High-Resolution Cross-Relaxation Imaging of the Rat Brain at 3.0T

H. R. Underhill[1], C. Yuan[1], and V. L. Yarnykh[1]

[1]University of Washington, Seattle, Washington, United States

Introduction

Cross-relaxation imaging (CRI) [1] is a method for quantitative mapping of kinetic parameters determining the transfer of magnetization between mobile water protons (free pool) and semi-solid macromolecular protons (bound pool). Recent technical advances have extended the utility of CRI for *in vivo* studies by allowing time-efficient data acquisition for reconstruction of maps corresponding to the principal magnetization transfer parameters: the cross-relaxation rate constant, *k*, and the fraction of the bound pool, *f*. The subsequent production of *k*- and *f*-maps has yielded high-resolution anatomic detail of distinct human white matter fiber tracts *in vivo*[1]. In this study, we sought to determine the feasibility of capturing the *in vivo* white matter fiber tracts of the rat brain using cross-relaxation MRI at 3.0T.

Methods

A live, adult, male rat (390g) was imaged at 3.0T whole-body scanner (Philips Achieva) with a 2-turn solenoid receive-only coil (4.5 cm diameter) after adequate anesthesia with 1.5% Isofluorane. Eight pulsed Z-spectroscopic data points with variable offset frequencies (Δ) of the off-resonance saturation pulse (effective flip angle 510°; Δ = 0.6, 1, 2, 4, 8, 16, 32, 96 kHz) were acquired with a 3D spoiled GRE pulse sequence (TR/TE = 37.2/6.5 ms, α = 10°) as previously described [1] with an isotropic spatial resolution of 0.3 mm^3 zero-interpolated to 0.12x0.12x0.15 mm. A complementary R_1 (=1/T1) map needed for reconstruction of *k* and *f* maps was reconstructed from variable flip angle data (3D spoiled GRE, TR/TE = 20/6.8, α = 3,10,20,40°) after correction for B1 heterogeneity (3D AFI [2], TR_1/TR_2/TE = 20/100/6.8, α = 60°). All images were acquired with one signal average and an imaging matrix () and FOV=40x40x14 mm. Total scan time was less than 40 minutes. Imaging data were fit to a constrained matrix model of pulsed magnetization transfer to produce 3D whole-brain *f*- and *k*-maps [1]. Anatomical correlations of *in vivo* cross-relaxation parametric maps were done using a histology atlas of the rat brain [3].

Results

The images in Fig. 1 represent *f*-, *k*-, and R_1-maps of the rat brain from three orthogonal projections. Parametric images demonstrate excellent anatomic contrast with clear definition of anatomic structures. Notably, the contrast between white and grey matter is much more pronounced on cross-relaxation *f*- and *k*-maps than on the R_1-map. Similar to previous findings in the human brain [1], regions of hyperintensity on *f*-maps demonstrate anatomical correlations with major white matter fiber tracts (Fig. 1), as identified according to the atlas [3]. The ventricular system and various grey matter structures are also indicated in Fig. 1 for anatomic reference. The cross-relaxation parameters for specific anatomic structures are presented in Table 1. The *f* values are in good agreement with the literature [1,4], while *k* appears systematically lower [4]. The reason may be related to either methodological aspects (*k* is sensitive to acquisition technique and reconstruction algorithm [5]) or field-strength [6].

Table 1. Cross-relaxation parameters* in the rat brain.

	f (%)	*k* (s^{-1})
Caudate/Putamen	9.5 ± 1.0	0.5 ± 0.1
Corpus Callosum	15.5 ± 1.6	1.2 ± 0.3
Cerebellar WM	14.9 ± 2.1	1.0 ± 0.1
External Capsule	14.3 ± 1.9	1.4 ± 0.1
Anterior Commisure	13.7 ± 1.0	1.1 ± 0.2
Deep Cerebral WM	13.6 ± 1.2	1.0 ± 0.1

* Mean ± SD; WM = white matter

Conclusion

Cross-relaxation imaging combines the capability of multi-parameter quantitative tissue characterization with high-quality anatomic contrast enabling detailed visualization of the white matter fiber tracts. This study demonstrated the feasibility of high-resolution time-efficient CRI of the rat brain *in vivo* on a clinical 3T scanner that provides a potential for using this method in translational research involving rat models of human disease.

