Optimisation of 3D Inversion Recovery Fast Spin Echo for lesion detection in multiple sclerosis brain

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Introduction Although multiple sclerosis (MS) affects both the grey matter (GM) and white matter (WM) of the central nervous system, only focal WM changes are relatively easy to detect using standard T_2-weighted MRI. To detect GM changes is more challenging (1). Double inversion-recovery (DIR) MRI has shown promise to improve delineation of focal MS changes in the GM *in vivo* by suppressing both cerebro-spinal fluid (CSF) and WM (2). In *post-mortem* tissue, the confounding effect of CSF is significantly reduced, but GM/WM contrast remains an issue. As part of a project to correlate MR changes and histopathology in MS brain, we describe here the optimisation of a (single) IR sequence for use in *post-mortem* brain slices.

Methods Unfixed *post-mortem* coronal brain slices (thickness 1cm) of subjects (one MS, two normal controls; mean age 72 years [SD 13 years]) were retrieved 8 hours [3 hours], and studied 25 hours [1 hour], after death. The individual brain slices were placed in a purpose made perspex box and immersed in perfluoropolyether. On a 1.5T GE MR system a 3D IR-FSE sequence was employed (3) using the following parameters: repetition time (TR)=4000ms, echo time (TE)=21.8ms, field of view=18cm and acquisition matrix 256x192. Six contiguous slices of 1mm thickness were obtained using 10 different inversion times (TI). Further, dual-echo spin-echo (SE) images (TR=2000ms; TE=30/120; two 3mm thick slices) along with a 3D FSPGR image (TR=8.54ms; TE=4.2ms; flip angles=5°/15°/25°; 28 slices of 3mm thickness) to calculate T_1 were acquired. Total scanning time was 31min. After scanning, the three contiguous IR-FSE images corresponding to one slice (3mm) of the SE images and T_1 maps were averaged and regions of interest (ROIs) were placed in five distinct tissue compartments: normal & normal appearing WM (NWM & NAWM), normal & normal appearing cortex (NC & NAC), and WM lesions (WML). T_1 values and signal intensities on the IR-FSE images were averaged across tissue samples and the TI for optimal suppression of each tissue compartment was determined.

Results Seven regions of NWM and NC, and three regions of NAWM, NAC and WML were analysed. T_1 values in this study of *post-mortem* brain were mildly elevated in all tissue compartments compared to *in vivo* values in the literature. ***Figure 1*** shows a normal *post-mortem* brain slice, an SE image and inversion-recovery images with 10 different TIs. Four ROIs are marked in the GM and in the WM, and one region to assess noise. Arrows indicate areas which – looking at the SE image alone – could have been mistaken for NWM, whereas the IR images suggest that these areas are "islands" of GM. In ***Figure 2*** signal intensities are plotted versus TI values for the tissue compartments investigated. The ***Table*** shows the T_1 of specific tissue compartments and the optimal TIs to suppress them.

Figure 1 **Exemplary *post-mortem* brain slice of a normal control. Spin-echo and IR-FSE images with respective inversion times (TI).**

