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# Phase sensitive reconstruction of T1-weighted inversion recovery in the evaluation of the cervical cord lesions in multiple Sclerosis; is it similarly eligible in 1.5 T magnet fields?

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ABSTRACT

*Background:* In primary studies with 3 T Magnets, phase sensitive reconstruction of T1-weighted inversion recovery (PSIR) have showed ability to depict the cervical multiple sclerosis (MS) lesions some of which may not be detected by short tau inversion recovery (STIR). Regarding to more availability of 1.5 T MRI, this study was designed to evaluate the eligibility of PSIR in 1.5 T for detection of spinal cord MS lesions.

*Method:* In a study between September 2016 till March 2017 the patients with proven diagnosis of MS enrolled to the study. The standard protocol (sagittal STIR and T2W FSE and axial T2W FSE) as well as sagittal PSIR sequences were performed using a 1.5 T magnet. The images were studied and the lesions were localized and recorded as sharp or faint on each sequence.

*Results:* Of 25 patients (22 females and 3 males, with mean age of 33.5 ± 9.8 years and mean disease duration of 5.4 ± 3.9 years) 69 lesions in STIR, 53 lesions in T2W FSE, 47 lesions in Magnitude reconstruction of PSIR (Magnitude), and 30 lesions in phase sensitive (real) reconstruction PSIR were detected. A Wilcoxon signed-rank test showed STIR has a statistically significant higher detection rate of the plaques rather than other three sequences. (STIR and T2W FSE, $Z = -4.000$, $p < 0.0001$, STIR and Magnitude, $Z = -4.690$, $p < 0.0001$, STIR and PSIR, $Z = -6.245$, $p = 0.002$) Also, STIR had a statistically significant superiority in the boundary definition of the plaques rather than other three sequences.

*Conclusion:* This study shows that in the setting of a 1.5 T magnet field, STIR significantly has a superiority over both of the PSIR reconstructions (i.e. real and magnitude) for the detection as well as the boundary definition of the cervical cord lesions of MS. These results have a good relevance to clinical practice by using MRI scanners and sequences routinely available, however, it is discrepant with other reports performed by 3 T Magnet fields.

## 1. Introduction

Multiple sclerosis (MS) is a chronic inflammatory and immune-mediated disease with complex etiology which causes neuronal demyelination in the brain and spinal cord. The spinal cord involvement is mostly found in association with the brain involvement, but in 15–20% may also occur in the absence of any visible cerebral lesions. (Hittmair et al., 1996) Asymptomatic spinal cord plaques represent a strong predictor of disease evolution in clinically isolated syndrome. (Sombekke et al., 2013) The lesion load as well as the tissue atrophy particularly in the upper cervical cord is strongly associated with the patient's disability. (Kearney et al., 2015; Lukas et al., 2013).

MRI stands as the single valid imaging method for diagnosis and follow up of MS. Spinal cord imaging, however, is associated with more technical challenges than brain imaging in MS patients. (Rovira et al., 2015) In two recent decades many efforts have been done to reach an ideal sequence in evaluation of spinal cord in MS. Fast spin echo technique could improve the image quality of the T2-weighted comparing with conventional spin echo sequences, but it could not significantly help in depicting the intrinsic cord lesions. (Hittmair et al., 1996) Applying the inversion recovery (IR) sequences was a great step in imaging of MS. Fluid attenuated IR (FLAIR) and short tau IR (STIR) became the essential sequences for the imaging of brain and spinal cord, respectively. (Hittmair et al., 1996; Philpott and Brotchie, 2011) By employing the high magnet fields in MS clinical researches another promising IR sequence i.e. T1 IR with phase sensitive reconstruction (PSIR) has been shown to be advantageous in the illustration of spinal MS lesions. (Alcaide-Leon et al., 2016; Hou et al., 2005; Philpott and

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Brotchie, 2011; Poonawalla et al., 2008; Sundarakumar et al., 2016) In the MAGNIMS consensus guidelines on the use of MRI in MS, PSIR was introduced as the alternative sequence of STIR for cervical segment of the cord. (Rovira et al., 2015).

Detection of the lesions in PSIR is based on the differences in T1 relaxation times of tissues rather than the differences in T2 relaxation times. The specific inversion time of this sequence (~350–400 ms) nulls the signal of normal white matter and displays it as intermediate gray consequently. All other tissues will have either lower or higher signal intensity than normal white matter which causes a high contrast between MS lesions and surrounding tissue.

In primary studies with 3 T Magnets, PSIR showed ability to depict the cervical MS lesions some of which are not detected by STIR. (Alcaide-Leon et al., 2016; Philpott and Brotchie, 2011; Poonawalla et al., 2008; Sundarakumar et al., 2016) The reconstruction of T1 IR images in 1.5 T is also possible and the acquisitioned images have an acceptable quality. Regarding to more availability of 1.5 T MRI in the most countries this study was designed to evaluate the eligibility of PSIR in 1.5 T for spinal cord MS lesions.

## 2. Method

### 2.1. Patients

In a study between September 2016 till March 2017 the patients with proven diagnosis of MS based on the 2010 McDonald criteria (Polman et al., 2011) referred from a neurologist enrolled to the study, consecutively. The imaging of cervical cord was a part of their disease follow up and was not purposed for our study. In patients who had willing to participate in our study a written consent for performing the additional sequences on cervical cord was obtained.

