T2 & T2ρ maps: Sequence Development and Clinical Impact on Joint Study

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Introduction

Dedicated MRI scanners are widely diffuse by now and new powerful sequences have been developed for permanent magnets. One of the major improvements still to be achieved is to obtain functional sequences.
It is known from the literature that T_2-maps allow to quantify the water content and, therefore, to estimate the presence of proteoglycans in the cartilage surface. The purpose of this work is the assessment of T_2- and $T_{2\rho}$-maps, obtained by a dedicated MRI system with a new acquisition protocol, as a diagnostic tool for the evaluation of the knee joint cartilage.

Materials and Methods

Two optimized Steady-State sequences have been added to the standard knee acquisition protocol (Esaote G-Scan – 0.25 T) of 80 patients: 3D SHARC (TR: 30 ms; flip angle: 25 deg); 3D SST1 without RF spoiling (TR: 21 ms; flip angle: 70 deg).
As for acquisition geometry, we set up two alternative configurations:
• FOV: 200 x 200 x 120 mm^3; Voxel: 1.0 x 1.0 x 2.5 mm^3; Overall scan time: 8 minutes;
• FOV: 200 x 150 x 120 mm^3; Voxel: 0.8 x 0.8 x 1.8 mm^3; Overall scan time: 9 minutes.
The related signal equations were inverted voxel-by-voxel to obtain quantitative PD-, T_1- and T_2-maps of the whole joint; the spurious susceptibility dependences of transversal relaxation time were suppressed by means of an accurate echo-time choice. Relying on the quantum theory of NMR relaxation processes, we were also able to derive the $T_{2\rho}$-map of the joint as harmonic mean of T_1 and T_2. T_2- and $T_{2\rho}$-maps were evaluated in consensus by two radiologists at fixed range scales (T_2 ranging from 0 to 150 ms; $T_{2\rho}$ from 0 to 300 ms) to find cartilage defects. The number of focal or diffuse cartilage alterations detected by means of each kind of map was then compared to the number of anomalies in original SS images (SSIs). Also bone focal or diffuse anomalies were analyzed to test map sensitivity and correlation between cartilage and bone defects was evaluated.

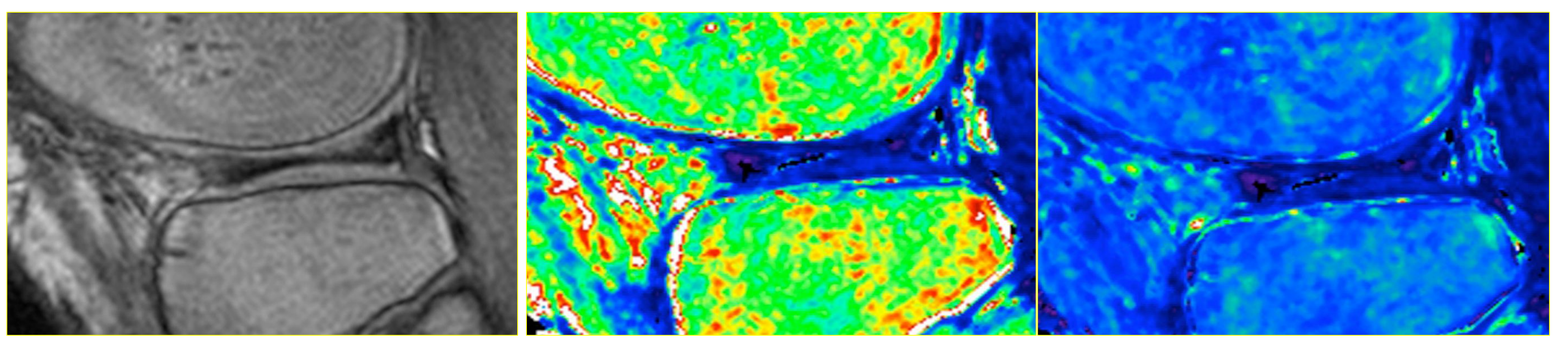


Figure 1 (a, b,c)

a) Sagittal 3D SHARC

b) Sagittal T_2 Map with the Osirix NIH colorimetric scale (T_2 ranging from 0 to 150 ms)

c) Sagittal $T_{2\rho}$ Map with the Osirix NIH colorimetric scale ($T_{2\rho}$ ranging from 0 to 300 ms)

Results

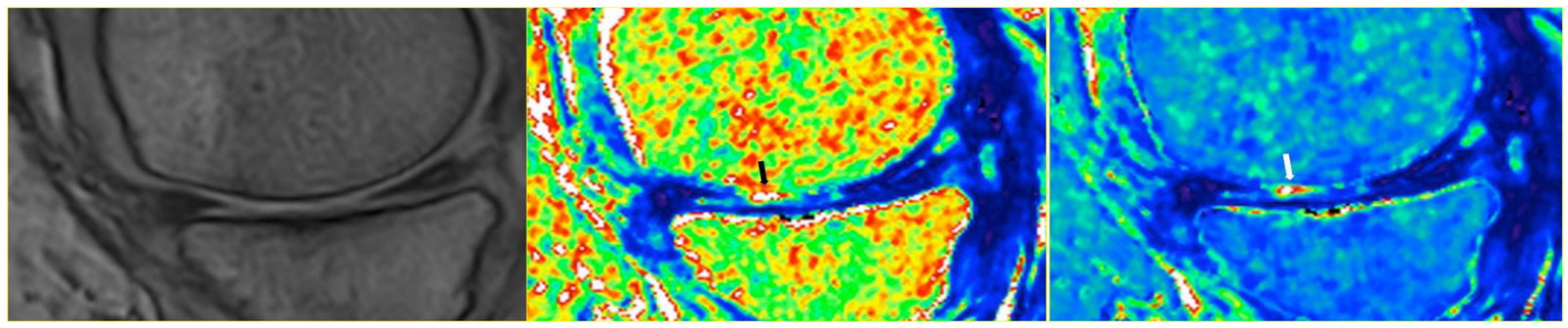
As for the evaluation of diffuse cartilage alterations, SSIs, T_2-maps and $T_{2\rho}$-maps were positive in 4, 35 and 24 cases, respectively. Moreover SSIs revealed 3 focal cartilage alterations, T_2-maps revealed 48 and $T_{2\rho}$-maps revealed 70.
As for the bone evaluation, SSIs showed 3 diffuse bone signal anomalies, $T_{2\rho}$-maps 10; no diffuse bone alterations were evident in T_2-maps. SSIs showed 40 focal bone cortical/subcortical anomalies, T_2-maps 10 and the $T_{2\rho}$-maps 14. A correlation between cartilage and bone anomalies was found in 3 cases by means of both SSIs and T_2-maps, and in 25 cases by $T_{2\rho}$-maps.

