High Contrast Magnitude And Phase Imaging of the Short T2 Components in White Matter of the Brain

Qun He[1], Lanqing Ma[1], Wen Hong[1,2], Vipul Sheth[1], Graeme M Bydder[1], and Jiang Du[1]
[1]*Radiology, UC, San Diego, San Diego, CA, United States,* [2]*Radiology, China-Japan friendship hospital, Beijing, Beijing, China*

INTRODUCTION

Multiple sclerosis (MS) is a disabling demyelinating disease of the central nervous system. Direct assessment of the integrity of myelin in white matter may be important for the diagnosis and assessment of prognosis in MS [1]. However, the protons in myelin have extremely short T_2s (less than 1 ms) [2-4] and cannot be directly imaged with conventional clinical MRI sequences which have TEs of several milliseconds or longer. As a result, conventional clinical sequences only provide indirect assessment of myelin. By using half-pulse slice selection, radial mapping of k-space, variable rate selective excitation (VERSE) and fast transmit receive switching, TEs down to 8 µs can be achieved with 2D UTE sequences [5, 6]. These sequences allow direct imaging of myelin protons. In this study we aimed to employ this approach to provide direct magnitude and phase imaging of the short T2 components of white matter of the brain using a whole-body 3T scanner.

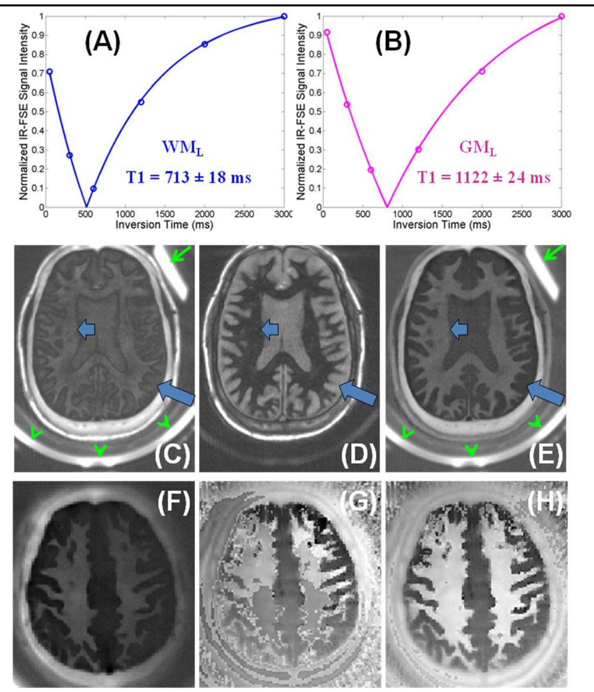

Fig 1. MRI of a 60 year old male volunteer: IR-FSE T_1 fitting shows a T_1 of 713 ± 18 ms for WM_L (A), and 1122 ± 24 ms for GM (B). IR-UTE with a TR of 1500 ms and TI of 412 ms depicts signal from myelin (short thick arrow) with a TE of 8 µs (C) and nulls WM_L as shown by the zero or near zero signal on the 2nd echo with a TE of 2.2 ms (D). Subtraction (E) suppresses the residual signal from GM (long thick arrows) and highlights white matter. Rubber (thin arrow) and coil (arrow heads) are only visible with UTE (C)&(E). Another slice: IR-UTE magnitude image (F) and the phase images without (G) and with (H) baseline phase correction. Baseline phase correction is critical for generating high contrast for white matter.

MATERIALS AND METHODS

We implemented a 2D adiabatic inversion recovery prepared dual echo UTE (2D IR-UTE) sequence with a TE of 8 µs to detect myelin signals. An adiabatic Silver-Hoult inversion pulse was used to invert and null the long T2 components in white matter. Myelin has an extremely short T2* and its magnetization is not inverted. Its signal is detected by the subsequent UTE data acquisition. Residual long T2 signals are suppressed via subtraction of the 2nd echo image from the first one, providing high contrast visualization of white matter. 10 volunteers were recruited for this study. A clinical IR-FSE sequence was used to measure the T1 of the long T2 white matter, followed by IR-dUTE imaging with the following parameters: FOV = 24 cm, slice thickness = 5 mm, bandwidth = 250 kHz, flip angle = 70°, TR = 1500 ms, TE ~ 420 ms, TE = 8 µs and 2.2 ms, sampling points=191, projections=131, reconstruction matrix=256×256, scan time=6.5 min. An 8-channel head coil was used for signal reception. Magnitude images were generated via sum-of-squares combination of the images from each coil. Phase images from each coil were base-phase corrected, using the averaged phase for the 1st k-space point (TE = 8 µs) of all the half-projections. This was subtracted to remove phase differences associated with hardware differences. The final phase images were calculated as the average of the base-phase corrected images for all the coil elements.

RESULTS AND DISCUSSION

Figure 1 shows IR-FSE T_1 measurement of WM_L and GM in a 60 year old normal volunteer, and illustrates the IR-UTE contrast mechanism for magnitude and phase imaging of white matter. The longitudinal magnetization of WM_L, which has a T_1 of 713 ms, was inverted and nulled with a TR of 1500 ms and a TI of 412 ms, as evidenced by the near zero signal of WM_L in the 2nd echo with a TE of 2.2 ms (Fig 1D). The white matter shows moderate signal in the 1st echo with a TE of 8 µs, and near zero signal at a TE of 2.2 ms (Fig 1E). Signal from the residual GM appears highlighted. Subtraction of the 2nd image from the 1st one provided high contrast imaging of white matter (Fig 1E). Also shown are IR-UTE magnitude and phase imaging. Without baseline phase correction, there is uncertain phase contrast generated for white matter. Excellent phase contrast is generated for myelin after baseline phase correction (Fig 1H).

CONCLUSIONS

The preliminary results show that the IR-UTE sequence can generate high contrast magnitude and phase images of the previously undetected short T2 components in white matter of the brain in vivo using a clinical 3T scanner.

REFERENCES

1. Waldman A, Neuroradiology 2003; 45 :887-892.
2. Ramani A, et al., MRI 2003 ; 21 :1039-1043.
3. Horch RA, et al, MRM 2011; 66:24-31.
4. Wilhelm MJ, et al, PNAS 2012; 109:9605-0610.
5. Du J, et al., NeuroImage 2014; 87:32-41.
6. Du J, et al., PlosOne 2014; 9(8):e103296.