Using the Null Point Imaging to improve cortical lesion detection in MS

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Purpose: Cortical grey matter (cGM) lesions are well recognised in MS pathology and have recently been detected in vivo using sequences such as DIR at 3T [1], and T2* at 7T [2]. However these sequences have limitations: low SNR and low perceived sharpness in DIR images, and anisotropic voxels generally needed to achieve high contrast in T2* images. Identifying intra-cortical, mixed or simply juxta-cortical remains an important unsolved problem since the pathogenesis of demyelination appears to be different in the grey and white matter. Recently Phase Sensitive Inversion Recovery (PSIR) has been introduced to provide T1w images in the brain with increased contrast to noise ratio (CNR) compared to MPRAGE and PSIR combined with DIR have been shown to provide increased rate of detection of cGM lesions at 3T [3]. However PSIR is generally reconstructed from two images acquired simultaneously, one at a short inversion time (TI) between the null points for grey matter (GM) and white matter (WM), herein called Null Point Imaging (NPI), and a second at a long TI. In PSIR the sign of the inversion recovery signal in the NPI (short TI image) is restored to increase dynamic range, by comparing the phase of the images acquired at short and long TI (assuming the later image is fully recovered). Contrast in the second, long TI image mainly reflects signal variations due to B1 inhomogeneity and it is used to correct the effects of such inhomogeneities in the final PSIR image. However the NPI contains useful information in its own right, as voxels containing both inverted and uninverted signal produce very low net signal, resulting in a black line at the GM/WM boundary (fig 1) and thus providing good delineation of the cortical ribbon, increasing the delectability of cGM abnormalities.

Aim: (1) To determine whether the use of PSIR images combined with the NPI images from which they are reconstructed can assist in determining the boundaries of GM lesions in MS (2) To compare the contrast of GM lesions on the NPI and PSIR images.

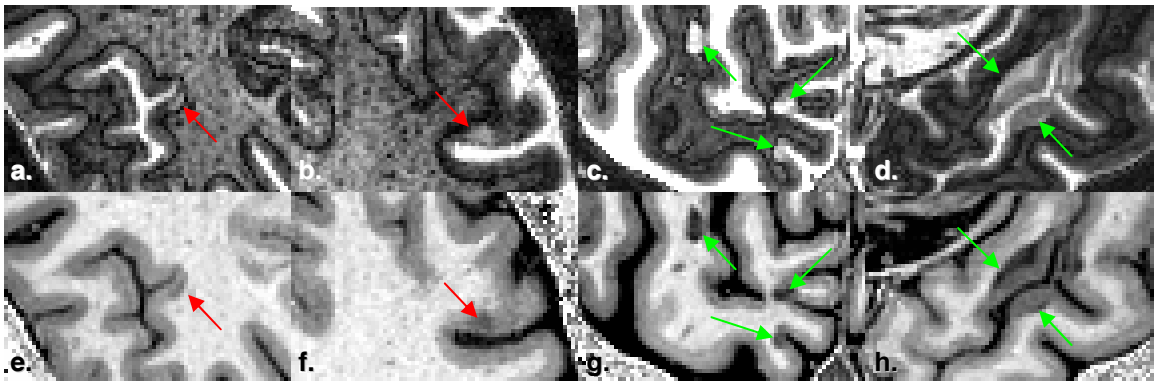

Fig 1: NPI images (a,b,c,d), together with corresponding PSIR (e,f,g,h) presenting cortical lesion hyperintense (hypointense) on NPI (PSIR) (red arrows) as well as mixed and juxtacortical lesions (green arrows). Note the black line between the white and grey matter in the NPI images, corresponding to the WM/GM boundary.

Method: 23 MS patients were recruited as part of a study to detect and quantify lesion in the grey matter. Expanded Disability Status Scale (EDSS- a marker of symptom severity) was recorded at the time of scanning. Scanning was performed on a 7T Philips scanner, with a NOVA 32 channel receive coil. High resolution PSIR images were acquired from two FFE reconstructions per inversion pulse (0.6x0.6x0.6mm^3, TI1/TI2=780/1600ms, SSi=5000ms, FA=8°, TE/TR=6/13ms, FOV = 200x180x140mm: Tacq=11min55s). The phase difference between the NPI and the long inversion time image was used to polarity restore the NPI and hence produce a PSIR. The long TI (low contrast) magnitude image was smoothed, and used to correct the signal variations in the PSIR image by a simple division. Manual detection was performed simultaneously on the PSIR/NPI images to delineate abnormalities purely inside the cortical ribbon (icGM), as well as mixed cortical lesions (mcGM: involving GM and WM) and juxta-cortical lesion (jcGM: in WM adjacent to GM). Regions of interest (ROI) were drawn in normal appearing tissue around the icGM lesions in the cGM (NAGM) and WM (NAWM) for 11 subjects.

	CNR in PSIR (+/- std)	CNR in NPI (+/- std)
WM / NAGM	**-4.33 (+/- 1.25)**	**1.72 (+/- 1.10)**
WM / icGM Lesion	**-5.94 (+/- 1.29)**	**3.19 (+/- 1.59)**
NAGM / icGM Lesion	**-1.62 (+/- 0.56)**	**1.87 (+/- 0.65)**

Table 1: CNR computed over 44 icGM lesions obtained on 11 MS patients.

Results: In all 23 MS patients scanned, the intracortical lesions were more clearly visible on the NPI than on the PSIR. Mixed and juxta-cortical lesions were detectable on the PSIR due to the dark white matter appearance of the lesions. Pure cGM lesions were found in 22 out of the 23 patients, with mean lesion number detected of 5.8 (+/-3.3). 86 mcGM and 88 jcGM were found in these 23 subjects giving an average of respectively 3.7 (+/-6.9) and_3.8 (+/-7.8) lesions per subject. EDSS varied within the group between 1 and 7, (average= 3.5 +/- 2.4) and did not correlate with the number of icGM lesions (p=0.33). The CNR (table 1) measured between the ROIS in NAWM and NAGM, was greater in the PSIR image than the NPI image as expected as the NPI image is designed to match the signal in NAWM and NAGM. The CNR between NAWM and icGM lesions was also greater in PSIR but the CNR between NAGM and icGM lesions was greater in the NPI than the PSIR image.

Discussion: GM involvement in icGM lesions was easier to determine on NPI images compared to PSIR since the GM/icGM lesion contrast was higher on NPI images, and the intra-cortical lesions appear hyperintense which also improves conspicuity. Involvement of the surrounding white matter in mGM and jcGM lesions is easier to spot on PSIR due to the strong lesion/WM contrast, however in these cases NPI can assist in determining whether or not there is a boundary between the GM and a jcGM lesion and also GM involvement in mixed lesions (fig. 1d and h). Previous work has shown that the NPI is robust to variations in T1 and partial voluming in the voxel. Future work will formally compare performance with other sequences such as MTR, DIR and T2*.

References: [1] Geurts *et al.*, Radiology 2005. [2] Mainero *et al.*, Neurology 2009. [3] Sethi *et al.*, J Neurol Neurosurg Psychiatry 2012.