The effect of the selection of measured tissue and assumed constant T1 values on the measurement of T1rho in patients with minimal and severe osteoarthritis (OA) at 3.0T MR system

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Background:

The purpose of this study was to evaluate the effect of the selection of real tissue and assumed constant T1 values on the measurement of T1rho using 3D-gradient echo-based T1rho-weighted imaging sequence in patients with minimal and severe osteoarthritis (OA) at 3.0T MR system.

Currently T1rho MR imaging has been increasingly used to investigate the cartilage degeneration in osteoarthritis and reported to be able to be useful for the improved diagnosis and management of the early stages of cartilage degeneration due to the fact that T1rho is very sensitive to early biochemical change in cartilage (1, 2). In a technical view, however, one of the problems in measuring T1rho using a 3D gradient echo sequence is about the dependence on tissue T1 on T1rho measurement and most investigators have assumed tissue T1 to be constant because the variation in T1rho by T1 distribution could be expected to be small (3). However, T1 values may be largely affected by the pathological change in OA and in addition, they have been known to be longer at 3.0T compared to 1.5T, which may make measurement error in T1rho to be larger in that case. Also, even small error in T1rho measurement caused by the constant T1 assumption may be the blockade for the precise diagnosis of patients with OA based on T1rho map.

As we know, there have been few reports on the T1rho measurement using tissue T1 values not the assumed ones. Therefore, we evaluated the degree of the variation in T1rho based on tissue T1 compared to using constant T1 with the severity in OA at 3.0T.

Materials and Methods:

Osteoarthritis subjects were classified into 2 patient groups of minimal and severe OAs (male=1, female=7, average age=60 years); each group consisted of 4 patients based on clinical symptoms and Kellgren-Lawrence grades (KL score).

Sagittal 3D-T1rho-relaxation mapping with parallel imaging (GRAPPA with 24 reference k-space lines, PAT factor = 2) were performed on a 3.0 Tesla (MAGNETOM Trio, Siemens, Germany) using a 3D FLASH T1rho sequence (TR/TE/flip angle = 175 ms/4.15 ms/30°, matrix=256x256, FOV=140mm, the number of slices=16, slice thickness=4mm) and a knee tranceiver coil. Five 3D- T1rho-weighted images with varying spin-lock pulse lengths (TSL = 2, 5, 10, 20 and 30 ms) were acquired in order to construct T1rho maps. It took 30 minutes and 5 seconds for all scans. Based on the variable flip angle method, $T1$ relaxation times of knee cartilage were measured from $T1$-weighted 3D FLASH images with a 2 different flip angles (flip angle=5 and 26).

T1rho maps from 5 different T1rho-weighted images were constructed by fitting them into Bloch equation of signal intensity using a nonlinear Levenberg - Marquardt least-squares fitting algorithm (4) and all programs were developed on a platform of IDL (ITT Visual Information Solutions, USA). Two T1rho map images were acquired; one ($T1rho_{tissue}$) using tissue T1 values and the other ($T1rho_{constant}$) using the assumed constant T1 (1240ms).

As regions to be evaluated in segmented cartilage images we selected the femoral compartments in minimal OA representatively and femoral ones with osteophytes in severe OA. Cartilages were segmented on T1-weighted 3D FLASH images using manual procedure by one radiologist and data pixels with a T1 under 1000ms were excluded from the evaluation because they may be thought to be from femoral bone. Two T1rho maps and their absolute percent change ($|T1rho_{tissue}-T1rho_{constant}|$) / $T1rho_{constant}$ *100 were compared pixel-by-pixel in 2 patient groups to evaluate the effect of the selection of T1, tissue and constant (1240ms) on T1rho.

Results:

Mean percent change between $T1rho_{constant}$ and $T1rho_{tissue}$ values were within 10 % in minimal OA and exceeded 10 % except one case in severe OA (Table 1). Most region of cartilage in mild OA showed small change under 8 % in T1rho, but in severe OA some abnormal region had large difference over 10 % (Figure 1). There was a tendency that the usage of tissue T1 instead of assumed constant T1 caused T1rho to be decreased. Mean T1 values in femoral cartilage compartment ranged from 1150 to 1355 ms in all patient groups and their distribution was between 12 and 25 % from mean values.

Conclusions:

Our preliminary study showed there was the overall real change in T1rho that can be not neglected by using tissue T1 instead of constant T1 at the femoral cartilage at 3.0T in OA and it can be affected more in severe OA than in minimal OA although the selection of constant T1 has been reported to have a small effect on T1rho in other literatures. Larger effect of T1 selection on T1rho in severe OA compared to mild one may be due to larger change in T1 by pathological conditions.

Therefore, the usage of tissue T1 when T1rho is measured should be taken into consideration for the precise analysis or the multi-center comparative study irrespective of the selection T1 value.

References:

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3. Regatte RR, Akella SVS, Arijitt Borthakur, Kneeland JB, Reddy R, In Vivo Proton MR Threedimensional. T1rho Mapping of Human Articular Cartilage: Initial Experience. Radiology 2003; 229:269–274
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Table 1. T1, $T1rho_{constant}$, $T1rho_{tissue}$ and their T1rho percent change at femoral cartilage in two groups of patients with OA (m:minimal, s:severe, value: mean(SD))

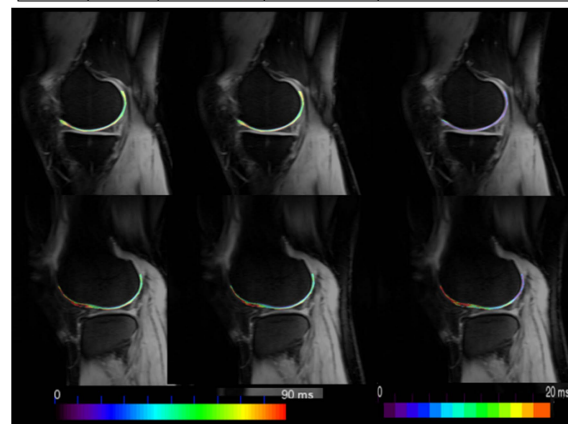| Patient	KL score	$T1rho_{constant}$ (ms)	$T1rho_{tissue}$ (ms)	Percent change in T1rho (%)
m1	2	45.9 (16.4)	45.6 (17.8)	6.1 (5.5)
m2	2	33.7 (12.8)	31.5 (11.1)	7.4 (5.6)
m3	2	46 (9.8)	43.5 (11.1)	7.3 (5.4)
m4	2	45.2 (11.7)	45.3 (13.2)	5.9 (4.6)
s1	4	49.6 (6.8)	40.5 (16.8)	18.5 (8.9)
s2	4	54.7 (17.1)	49.4 (16.1)	11.2 (9.2)
s3	4	20.7 (13.8)	21.6 (14.9)	5.1 (5.5)
s4	4	47.5 (16.7)	43.7 (21.8)	10.5 (7.4)

Figure 1. T1rho map images based on the constant T1 (left) and measured tissue T1 (middle) and their difference map image (right, $|T1rho_{tissue}-T1rho_{constant}|$) in patients with osteoarthritis (top: minimal OA, bottom: severe OA). While T1rho in whole cartilage showed small difference between two different usages of T1 value in minimal OA, in severe OA large difference (over 5ms, red color) were shown at damaged cartilage.