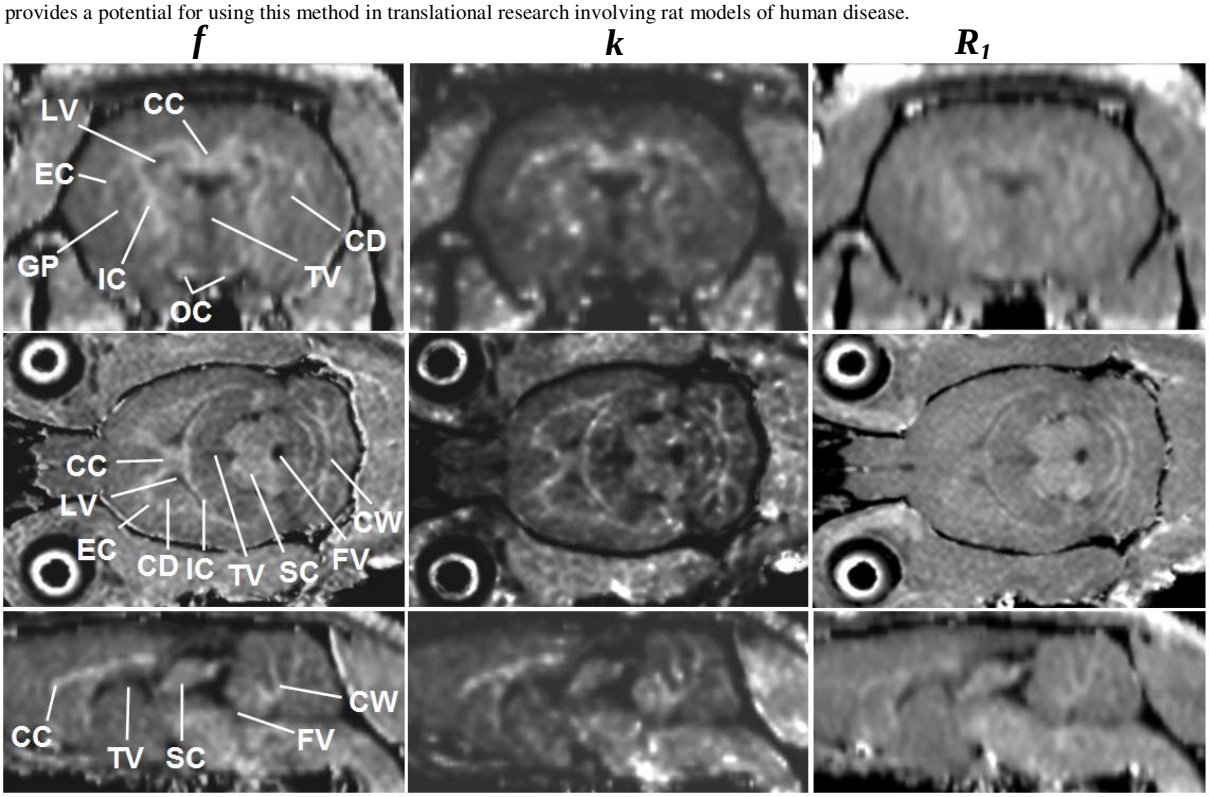

Figure 1. Parametric 3D *f*, *k*, and R_1 maps of the rat brain. **CC** = corpus callosum; **CD** = caudate putamen; **CW** = cerebellar white matter; **EC** = external capsule; **FV** = fourth ventricle; **GP** = globus pallidus; **IC** = internal capsule; **LV** = lateral ventricle; **OC** = optic chiasm; **TV** = third ventricle; **SC** = superior colliculus

References: (1) Yarnykh VL, Yuan C. *NeuroImage* 2004;23:409-424. (2) Yarnykh VL. *MRM* 2007;57:192-200. (3) Paxinos and Watson. The Rat Brain in Steroetaxic Coordinates, 5th Ed. 2005. (4) Quesson B et al. *MRM* 1997;38:974-980. (5) Portnoy S, Stanisz GJ, *MRM* 2007;58:144-155 (6) Stanisz G et al, *MRM* 2005; 54:507-512.