# T1 contrast in the human brain at 7 Tesla

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## Introduction:

MRI in humans at ultra-high field offers not only high baseline sensitivity but also interesting contrast behavior. Compared to lower field strength T1 relaxation times generally increase but seem to remain highly diverse, promising strong T1 contrast especially in brain imaging. Exploring this potential is mainly hampered by the non-uniformity of the transmit RF fields generate by available RF resonators (Fig.1, top row). In the present work we report sequence considerations for robust T1-weighted brain imaging at 7T and discuss the anatomic contrast thus obtained.

## Methods:

To achieve reliable and strong T1 contrast despite RF field inhomogeneity an inversion recovery (IR) approach with an adiabatic inversion pulse was chosen. To use the inherently high power deposition of such pulses efficiently, the adiabatic full-passage pulse of 45 ms was followed by approximately 100 low flip-angle excitations in a transient gradient-echo 3D imaging scheme taking a total of 2 min. The B1 integral of the inversion pulse was optimized between the competing goals of robustness against B1 inhomogeneity, bandwidth and specific absorption rate. Using relatively low inversion times of 400-600 ms deep brain regions such as the thalamus were considered especially, comparing the 7T in-vivo data with a histological image and an MR scan of a formaldehydepreserved ex-vivo sample. The latter was imaged at 3T, averaging a protondensity-weighted CPMG sequence over 5 hours. All in-vivo imaging was performed on a Philips 7T Achieva system, using a volume transmit resonator and a 16-channel receive array.

## Results:

As Fig.1 shows, the described sequence yields stable T1 contrast across the whole brain despite considerable transmit RF inhomogeneity especially in the temporal lobes and deep brain regions. Close inspection of the thalamic region (Fig.2) revealed higher contrast than known from lower field strengths, permitting the differentiation of several thalamic nuclei, pallidothalamic, cerebellothalamic and other fibertracts (mtt, ft, frf, fct) .

## Discussion:

This work demonstrates that robust acquisition of T1-weighted images is feasible at 7T, requiring moderate scan time for full brain coverage. It was found that the high field yielded not only high SNR and resolution but also surprisingly strong contrast throughout the brain. It permitted the distinction of anatomical structures which have been hard to recognize at lower field strengths. Such enhanced contrast may be particularly useful for MR-guided interventions. The higher-than-expected contrast may be related not only to changes in relaxation time but also to saturation transfer effects due to the long adiabatic prepulse.

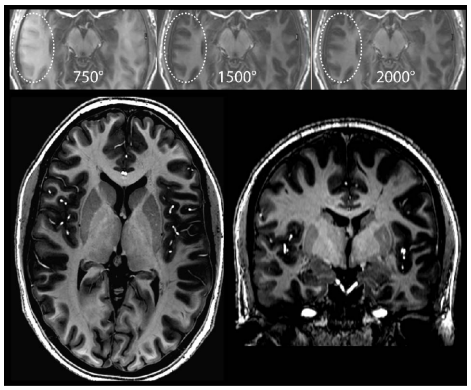


Figure 1: The inversion recovery sequence (IR) was optimized in order to achieve a uniform inversion over the entire brain despite severe non-uniformities in both, RF excitation and $B_0$ off-resonances as they are found at 7T. The three images on top show the regions around the temporal lobes, which usually suffer from lower excitation field strength as well as severe off-resonances. The first two images on top (750° and 1500°) show how these effects lead to a loss in contrast typically at the temporal lobes (as marked by the circles), deep brain regions and in the vicinity of the frontal sinuses. This problem can be solved by appropriate adjustements of the adiabatic flip-angle and the bandwith (frequency span) of the adiabatic inversion pulse (2000°). The two images on the bottom show that a uniform inversion ensures constant contrast ratios with full brain coverage even at 7T and fast sequences.

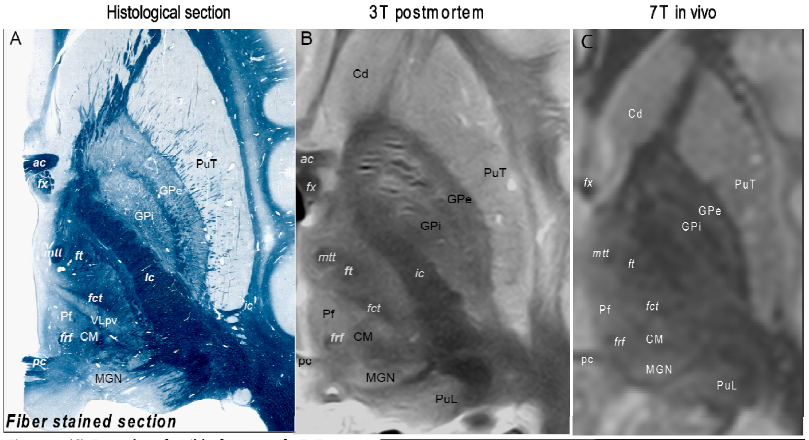


Figure 2: (C) Examples of visible features of 7T IR scan lasting 2 min for 50 slices with 1 mm isotropic resolution, compared to a 3T ex-vivo proton weighted TSE scan (B) of a brain in formaldehyde lasting 5 h and a histological section (A). The high SNR and the increased contrst allow to correlate most structures with ex-vivo sections. In this section a particular focus was set on the thalamic structures especially the thalamic nuclei.

Fig A,B: From A. Morel (2007) *Stereotactic Atlas of the Human Thalamus and Basal Ganglia*. Informa Healthcare USA, Inc., New York, USA.

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|---|---|
| Cd | Caudate nucleus |
| PuT | Putamen |
| Pf | Parafascicular nucleus |
| CM | Centromedian nucleus |
| ac | Anterior commissure |
| pc | Posterior commissure |
| MGN | Medial geniculate nucleus |
| PuL | Lateral pulvinar |
| GPi | Internal pallidum |
| GPe | External pallidum |
| *mtt* | Mammillothalamic tract |
| *ft* | Fasciculus thalamicus |
| *fct* | Fasciculus cerebello thalamicus |
| *frf* | Fasciculus retroflexus |
| *fx* | Fornix |

*7T scan parameters:*

| | |
|---|---|
| Method: | Inversion recovery |
| iR-time: | 500 ms |
| Read-out: | 3D transient gradient echo |
| Resolution: | (1 x 1 x 1) $mm^3$ |
| # Slices: | 50 |
| TSI/TR/TE: | 3 s / 5.45 ms / 2.7 ms |
| Total time: | 120 s per IR time |