Phase Sensitive Inversion Recovery in Post Mortem Multiple Sclerosis Spinal Cord: Shades of Grey and White

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Target Audience

This study is of relevance to MR physicists and clinicians with an interest in multiple sclerosis (MS).

Purpose

The increased dynamic range of **phase sensitive inversion recovery (PSIR) MRI** has shown promise to improve (i) the visual distinction between grey matter (GM) and white matter (WM) in the central nervous system (CNS), including the spinal cord [1], and (ii) the detection of MS lesions in the GM *in vivo*. We explored the usefulness of PSIR to improve CNS WM/GM contrast and lesion detection in *post mortem* spinal cord samples of people with MS (pwMS) and controls with no known CNS disease. As the relaxation properties of CNS tissue change significantly after death and tissue fixation, we aimed to optimize PSIR for *post mortem* tissue as a pre-condition to correlate MS lesions detected in the spinal cord GM using PSIR with their histological substrate.

Methods

Five formalin fixed spinal cord samples of three women with MS (age= 57-96 years; disease duration= 29-68 years) and one male reference subject (age= 81 years) were used. Samples were inserted into Universal tubes and immersed in 10% formalin solution. Images were acquired on a Siemens TIM Verio 3T whole-body MR system using a 32-channel head coil. Images were acquired using a standard spin echo (SE) IR sequence (TE/TR= 15/5000ms, pixel size= 0.5×0.5mm^2, slice thickness= 2.0mm, slices 29, matrix= 384×384, TI= 50, 150, 300, 600, and 1000ms). Total scanning time was 2.5hours. T_1 maps were calculated using the code developed by Barral et al. (http://www-mrsrl.stanford.edu/~jbarral/t1map.html) [2]. T_1 values obtained in each spinal cord were used to optimize the inversion time of an IR-TSE sequence with phase sensitive reconstruction (TE/TR= 16/16000ms, pixel size= 0.5×0.5mm^2, slice thickness= 2.0mm, slice gap= 0.4mm, slices 64, matrix= 384×384, NSA= 2, echo train length= 7). Scanning time with this sequence was 29min.

Results

The mean T_1 in all MS spinal cord samples was 249±14ms in WM and 318±18ms in GM. Mean T_1 in the control cord was 283±14ms in WM and 393±18ms in GM. There was no significant difference between WM and GM lesion T_1 values at 498±22ms and 512±17ms respectively.

Sample	MS 1	MS 2	MS 3	MS 4	MS 5	Control		
Spinal cord level	Cervical	Cervical	Thoracic	Lumbar	Lumbar	Cervical	Thoracic	Lumbar
T_1 WM [ms]	286±17	250±8	233±17	235±11	241±16	294±15	271±8	284±17
T_1 GM [ms]	321±25	308±34	331±9	316±14	312±7	388±23	386±9	406±21

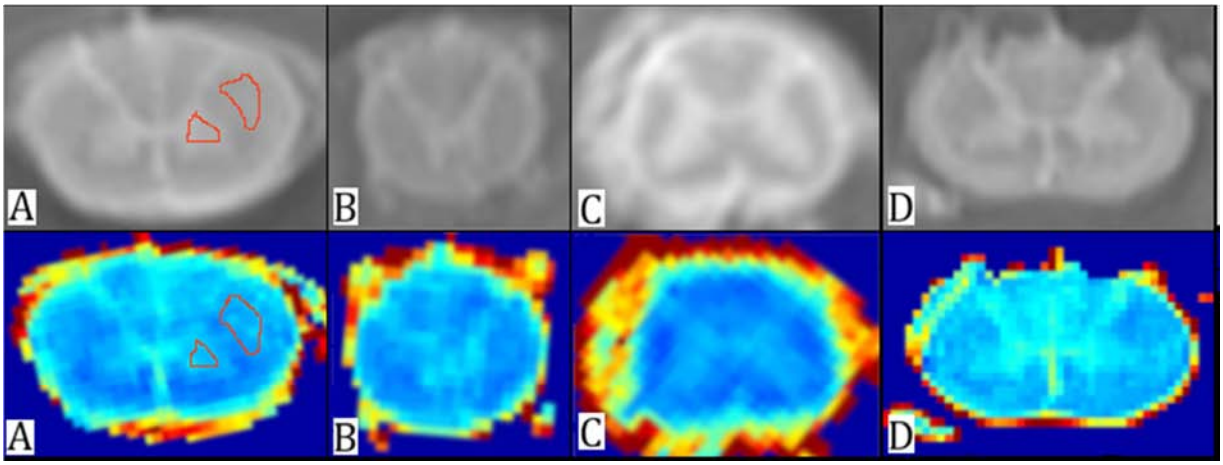

Figure 1 : *Magnitude images TE/TR= 16/16000ms, TI 2000ms (top row) and T_1 maps (bottom row) of post mortem MS spinal cord at three different levels, (a) cervical, (b) thoracic and (c) lumbar spinal cord and post mortem spinal cord of a health control (d).*

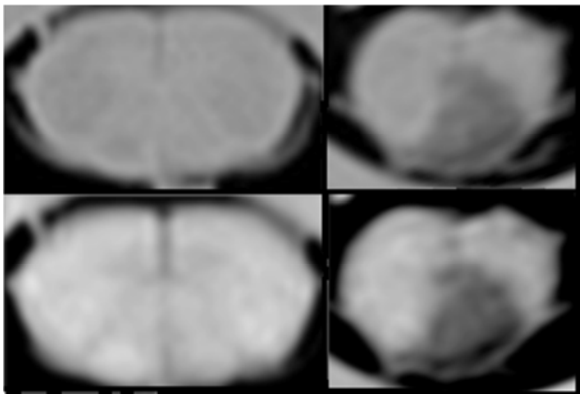

Figure 2 : *Magnitude IR (top row) and PSIR images (bottom row) of MS cervical (right) and thoracic (left) spinal cord TE/TR= 16/16000ms, TI 170ms*

Discussion Though no data was obtained of *post mortem* samples prior to fixation, it is reasonable to assume T_1 in our tissue samples dropped due to both, direct post mortem effects and tissue fixation. Data acquired in MS brain samples at 1.5T suggest only a minor decrease of T_1 occurs as a result of death, whilst fixation leads to a reduction of T_1 in the order of a 50% in both WM and GM. Nevertheless, significant T_1 contrast between WM and GM is retained after fixation (T_1 in WM= 377±73ms, T_1 in GM= 616±114ms) [3,4]. In our MS spinal cord samples the WM/GM difference in T_1 was only just over 20% (WM= 249±14ms, GM= 317±18ms), indicating a more challenging starting point for T_1 based techniques in this area of the CNS. With a short T_1 the best WM/GM is expected on IR images with a long TI (i.e. PD weighting) (figure 1). However, at this time point both WM and GM values are above the null point of the IR curve with very little T_1 weighting left to provide for a substantial difference between PSIR and magnitude IR images. Thus, whilst it may be possible to explore the histological substrates of PSIR in the brain using fixed *post mortem* tissue, corresponding experiments in the spinal cord may have to be pursued on unfixed tissue samples.

References

[1] Kearney H, et al. MSARD 2013:**2**:103-8.[2] Barral, J. K. et al. *Magn Reson Med* 2010;**64**(4):1057-67. [3] Schmierer, K. et al. *Magn Reson Med* 2008; **59**(4):268-77. [4] Schmierer,K. et al. JMRI 2010 **32**(5): 1054-1060.