AGE-DEPENDENT CHANGES IN WHITE-MATTER AND GRAY MATTER T1RHO VALUES

Richard Watts[1] ,Trevor Andrews[1,3],Scott Hipko[1], Jay Gonyea[1], Christopher G. Filippi[1,2,4]

PHILIPS

Departments of [1]Radiology and [2]Neurology, University of Vermont College of Medicine, Burlington, VT.
[3]Philips Healthcare, Cleveland, OH. [4]Department of Radiology, Columbia University Medical Center, New York, NY.

Purpose

To investigate variations in brain $T_{1\rho}$ (T1-rho) values over adulthood, and present normative values for cortical gray matter (GM), juxtacortical white matter (WM), and selected white matter tracts. Since T1ρ is sensitive to the macromolecular content of biological tissue, this technique may have important applications to neurological disorders.

Introduction

$T_{1\rho}$ has been shown to be sensitive to the macromolecular content of biological tissues, and has been applied to studies of articular cartilage, disc degeneration, and liver fibrosis.

In the human brain, $T_{1\rho}$ may be sensitive to both normal and pathologic changes in tissue protein content. However, only a small number of studies have applied $T_{1\rho}$ imaging to Alzheimer's[1,2], Parkinson's disease[2,3], stroke[4] and tumors[5,6].

Methods

Subject Selection

- 23 males (ages 18-76, 44 19 years).
- 18 females (ages 21-73, also 44 19 years).
- Exclusion criteria: history of neurological disorder including multiple sclerosis, brain tumor, vasculitis, prematurity, seizure disorder, traumatic brain injury, stroke, infection or any cranial procedure.
- IRB approved and HIPPA compliant.

Data Acquisition

Data was acquired using a Philips 3T Achieva TX scanner with 8-channel head coil. $T_{1\rho}$-weighted images were acquired using a whole-brain fluid suppressed 3D turbo spin echo technique.

- $T_{1\rho}$ weighting was produced by a ΔB_0- and ΔB_1-insensitive non slice-selective $90_{+x} - SL_{+y} - 180_{+y} - SL_{-y} - 90_{+x}$ sequence, where SL represents the spin lock pulses with a frequency of 500Hz. Total spin lock times (TSL) of 0, 20, 40, 60, 80 and 100ms were used.
- Data readout used a variable flip angle 3D turbo spin echo (3D VIEW) technique with an echo train length of 200, low-high view ordering and a SENSE factor of 2.2.
- Fluid suppression was achieved through a combination of T2-preparation and inversion recovery (TI=1650ms).

Whole brain coverage was achieved using an axial AC-PC aligned acquisition matrix of 140 140 100 with a spatial resolution of 1.8 1.8 1.8mm^3. With a TR of 4800ms, the acquisition of each spin lock time took 2 minutes 19 seconds, giving a total acquisition time of approximately 14 minutes.

See Poster 1250, ISMRM 2013 for further details and validation.

Data Analysis

- $T_{1\rho}$-weighted images co-registered using SPM8.
- $T_{1\rho}$ map calculated using a weighted least-squares fit to

$$S = S_0 e^{-TSL/T_{1\rho}}$$

- $T_{1\rho}$ map co-registered to the T_1-weighted anatomical.
- Unified segmentation (SPM8) of T1 used to GM and WM probability maps and nonlinear transformation to MNI space.

Regions-of-Interest

- WM tracts were defined by an intersection of the individual spatially normalized WM probability map thresholded at 50% with the JHU ICBM-DTI-81 white matter labels atlas supplied with FSL.
- Cortical gray matter and juxtacortical white matter regions were similarly defined by the intersections of the individual spatially normalized GM and WM probability maps with the Harvard-Oxford cortical atlas dilated by 5mm.

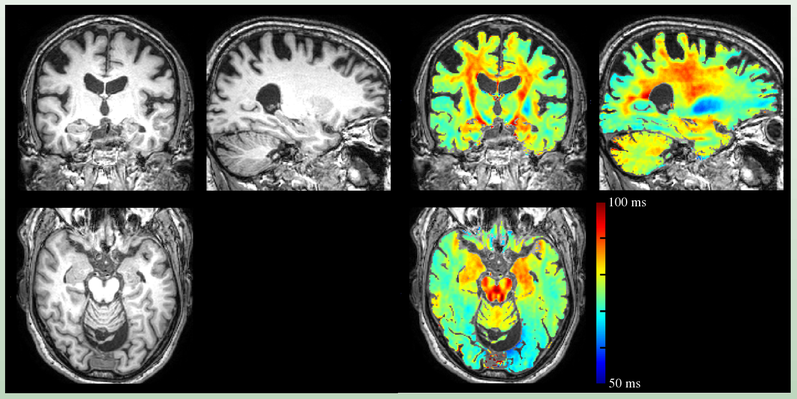

Figure 1. T1-weighted image and corresponding $T_{1\rho}$ map from a 72 year old male.

Results

Figure 1 shows an example $T_{1\rho}$ map demonstrating excellent SNR and clear WM/GM delineation. Quantitative analysis of the age-dependence of $T_{1\rho}$ are shown in Tables 1 and 2, and Figure 2.

