Assessment of the clinical relevance of triple-echo steady-state T2 mapping in articular cartilage

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TARGET AUDIENCE Musculoskeletal Radiologists and Physicists

PURPOSE Transversal relaxation time (T_2) mapping in articular cartilage has been previously reported as a reliable marker for the evaluation of collagen matrix and water content [1,2]. Recently, a triple-echo steady-state (TESS) relaxometry method has been introduced for fast and accurate T_2 and T_1 mapping [3]. In this study, the clinical relevance of T_2, measured by TESS in knee cartilage, was assessed in comparison to standard multi-echo spin-echo T_2.

METHODS Thirteen volunteers (31.4±9.4yrs) and ten patients (35.1±10.5yrs) with a focal cartilage lesion were included in the study; right knees were measured. The local ethics commission approved this study, and all participants gave written, informed consent. All subjects underwent MR examinations at 3 Tesla (Siemens, Erlangen, Germany) consisting of two methods: multi-echo multi-slice spin echo sequence (CPMG) as a reference method for T_2 mapping (time of acquisition, TA, 4:30 min) [1]; and 3D TESS [3] with the exact same geometry settings, but variable TA—standard (TESSs TA 4:35 min) and quick (TESSq TA 2:05 min). For TESSq, the TA was reduced by employing a phase and slice partial Fourier. T_2 values were compared in six different regions in the femoral and tibial cartilage using a paired t-test (difference) and the Pearson correlation coefficient. Also, the correlation of TESSs and TESSq were compared to validate the similarity of T_2 values. For patients, the T_2 values from a focal lesion were compared to the adjacent native cartilage, similarly to [4].

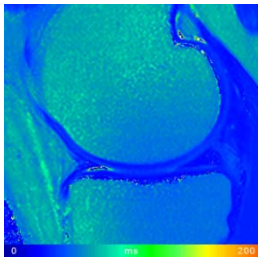


Fig. 1. Example of T_2 map measured by CPMG

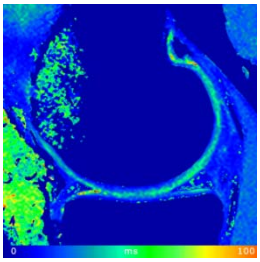
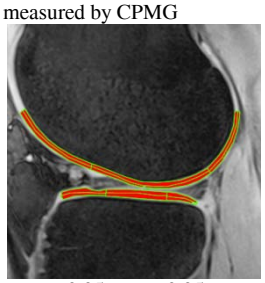


Fig. 2. Example of T_2 map measured by TESS


■ p =< 0.05 ■ p > 0.05
Fig. 3. P-values calculated from paired t-test (CPMG vs TESS)

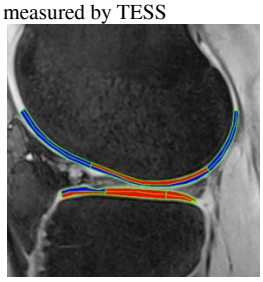

■ Pearson >= 0.8 ■ Pearson < 0.8
Fig. 4. Correlations calculated between T_2 values of CPMG and TESS

Table 1	FEMORAL CARTILAGE					
	AFCs	AFCd	MFCs	MFCd	PFCs	PFCd
T_2 (CPMG)	**62.40**	**53.40**	**68.93**	**55.42**	**59.36**	**54.29**
T_2 (TESS)	**36.99**	**28.32**	**32.69**	**23.10**	**34.53**	**29.59**
t-test	0.000	0.000	0.000	0.003	0.000	0.000
PEARSON	0.535	0.455	0.701	0.808	0.497	0.300

Table 2	TIBIAL CARTILAGE					
	ATCs	ATCd	MTCs	MTCd	PTCs	PTCd
T_2 (CPMG)	**51.17**	**33.58**	**52.65**	**38.00**	**57.65**	**42.78**
T_2 (TESS)	**32.08**	**20.40**	**30.39**	**23.78**	**31.18**	**24.73**
t-test	0.001	0.000	0.000	0.000	0.000	0.000
PEARSON	0.136	0.806	0.807	0.865	0.740	0.913

Acronyms: *FC* Femoral Condyle, *TC* Tibial Condyle, *A* Anterior, *P* Posterior, *M* Medial, *d* Deep, *s* Superficial

RESULTS Both TESS and CPMG maps were of high quality and artifact-free (Figs. 1 and 2). In volunteers, quantitatively, the mean T_2 values measured by CPMG were significantly higher compared to those measured with TESS in all regions (total mean 45.97±9.3ms versus 30.87±4.9ms), the correlation was found mostly in weight-bearing zones (Fig. 3 and 4). Both the standard and quick versions provided highly correlated T_2 values in cartilage (mean Pearson 0.816). As for patients, TESS and CPMG performed similarly, but TESS provided a slightly larger difference between lesions and native cartilage (CPMG: 90.21ms→61.70ms, p=0.0125; TESS 31.71ms→24.15ms, p=0.0839).

DISCUSSION Compared to CPMG, 3D-TESS provides a very similar distribution of T_2 values in cartilage, although with systematically reduced absolute values (in approx. 33%). None of the methods was superior with regard to T_2 variation (relatively high standard deviations are likely attributable to the complex cartilage structure). Both methods demonstrated the ability to distinguish between healthy cartilage and lesions. Most importantly, 3D-TESS provides results similar to CPMG within substantially shorter scan times. This benefit will be even more pronounced at ultra-high-field MR systems, where the TA of conventional T_2 mapping is substantially compromised due to specific absorption rate issues. T_1 mapping, which is also a product of the 3D-TESS sequence, was not tested in our study, although it also may have great potential.

CONCLUSION 3D-TESS provides fast, reliable, and B_0- and B_1-insensitive T_2 mapping in cartilage, opening a variety of possible applications requiring high temporal resolution (e.g., the monitoring of cartilage response to loading).

REFERENCES

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