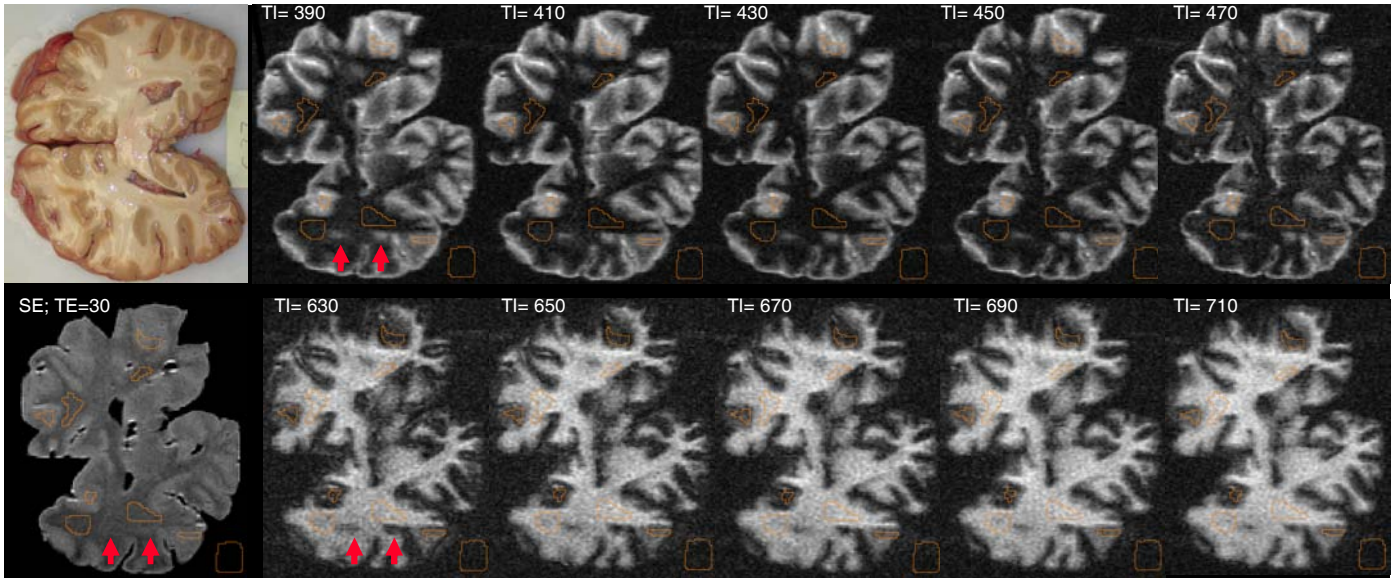
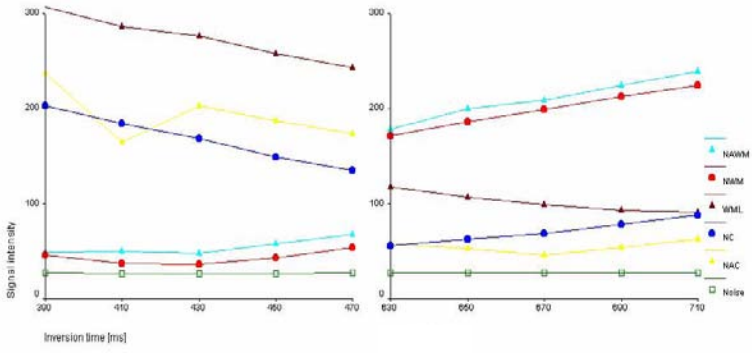


Table **Inversion times (TI) for best tissue suppression**

Tissue	T_1 [ms] (SD)	TI [ms]	signal intensity
NWM	753 (44)	410	37
NAWM	817 (41)	430	48
NC	1136 (9)	≤ 630	56
NAC	1353 (196)	670	46
WML	1539 (70)	≥ 710	91

Figure 2 **Inversion times versus signal intensity in *post-mortem* brain**



Conclusion

The results of this study suggest that, in *post-mortem* brain, 3D IR-FSE is a useful tool that improves the visual distinction between WM and GM relative to standard SE MRI. Our results suggest that a TI slightly shorter than $\ln(2)\times T_1$ provides a favourable "starting point" to suppress a given tissue compartment (4). The case illustrated in ***Figure 1*** suggests that inversion-recovery imaging may be very helpful to accurately distinguish WM from GM even in areas of the brain with such seemingly unequivocal anatomical structure like the deep white matter (***Table***). Whereas we did not detect any GM lesions in the MS sample, the difference in signal intensity between NC and NAC at any given TI suggests that diffuse cortical changes (e.g. microscopic de- or remyelination) are taking place (***Figure 2***). Provided that (i) there is only little cerebro-spinal fluid left in the tissue when scanning of *post-mortem* brain is performed using a brain slice (as opposed to scanning the brain *in situ*) and (ii) the sample is immersed in a proton-free liquid such as perfluoropolyether, a single suppression technique (as used in this study) may be advantageous compared to DIR techniques (2, 5). DIR is more complex to implement, and the two inversion pulses inevitably result in reduced SNR in the unsuppressed tissue compared to a single inversion-recovery sequence. Future work will include (i) the collection of a larger number of samples, (ii) extended scanning times to improve resolution and signal-to-noise, (iii) collection of further TI's to accurately determine the optimal suppression of NC and WMLs and (iv) the assessment of the histological correlates of the detected MR changes.

References 1. Geurts JJG, et al. Radiology 2005;236:254-260. 2. Pouwels PJ, et al. Radiology 2006, Oct. 3. Barker GJ. Magn Reson Imaging 1998;16:715-720. 4. Meara SJP & Barker GJ Magn Reson Med 2005;54:241-245. 5. Boulby PA, et al. Magn Reson Med 2004;51:1181-1186.