Measurements of T1 Relaxation times at 3.0T: Implications for clinical MRA

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Introduction
3.0T systems are beginning to find routine clinical use. T1 relaxation is a basic mechanism for MR imaging contrast, and knowledge of T1 relaxation times is important for optimizing imaging protocols. Although there have been numerous studies of the T1 of gadolinium chelates, vitro blood, and in vivo human brain, most of them were performed at field strength 1.5T or less.

As part of the effort to optimize our neuro-imaging protocols for a 3.0T scanner, we measured in-vivo T1 relaxation times of various brain tissues in a group of volunteers, and compared the measured T1 values at 3.0T with published results obtained at 1.5T – 4.0T. We also measured T1 values in distilled water and pig blood with various gadolinium concentrations for predicting contrast enhancement in MRA applications. The study was performed with Institution Review Board approval.

Methods
A GE 3T-94 VH/i scanner was used for the T1 measurements. To achieve good image quality with acceptable scan time, a fast spin echo (FSE) sequence with echo train length (ETL) of 4 was used. An algorithm was developed to correct the sign of the pixel intensities before zero crossing in their inversion recovery time course. Using non-linear least square fitting, T1 relaxation times were calculated on a pixel-by-pixel basis.
The same method was used to measure T1 of a serial dilution of gadoteridol [Gd-HP-DO3A; ProHance] in both distilled water and pig venous blood sample at 1.5T and 3.0T. To prevent coagulation of the blood sample, 2 units of Heprin was added per 1ml of blood sample. The measured T1 values were compared to previously published values.
For the in-vivo brain T1 measurement at 3.0T, ten normal volunteers (mean age 31.2 +/-10.3 years, 6 male, 4 female) were recruited. For each volunteer, a single axial section of 5mm thick was acquired with TI = 50, 800, 1500, 4000 and 12000ms, and TR = 15s. The matrix size was 256x192, and the FOV was 20cm.
To measure T1 relaxation times of gray matter (GM), white matter (WM), cerebral spinal fluid (CSF) and caudate nucleus (CN), regions of interest (ROI) were placed in a selected inversion recovery images (Figure 1a). The mean and standard deviation of T1 relaxation times were obtained from the corresponding ROIs in the calculated T1 map (Figure 1b).

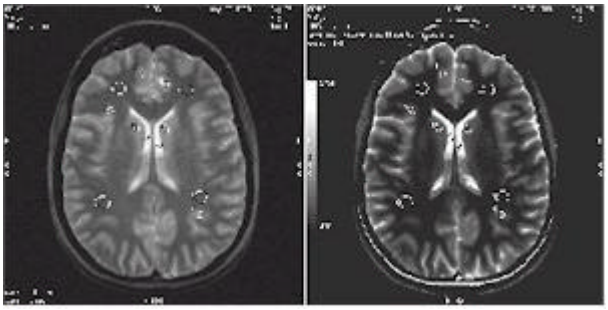

Figure 1 a, b

Results
Table 1 shows the measured in-vivo T1 relaxation time of human brain tissues at 3.0T.
The measured T1 relaxation times of GM and WM at 3.0T agree with another published study [3]. Compared with in-vivo T1 values at 1.5T and 4.0T, T1 of GM, WM and CN all increase with field strength. However, the T1 of CSF does not change substantially with field strength (Table 2).
The measured relaxivity of the gadoteridol in distilled water was 4.74+/-0.05 /mM/s at 1.5T and 4.43+/-0.03 /mM/s at 3.0T at a temperature of 23C.The relaxivity measurement is in good agreement with extrapolation of published values at lower field strength [6-7]. The measured relaxivity of the gadoteridol in pig blood was 5.2+/-0.2 /mM/s at 1.5T and 5.0+/-0.3 /mM/s at 3.0T. The measured T1 of pig's blood without contrast agent was 1184+/-31ms at 1.5T and 1264+/-21ms at 3.0T at 23C. This also agree with the published result at 1.5T [8]. In summary, we measure only a small decrease of gadoteridol relaxivity from 1.5T to 3.0T.

Discussion
Our study shows that the T1 of brain parenchyma increases by 25-40% between 1.5 and 3.0T, while the T1 of a given concentration gadoteridol increases by only about 7%. Since the signal for CE MRA is inversely proportional to the square root of T1, nearly the full factor of 2 increase in S/N is available for that application at 3.0T compared to 1.5T. For other applications like 3DTOF, which employ a longer TR (e.g. 40ms), the increase of T1 for brain parenchyma can also potentially improve the C/N at 3.0T. In summary, our T1 measurements confirm that 3.0T is an advantageous field strength for MR angiography.

References
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Table 1

	Mean	St. Dev.
GM	1445	119
WM	791	27
CSF	4163	263
CN	1271	91

Table 2

	GM	WM	CSF	CN
1.5T (1)	1013	560	4282	928
1.5T (2)	998	718		1157
3.0T	1445	791	4163	1271
3.0T (3)	1331	832		
4.0T (4)	1724	1043	4550	1458
4.0T (5)	1354	939		1425