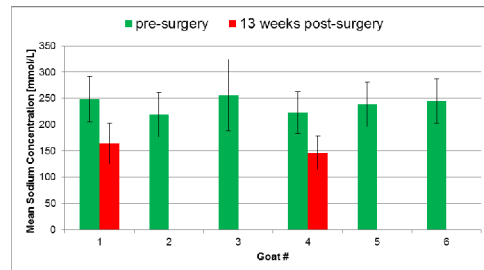
Fig 1: Mean sodium concentration in mmol/L in the medial cartilage region for six goats pre- and two goats 13 weeks post-surgery.
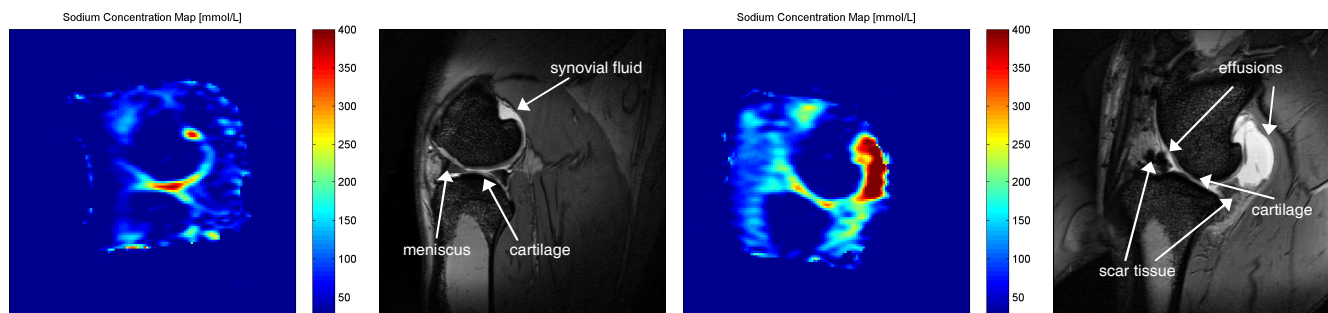
Fig 2: Left: Sodium concentration map and corresponding T_1/T_2^*-weighted proton image of a healthy pre-surgery subject; **Right:** Sodium concentration map and corresponding T_1/T_2^*-weighted proton image of an OA subject;

Conclusion:

The described surgical model induces increased stress to the cartilage which leads to degradation and can thus be used perfectly to mimic the progressive nature of OA. This process was successfully tracked for several subjects by the presented quantitative sodium MRI. Sodium fluid suppression [5] and high resolution imaging to improve delineation of the cartilage is advisable in this surgical model but hardly feasible at 1.5 T due to low SNR. Less invasive surgical models for the goat [6] which cause only minor post-surgical trauma are more suitable for quantitative MRI studies.

Acknowledgement:

References:

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