Comparison of $T_{1\rho}$ and T_2 relaxation times in articular cartilage

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Introduction. In the last years it was shown both in vitro and in vivo that $T_{1\rho}$ is a useful parameter for detecting degenerative changes in articular cartilage (1). Similar to the single spin echo, the technique of spin-locking (SL) used for measuring $T_{1\rho}$ relaxation times eliminates dephasing of stationary spins precessing in an inhomogenous magnetic field. In addition, it also suppresses dynamic processes (relaxation mechanisms and dephasing of magnetization due to diffusion in the inhomogeneous field) having their characteristic times longer than the inverse of the spin locking amplitude B_1 (in frequency units). The Carr-Purcell-Meiboom-Gill multiple spin echo technique (CPMG), however, is also capable to reduce effects of relaxation processes with long correlation times (2,3) and dephasing of magnetization due to diffusion (4). The aim of this study was to compare the ability of both technique, CPMG and SL, to eliminate dephasing of the transverse magnetization due to the above effects, and to assess their potential to map pathological defects in articular cartilage.

Methods. Human cartilage-bone specimens were wrapped in a paraffin film and stored in a fridge in sealed plastic tubes. MR images were obtained at 24 °C on a 3 Tesla Bruker MEDSPEC scanner equipped with a microimaging gradient set, delivering the maximum gradient strength of 200 mT/m. A 35 mm diameter resonator was used both as a transmitter and receiver. The specimens were positioned in the resonator with the cartilage surface nearly parallel with the static magnetic field. The T_2 relaxation times were obtained by a CPMG technique using a repetition time of 1.5 s, a field-of-view of 5 × 3 cm, a slice thickness of 1.7 mm, a matrix size of 128 × 96, and 4 averages. Inter-echo delays (TE) were 20, 10 and 6.2 ms with the corresponding total echo times varied in the range from 20 to 60 ms, from 10 ms to 60 ms, and from 6.2 to 62 ms, respectively. To reduce the effect of non-ideal flip angles across the slice, the first echo in each experiment was discarded (5). $T_{1\rho}$-weighted images were measured using a magnetization preparation SL pulse sequence (6), followed by a gradient echo sequence with a repetition time of 1.5 s and an echo time of 3 ms. Geometrical parameters were the same as in case of T_2 maps. The $T_{1\rho}$ relaxation maps were calculated from series of six images measured as a function of the spin-locking time, which was varied from 6 ms to 80 ms. Amplitudes of the spin-locking field B_1 in frequency units, $\gamma B_1/2\pi = f1$, were 500, 1000, 1500 and 2500 Hz.

Results. Fig. 1 shows that the mean T_2 values measured with TE of 20 and 10 ms are substantially lower than T_2 obtained with TE = 6.2 ms. At the same time, T_2 obtained with TE = 6.2 ms is close to $T_{1\rho}$ at f1=500 Hz. The $T_{2,TE=20ms}$ value seems to approximate the total transverse relaxation time (T_{2total}), which includes effects of all true relaxation mechanisms as well as diffusion dephasing. Then, the contribution of relaxation mechanisms with long correlation times and of diffusion dephasing suppressed by the SL sequence with f1=500Hz can be calculated as $1/T_{2total} - 1/T_{1\rho,f1=500Hz} = 33\ s^{-1}$, whereas the contribution suppressed by the short-TE CPMG sequence is equal to $1/T_{2total} - 1/T_{2,TE=6.2ms} = 29\ s^{-1}$, that is 88 % of that suppressed by the SL sequence. In Fig. 2, the lower T_2 map shows more prominent laminar appearance and both T_2 maps exhibit higher local variability than the $T_{1\rho}$ ones. However, pathological lesions in both specimens (indicated by arrows) are demonstrated by increasing T_2 as well as $T_{1\rho}$ values.

Discussion and conclusion. The short-TE CPMG sequence shows the ability to eliminate contributions of slow dynamic processes to the transverse relaxation, which is comparable with that of the SL technique. In the same way, $T_{2,TE=6.2ms}$ and $T_{1\rho,f1=500Hz}$ maps of the same specimens demonstrate analogous responses to pathology. Hence it can be concluded that short-TE CPMG and the clinically feasible SL protocols seem to be capable of providing similar information about cartilage pathology.

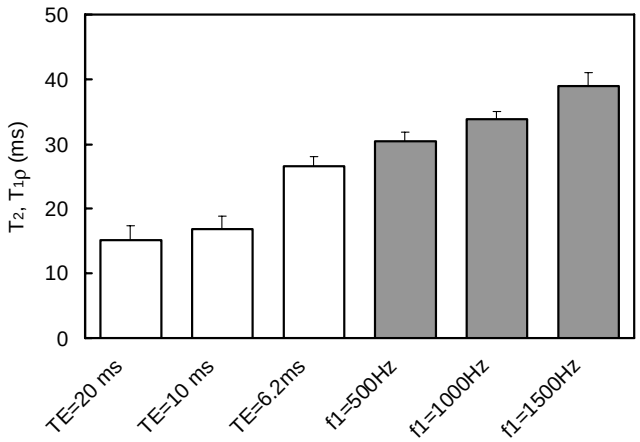

Fig. 1. Mean values of T_2 (empty columns) and $T_{1\rho}$ (shaded columns) relaxation times measured in six cartilage-bone specimens at different inter-echo delays (TE) and spin-locking amplitudes (f1), respectively.

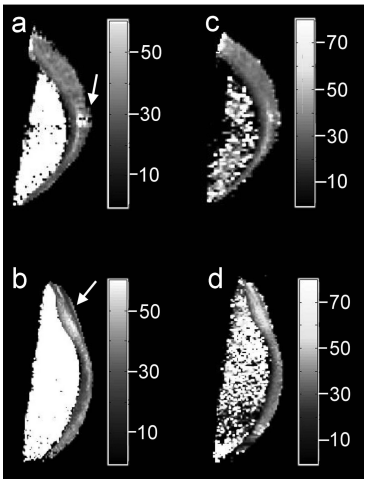

Fig. 2. $T_{2,TE=6.2ms}$ (**a** and **b**) and $T_{1\rho,f1=500Hz}$ (**c** and **d**) relaxation maps of two cartilage-bone specimens (**a** – **c** and **b** – **d**, respectively) from femoral condyles. The artifact visible in the bottom part of the lower specimen in the $T_{1\rho}$ map is due to a drop of the B_1 field outside the active volume of the RF coil.

References

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