Figure 2 (a, b, c)

a) Negative sagittal 3D SHARC

b) Sagittal T_2 map of same subject shows focal alteration (arrow) in the femoral cartilage.

c) Sagittal $T_{2\rho}$ map of same subject shows focal alteration (arrow) in the femoral cartilage.



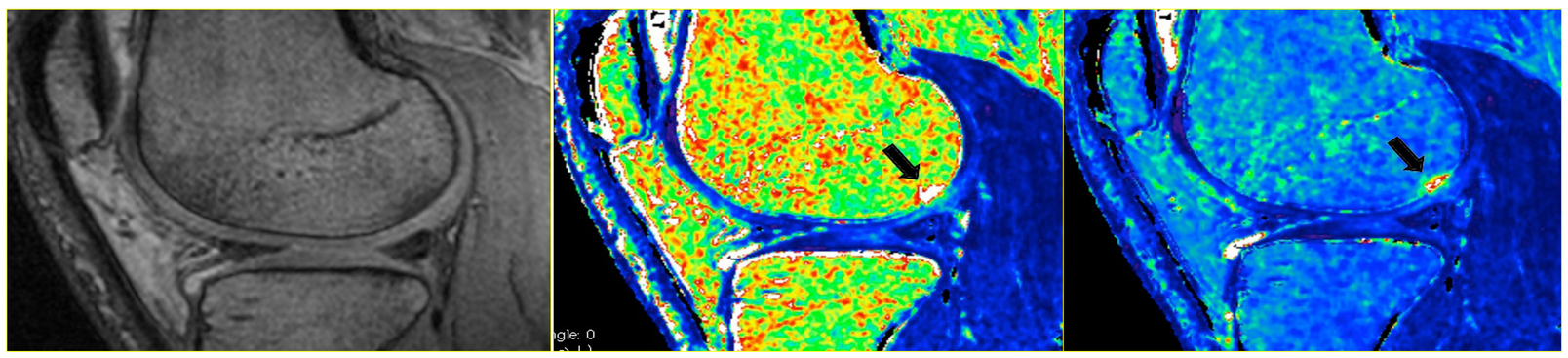


Figure 3 (a,b,c)
a) 3D SHARC with no abnormal cartilage evidence; bone marrow hypointensity is slightly appreciable in the posterior area of femoral condyle

b) The T_2 map shows focal alteration (arrow) in the femoral cartilage not seen in the 3D SHARC; also in the adjacent bone marrow it shows an intense focal signal alteration.

c) The $T_{2\rho}$ map shows focal alteration (arrow) in the femoral cartilage not seen in the 3D SHARC; also in the adjacent bone marrow shows an intense focal signal alteration.

Discussion & Conclusions

Cartilage evaluation is one of the most difficult challenges to face in MRI study of the knee. Several sequences have been developed to visualize cartilage and to outline its margins. Unfortunately, morphological cartilage evaluation is often insufficient for locating malacic cartilage areas: indeed, normal cartilage appearance does not imply normal cartilage structure. During arthroscopic surgery performed for menisci or other causes, orthopedists often have to correct cartilage defects that were not detected by the routine pre-surgical MRI examinations.
The possibility to have more specific information about cartilage is even more desirable if the MRI study is performed with dedicated systems that are cheaper and have a higher patient compliance. In this work we developed and tuned an acquisition protocol of 3D sequences allowing to extract a considerable amount of relaxometric information about the knee joint; the resulting quantitative imaging was assessed against the evaluation of cartilage defects and bone anomalies. Our initial results show that both T_2- and $T_{2\rho}$-maps provide extra information on the health status of knee cartilage, even in absence of morphological evidence of alteration on native 3D images; in particular, $T_{2\rho}$-maps appeared more sensitive than T_2-ones.
This kind of results could be suitable not only to help surgeons but also in the follow-up of the outcome of cartilage integrator administered *per os* or directly in the joint space. The thoroughness of the relaxometric properties we are able to extract from the sample allows, at least in principle, to simulate several MRI sequences. In particular, the generation of a synthetic STIR contrast would reduce the scan time needed to acquire the complete MRI examination (at the moment, the relaxometric protocol scan time adds to 15 minutes of the basic study duration). If the simulated STIR images comply with the acquired STIR standards, we will be able to obtain the total MRI knee study in less than 20 minutes. Another improvement will be the cartilage study in weight-bearing position. Esaote G-Scan permits the examination of patients in orthostatic position; as cartilage is known to vary its water content after sport, weight-bearing position could allow the relaxometric tool to be more sensitive to individuate malacic cartilage zones.

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