A fast method for T1 and T2 mapping of cerebrospinal fluid at 7T

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Purpose: In previous studies it has been shown that brain perfusion decreases in Alzheimer's Disease (AD) patients [1], which could affect the oxygen content of cerebrospinal fluid (CSF) and perivascular fluids (PVF). Since both T_1 and T_2 of CSF (and PVF) depend on its oxygen level [2], T_1/T_2 mapping of CSF could potentially give important information on its oxygen content. However, at this point there is no fast, reliable method available to perform T_1/T_2 mapping in the brain specifically for CSF and PVF at higher field strengths. The purpose of this study was to develop a method for T_1/T_2 mapping of CSF and PVF for 7T MRI.

Methods: In Qin (2011) [3] the use of an MLEV pulse sequence for CSF imaging is described for mapping of the CSF volume fraction. We extended this method to perform T_1 and T_2 mapping, by varying the delay time (T_{delay}, for T_1) or the effective echo time (TE_{prep}, for T_2), which depends on the MLEV-spacing τ and the number of MLEV pulses. Table 1 summarizes the used variables. The readouts after the MLEV preparation consisted of a single shot 2D SE-EPI (4x4 mm^2, slice thickness 6 mm, SENSE 2.3). Both B_0 and B_1 dependency of the method were characterized by applying the method to a water phantom and using an extra linear shim gradient to induce +/- 250 Hz B_0 variation in the background. Reference T_1 and T_2 maps were made with a Look-Locker and a Spin Echo sequence, respectively (without the extra shim gradient). Four volunteers (1 male, aged 24-33) were scanned with the MLEV pulse sequence. All experiments were performed on a 7T MR scanner (Philips), using a volume transmit, and 32 channel receive coil (Nova Medical).

Results: For the water phantom the reference T_1 and T_2 were (mean±sd) 2510±15ms and 1581±11ms, respectively. The T_1 and T_2 resulting from the MLEV scans were 1972±186ms and 1382±197ms. The results of the B_0/B_1 characterization are shown in Figure 1. For the volunteers the mean T_1 and T_2 resulting from the MLEV scans were 4261±270ms and 918±34ms in the ventricles, and 3470±89ms and 754±32ms in the peripheral subarachnoid spaces. The T_1 and T_2 were homogeneous in both the ventricles and the subarachnoid spaces, for all volunteers. $\Delta B_0/B_1$ was approximately 0Hz/110% in the ventricles and 20Hz/70% in the subarachnoid spaces.

Discussion: The results show that the proposed method is relatively insensitive to B_1 variations, but T_2 scans in particular show sensitivity for B_0 variations; the method can be applied at 7T for B_0 +/-50%. Compared to the reference values, both T_1 and T_2 of the phantom were underestimated. The in vivo results were comparable to previous studies [3, 4]. A possible T_1/T_2 underestimation may not be a problem for comparison between groups of subjects or between regions within a subject. As B_0 and B_1 were within the range in which the method performs well, the results may suggest that the oxygen level in the peripheral CSF is different from that in the ventricles [2]. However, partial volume effects from the parenchyma in combination with the lower B_1 may play a role as well in the lower T_1 and T_2 in the peripheral CSF. Future work is needed to assess reproducibility and to gauge the effects of partial volume and oxygen dependence and/or protein content, and the effect of partial volume effects between tissue and CSF in the presence of reduced B_1 needs to be studied by simulations.

Conclusions: The MLEV method is suitable for T_1/T_2 mapping of CSF, also at high field strengths. This method is relatively insensitive to B_0 and B_1 variations.

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References: [1] Binnewijzend MA, et al., Eur Radiol, 2014; [2] Zaharchuk G, et al., Magn Reson Med, 2005; [3] Qin Q, Magnetic Resonance in Medicine, 2011; [4] Rooney WD, et al., Magn Reson Med, 2007

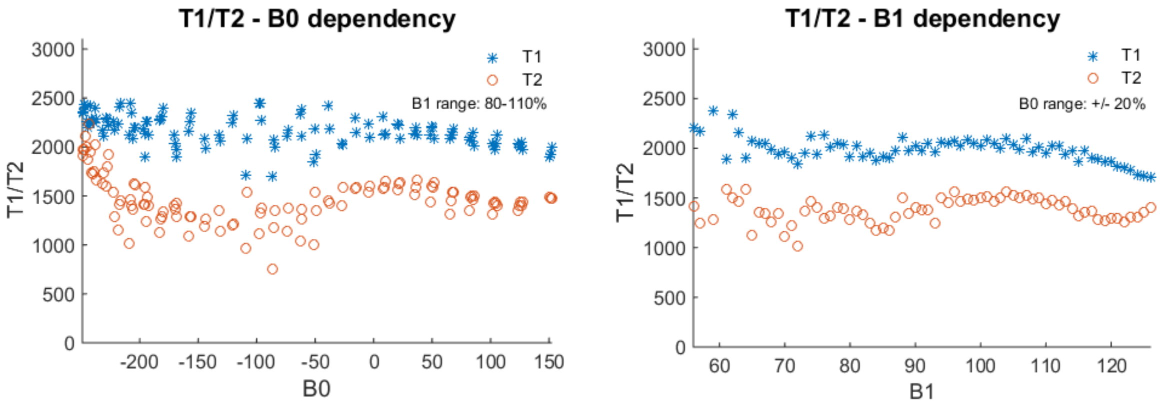

Figure 1: *T_1/T_2 measurements in the water phantom showed that the method yielded consistent values for B_1 in the range of 80-110% of its nominal value, and for $B_0 \leq 20$ Hz off-resonance. Each point in the B_0-dependency graph represents the mean T_1 or T_2 over 1Hz bins for B_0, taking only pixels with 80-110% B_1. Each point in the B_1-dependency graph represents the mean T_1 or T_2 over 1% bins for B_1, taking only pixels with $B_0 \leq 20$ Hz off-resonance.*

Table 1: *The parameters used to perform T_1/T_2 mapping with the MLEV method*

	T_{delay} [ms]	nr MLEV-pulses	τ [ms]	Scan time (single slice)
T_1 mapping	30000, 15000, 7500, 3750, 1875, 900, 450, 225, 100, 30	8	75	1:34 min
T_2 mapping	15000	0, 4, 8, 16, 32	75	1:45 min