Three-dimensional delayed Gadolinium enhanced MRI of cartilage (dGEMRIC) for in vivo evaluation of reparative cartilage after matrix-associated autologous chondrocyte transplantation at 3.0 Tesla – preliminary results

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Introduction: Delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC) is known to be a reliable technique for evaluating the glycosaminoglycan (GAG) concentration of articular cartilage and has been validated in both basic scientific and clinical studies[1-3]. However the standard dGEMRIC technique is either limited to single slices in 2D acquisition or suffers from long acquisition times in 3D sequences. This therefore limits attractiveness of dGEMRIC for clinical use. The aim of our study was therefore threefold:

1. to reduce scan time of the dGEMRIC method with a 3D GRE sequence with two different flip angles at 3.0T.
2. to validate the technique against a standard Inversion Recovery-sequence on phantoms and define the optimal flip angle combination.
3. to apply this dGEMRIC technique in the follow-up of patients at different post operative intervals following matrix-associated autologous chondrocyte transplantation (MACT) surgery to evaluate the global GAG content of the graft.

Materials and Methods:

Phantom study like the clinical study was performed on the same 3T Trio scanner (Siemens, Erlangen, Germany) using the same dedicated 8 channel knee coil. Phantoms were prepared from 7 different concentrations of NaCl and gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany). In order to calibrate the phantom fluids an inversion recovery sequence was performed at 7 different non-equidistant TI times: 25, 75, 180, 350, 650, 1100,and 1680 ms. A 3D dual flip angle GRE sequence for dGEMRIC technique was used for evaluation of the same phantoms. Several different flip angle combinations were tested: 35°-10°, 37°-7°, 42°-8°, 46°-8°, 52°-10°, 61°-12°, 68°-13°, 71°-14° and 72°-15°. The parameters of the 3D GRE sequence were: TR/TE (ms): 50/3.67, matrix size: 256x256, FOV (mm): 120x120. The effective slice thickness was 2mm. Quantitative T1 mapping by dGEMRIC was performed in fifteen consecutive patients (two females; thirteen males; age range: 21-54 years, mean age: 37.8 years) after MACT on the femoral condyle using a hyaluronan based scaffold (Hyalograft®C scaffold [Fidia Advanced Biopolymers, Abano terme, Italy]. For quantitative T1 mapping a 3D GRE sequence, Volume Interpolated Breath-hold Examination, (VIBE), with a TR/TE:50/3.67ms, FOV:183x200 mm and matrix size: 317x384 was performed, in-plane resolution: 0.6x0.5 mm with an effective slice thickness: 1mm. Slab with 36 slices was applied. The scan time was 6 mins 53 secs. With respect to the postoperative time interval patients were subdivided into four groups: Group I, 3-6 months (three patients); group II, 10-13 months (three patients); group III, 19-22 months (five patients); and group IV, 26-42 months (four patients).The T1 time constant were calculated on a pixel-by-pixel basis j,k according to the next equation, where $T1c_{j,k}$ = T1-value and $Q_{j,k}$ = quotient-pixel-values

$$T1c_{j,k} = \frac{TR}{\ln\left[\frac{\sin(\alpha_1)*\cos(\alpha_2) - Q_{j,k}\sin(\alpha_2)*\cos(\alpha_1)}{\sin(\alpha_1) - Q_{j,k}*\sin(\alpha_2)}\right]} \qquad Q_{j,k} = \frac{meas\_1_{j,k}}{meas\_2_{j,k}}$$

Results Fig.1 shows correlation of T1 values obtained from IR and dual flip angle technique with several excitation pulse combinations on phantoms. Best agreement with IR for short as well as long T1 values on phantoms is shown for the dual flip angle combination with 35-10 degree (fig.2). Fig.3 show an example of color-coded T1 relaxation time map after intravenous contrast agent administration in a patient 24 months after MACT surgery, which show different T1 values at the cartilage repair site compared to adjacent normal hyaline cartilage. The mean Δ R1 for repair tissue in patient group I was 2.96 versus 0.94 at the reference site with normal hyaline cartilage ($p<0.05$), in group II: 2.02 vs 1.13 ($p=0.096$), in group III: 1.48 versus 0.62 ($p<0.05$) and in group IV: 2.13 vs 1.13 ($p<0.05$) (fig.4). The mean relative Δ relaxation rate R1 was 3.14 in patient group I, 1.79 in group II, 2.39 in group III and 1.88 in group IV. The spatial distribution of ΔR1values are shown for the medial and lateral portions of the implant. No statistically significant difference between the mean ΔR1 of the medial portion of implant in group I compared to refference ΔR1 was found, representing higher GAG content (fig.5).

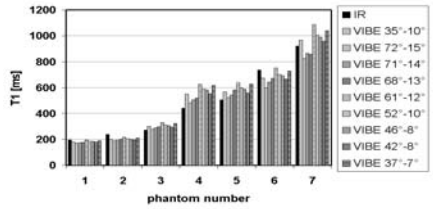

Figure 1

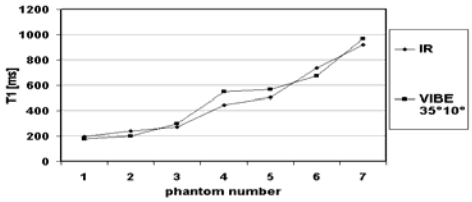

Figure 2

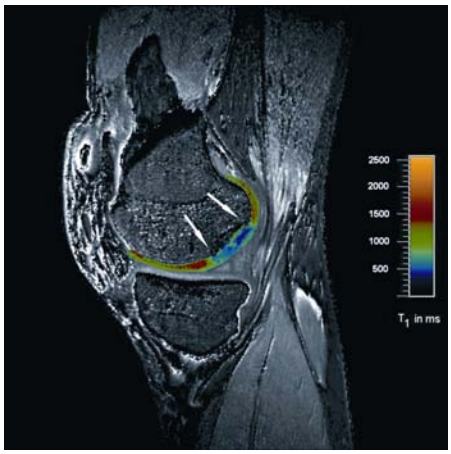

Figure 3

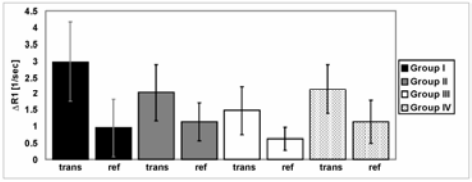

Figure 4

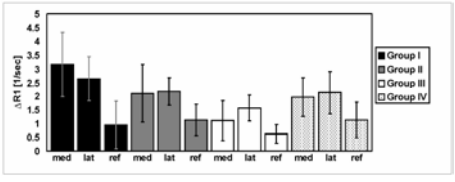

Figure 5

Discussion/Conclusion:

In conclusion the 3D dual flip angle dGEMRIC technique is comparable to standard T1 inversion recovery technique for T1 mapping and its application in patients after MACT surgery is feasible and can be performed in clinical acceptable scan times.

References:

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