Structure	Mean $T_{1\rho}$ (ms)	Regression Coefficients with Age: Intercept (ms)	Gradient (ms/year)	Correlation with age	p-value
Cortical GM**	78.4 ± 1.6	80.7	-0.051	-0.599	<0.001
Juxtacortical WM	75.6 ± 1.4	75.5	0.002	0.035	0.830
WM tracts*	76.8 ± 1.7	74.7	0.048	0.527	<0.001
Whole brain	77.9 ± 1.3	78.8	-0.020	-0.296	0.061

Table 1. Descriptive statistics, regression coefficients and correlation with age for cortical gray matter, juxtacortical white matter, and major white matter tracts. *Significant at p<0.05, **Significant at p<0.005.

Structure	Laterality	Mean $T_{1\rho}$ (ms)	Regression Coefficients with Age: Intercept (ms)	Gradient (ms/year)	Correlation with age	p-value
Anterior thalamic	Left	75.1 ± 1.7	73.4	0.037	0.414	0.007
radiation	Right	75.6 ± 1.7	74.0	0.036	0.416	0.007
Corticospinal tract	Left	86.1 ± 2.1	85.8	0.008	0.068	0.672
	Right	85.6 ± 1.9	84.9	0.016	0.159	0.322
Forceps major	-	84.4 ± 2.5	82.7	0.039	0.302	0.055
Forceps minor**	-	73.6 ± 2.1	71.0	0.061	0.566	<0.001
Inferior fronto-occipital	Left	77.5 ± 1.9	76.0	0.032	0.336	0.032
	Right	76.8 ± 2.0	74.9	0.044	0.422	0.006
Inferior longitudinal	Left	76.8 ± 2.4	75.3	0.035	0.281	0.075
fasciculus*	Right	77.8 ± 2.6	75.7	0.049	0.356	0.022
Superior longitudinal	Left	77.0 ± 2.1	74.5	0.056	0.505	0.001
fasciculus**	Right	77.4 ± 2.5	74.4	0.067	0.520	<0.001

Table 2. Descriptive statistics, regression coefficients and correlation with age for selected white matter tracts. *Significant at p<0.05, **Significant at p<0.005.

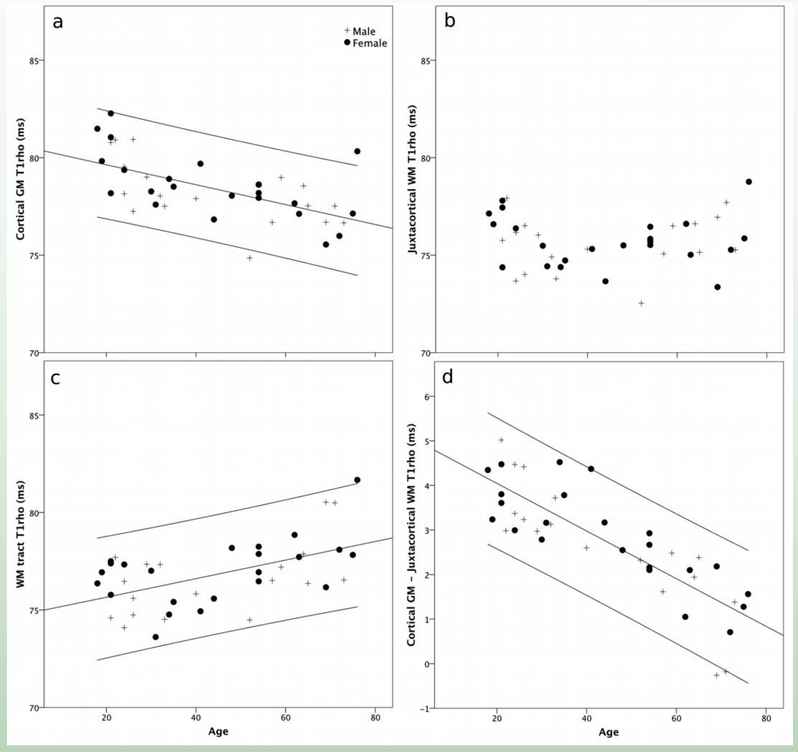

Figure 2. (a) Cortical GM, (b) juxtacortical WM, (c) WM tracts, and (d) the difference between cortical GM and WM tract $T_{1\rho}$ values as a function of age. Cortical GM shows a negative correlation with age ($r=-0.599$, $p<0.001$), juxtacortical WM shows no significant correlation ($r=0.0735$, $p=0.830$), and WM tracts show a strong positive correlation ($r=0.527$, $p<0.001$). The difference between cortical GM and WM tract $T_{1\rho}$ shows an extremely strong correlation with age ($r=-0.828$, $p<0.001$). 95% confidence intervals are shown.

Discussion

With a total scan time of approximately 14 minutes (6 individual scans of approximately 2 minutes each) for whole brain coverage, the technique presented is clinically applicable. Using a sagittal acquisition and applying SENSE in two directions, initial testing has indicated that substantial reductions in scan time could be achieved while maintaining acceptable SNR.

Significant decreases in $T_{1\rho}$ with age were observed in cortical GM, while increases were seen in WM tracts except the corticospinal tract and forceps major. A very strong correlation between the $T_{1\rho}$ difference between cortical GM and juxtacortical WM and age was noted ($r=-0.828$). These observations indicate that this technique is sensitive to processes associated with normal aging and that it may provide an important biomarker for neurodegenerative disease and other pathology.

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