Skin T_1 Mapping at 1.5T, 3T, and 7T.

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Introduction: The signal gains from higher field strengths are attractive for high-resolution skin imaging [1]. However, a legitimate concern is the increase in the spin-lattice relaxation parameter T_1. When T_1 increases, a prolonged TR is necessary to maintain the signal level, which lengthens the scan time. In this work, we compare skin T_1 maps at 1.5T, 3T, and 7T. In addition, we propose a novel non-linear least-square approach for fast and accurate T_1-estimation.

Methods: Protocol: The calf of a 29 year-old healthy volunteer was imaged at room temperature (20°C) on 1.5T, 3T, and 7T GE scanners using custom built 1-inch-diameter coils (receive-only at 1.5T and 3T; transmit-receive at 1.5T and 7T) and an adiabatic inversion recovery spin echo sequence with the following parameters: FOV 6 cm, matrix size 512x128, slice thickness 2 mm, frequency direction anterior/posterior (i.e., perpendicular to the skin surface), BW 32 kHz, TR/TE 5000/15 ms, TI (inversion time) [50, 300, 1000, 2000] ms, and total scan time 47 min. To reduce spurious motion, the subject's leg was immobilized using a plastic walker boot glued on a stable plank.

Fitting procedure: For each point of the image, the signal intensity is a function of TI given by $S = K(1-2e^{-TI/T_1}+e^{-TR/T_1}) = K\beta$, where K is a catchall factor including proton density, T_2 decay, and coil sensitivity. We estimate the parameters K and T_1 by minimizing $\|y-S\|^2$ where y (vector) represents the acquired data and $\|.\|$ the L_2-norm [2].

Expanding this expression gives the optimal T_1-estimate: $\hat{T}_1 = \arg\max_{T_1} \frac{|\beta^T y|^2}{\|\beta\|^2}$. K can then be estimated as $\hat{K} = \frac{\beta^T y}{\|\beta\|^2}$. The data-independent variables are computed offline, and a grid search over the set of possible values (typically 1 to 3000) is done to find the optimal T_1.

Validation: The fitting procedure was validated by comparison with the classical Levenberg-Marquardt (LM) algorithm [3,4]. A phantom was imaged using TR 3000 ms and 20 TI values logarithmically spaced between 50 and 2000 ms.

Results and Discussion: For the phantom, we found T_1 values of 234 (LM) and 235 ms (proposed algorithm). Our algorithm was more than five times faster than the LM algorithm and the histogram was sharper (Fig. 1). For skin, the main layers are easily distinguishable (Fig. 3). Figure 2 presents a typical fit (real part). The corresponding histograms are given in Fig. 4 and mode T_1 values in homogeneous ROIs are summarized in Tab. 1. With the transmit-receive coils the signal decreases rapidly with depth, therefore T_1 cannot be estimated in muscle. In addition, at 7T, chemical shift displaces fat by 8 pixels within the muscle layer. The dermis is a heterogeneous layer and a broad range of T_1 values was found in the component histogram at all field strengths.

At 1.5T, we found significantly lower values than the ones reported by Richard et al. [5], which might be attributed to the fact that we used an inversion recovery sequence (gold standard for T_1 mapping [6]) and not a saturation recovery sequence. Values found in muscle are also low, which is more surprising [7,8]. Partial volume effects and imperfections in the inversion pulse (although adiabatic) might explain the discrepancy. We have derived a fitting procedure similar to the one presented in this work for a general model taking imperfections into account, which will be used in future experiments.

Conclusion: A 30% increase in T_1 was found for dermis, hypodermis and muscle between 1.5T and 3T. Fat T_1 was found to double between 1.5T and 7T. This drastic change is not surprising but needs to be taken into account when porting sequences to 7T. The proposed fitting algorithm is accurate and fast and can be generalized to other relaxometry techniques.

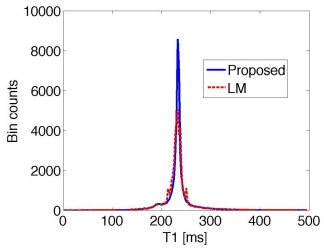

Fig. 1: *Histograms in a phantom.*

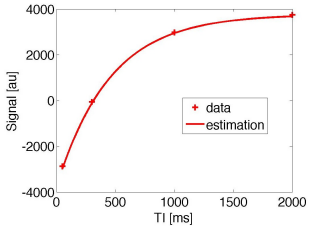

Fig. 2: *Typical fit (7T, fat pixel)*

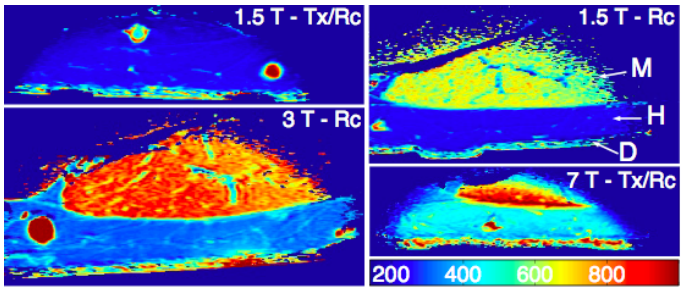

Fig. 3: *Skin T_1 maps [Colorbar in ms]. The background noise is masked. D: dermis, H: hypodermis (fat), M: muscle.*

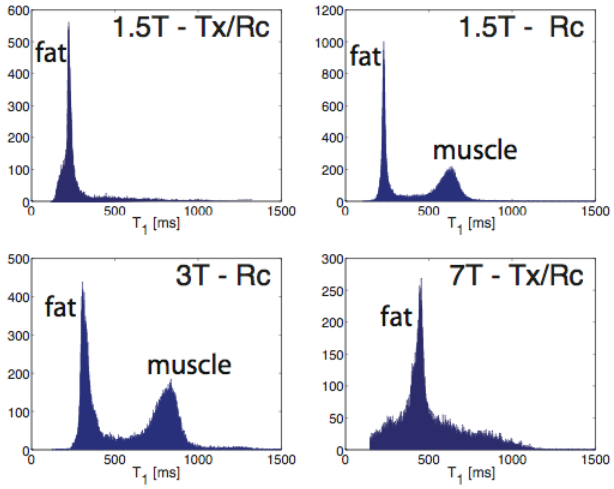

Fig. 4: *Histograms corresponding to the T_1 maps of Fig. 3*

	1.5 T (Tx/Rc)	1.5 T (Rc)	3T (Rc)	7T (Tx/Rc)
dermis	440±130	454±217	200-1000	200-1200
hypodermis	225±10	230±8	306±18	451±18
muscle	NA	629±50	832±62	NA

Tab. 1: Skin T_1 estimates [ms]. Peak value ± standard deviation (taken as 0.64*FWHM) or range where no peak value was found.

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