In vivo blood T1 measurements at different field strengths: How much do we gain in ASL by moving to higher field strengths?

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Introduction: The longitudinal relaxation time (T1) determines how fast the endogenous tracer of arterial spin labeling decays and is therefore one of the main determinants of the SNR of the resulting perfusion map. In addition, the blood T1 is an important parameter for the calculation of quantitative CBF values and an accurate value is required for quantitative CBV measurements using the VASO technique. It is well-known that the blood T1 increases with magnetic field strength and this is one reason why 7T MRI is very promising for ASL-applications. However, only a single in vivo study has so far provided measurements of T1,blood at 7 Tesla and this value (2600ms, [1]) was much higher than earlier ex-vivo measurements (2212ms, [2]). To be able to estimate the expected gain in SNR of ASL by moving to 7T, we have measured the T1 of blood in the sagittal sinus at 7T and compared it to measurements at 1.5 and 3T.

Materials and Methods: Six healthy volunteers were scanned at 1.5T, 3T and 7T MRI scanners(Philips Healthcare) using a 32ch (3 and 7T) and 15ch (1.5T) head coil. Measurement of T1,blood was performed with the technique as proposed by Varela et al [3]. This sequence starts with a non-selective 180° inversion pulse followed by a slice-selective Look-Locker EPI readout (Fig.1). The following parameters were used: LL-EPI: α=95°; slice thickness: 2mm; voxel size: 1.5mm×1.5mm; TR= 10s (20s at 7T); SENSE-factor: 3.5 (3 and 7T) and 3 (1.5T); NSA: 6; first TI=190ms; ΔTI=150ms, nTI=60. The Nelder-Mead search method (function fminsearch, MATLAB, The MathWorks) was employed to obtain the blood T1 estimation by fitting the signal of each voxel as a function of three parameters (M0, offset and T1,blood):

\[ M(T1) = \text{abs}(M0*[1-2*e^{-\frac{T1}{T1,blood}}]) \]

The offset was included in the model to correct for possible impermanent inversion efficiency.

Results and Discussions: Fig.2.a shows all the T1,blood values obtained from the six subjects at the three different field strengths. In every subject a clear increase in T1,blood could be appreciated for higher magnetic field strengths. Blood T1 at 1.5T ranged from 1427ms to 1556ms with a population mean of 1480ms± 61ms. This is in agreement with previous studies[4]. T1,blood at 3T ranged from 1580ms to 1733ms with a population mean of 1649ms± 70ms, also in excellent agreement with ex-vitro measurement[6]. At 7T these values varied between 1864ms and 2254ms with a population mean of 2087ms±130ms. Our results in this study show that the relation of the longitudinal relaxation time T1 and the field strength B0 is approximately linear (Fig.2.c): T1,blood =110.2ms/T * B0+1316.2ms (R^2=1), which is in agreement with ex-vitro measurements ([2]). Furthermore, it can be observed that the T1,blood of female subjects are consistently higher than those of male subjects (Fig.2.b). This finding can be explained by the on average higher hematocrit in males[5].

Compared to the study of Rooney et al[1], this study shows a shorter T1,blood which implies that the anticipated gain in SNR for ASL scans by going to 7T is 20% smaller than that which could be expected based on Rooney’s measurements. This lower value can be explained by the use of a specialized sequence for blood T1 measurements in this study that employs 95° flip angles for the Look-Locker EPI readout, which leads to suppression of background signal and thereby elimination of partial volume effects with CSF.

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