### 2.2. Image acquisition

All the studies were performed by a 1.5 T Magnetom Avanto (Siemens, Erlangen, Germany) using a head and neck coil. The patients laid in supine position with the head pointing towards the magnet. The laser beam localizer was centered over the sternoclavicular joints. The routine protocol in our center for evaluation of cervical cord in MS includes sagittal STIR (TR = 4000 ms, TE = 70 ms, flip angle: 180°, inversion time:160 ms, FOV = 220, NEX = 2), sagittal T2W FSE (TR = 2500 ms, TE = 102 ms, flip angle: 90°, FOV = 240, NEX = 2) and axial T2W FSE images (FOV = 180, NEX = 1). For each sagittal series 12 slices with 3 mm thickness and 0.3 mm intersection gap and for the stacked axial series 25 slices with 4 mm thickness and 0.8 mm intersection gap are taken.

For this study T1W IR with phase sensitive and Magnitude reconstruction (using MAGNETOM Aera with syngo MR D13A software, TR = 3500 ms, TE = 70 ms, Inversion time = 350 ms, FOV = 220, NEX = 2, averaging mode = long term) were acquisitioned. For each sagittal series of IR reconstruction 12 slices with 3 mm thickness and 0.3 mm intersection gap was taken. For those cases who had also a request by the neurologist for contrast enhanced study, sagittal T1W FSE sequence (TR = 450, TE = 16, FOV = 240, NEX = 2, 3 mm slice thickness with 0.3 mm intersection gap) with and without IV administration of 0.1 mg/kg gadoterate meglumine (Dotarem, Guerbet) was also performed.

### 2.3. MRI interpretation

The images were studied by two radiologists, separately. They were asked for determining the number and the level of MS plaques and also for scoring the sharpness quality of each plaque in sagittal planes as 1 for a conspicuous lesion with well demarcated boundaries, or 2 for a faint lesion with ill-defined margins. We documented the presence of the lesion as well as the sharpness quality on each sequence when a consensus by both radiologists was reached. The radiologists might ask for taking axial plane of Magnitude or PSIR for each lesion detected in Magnitude or PSIR but not in STIR or T2W FSE.

### 2.4. Statistical analysis

The difference between the detection rate as well as the sharpness depiction of the lesions between the applied sequences was analyzed by Wilcoxon signed-rank test, Friedman test and concordance correlation coefficient. Cohen's kappa coefficient for inter-rater agreement was used. $P$-values $< 0.05$ were considered significant. (IBM SPSS Statistics, version 24, IBM, North castle, NY, USA).

## 3. Results

### 3.1. Clinical data

Twenty-five patients (22 females and 3 males) with mean age of 33.5 ± 9.8 years filled the inclusion criteria. All had been registered with Isfahan MS Society (IMSS). Details of the database were published before. (Etemadifar et al., 2013) The pattern of MS in all of our study patients was relapsing remitting. The mean disease duration was 5.4 ± 3.9 years. The indication of cervical cord imaging in 16 patients was routine follow up and the patients had no new symptom. New onset lower limb weakness (5 patients), numbness (2 patients) and blurred vision (2 patients) were other indications of MRI. For all the seven patients that the limb weakness or numbness was the cause of cord imaging, neurologist requested MRI with GAD.

EDSS of study patients ranged 0-4 with mean of 1 ± 1.2, and median of 1.5.

### 3.2. Lesion detection

Of cervical cord imaging of our patients 69 lesions in STIR, 53 lesions in T2W FSE, 47 lesions in Magnitude reconstruction of T1 IR (Magnitude), and 30 lesions in phase sensitive reconstruction of T1 IR (PSIR) were detected in cervical cord. (Fig. 1–6).

Among the lesions detected on the sequences other than STIR no lesion was additional or non-detected on STIR. Comparing with STIR, T2W FSE, Magnitude and PSIR could detect 76.8%, 68.1% and 43.5% of cervical cord lesions, respectively. A Wilcoxon signed-rank test showed STIR has a statistically significant higher detection rate of the plaques rather than other three sequences. (STIR and T2W FSE, $Z = -4.000$, $p < 0.0001$, STIR and Magnitude, $Z = -4.690$, $p < 0.0001$, STIR and PSIR, $Z = -6.245$, $p = 0.002$).

Also a concordance correlation coefficient showed poor concordance between lesion counts across sequences. (Kendall's $W = 0.303$).

The inter-rater agreement for the detection of lesions for STIR, T2W FSE, Magnitude and PSIR was found to be $K = 0.90$ ($p < 0.0005$) 95% CI (0.76–1), $K = 0.70$ ($p < 0.0005$) 95% CI (0.49–0.9), $K = 0.84$ ($p < 0.0005$) 95% CI (0.66–1) and $K = 0.73$ ($p < 0.0005$) 95% CI (0.54–0.92).

There were seven plaques detected by Magnitude which were not detected by T2W FSE. Also there were 13 lesions detected by T2W FSE which were not detected by Magnitude. A Wilcoxon signed-rank test showed there is no statistically significant difference in detection of the plaques between Magnitude and T2W FSE sequences. ($Z = -1.342$, $p = 0.180$).

There were twenty-six lesions detected by T2W FSE which were not detectable on PSIR. Also there were three lesions detected on PSIR which were not detectable on T2W FSE. There were twenty lesions were detected by Magnitude which were not detectable on PSIR. Also three of lesions detected on PSIR were not detectable on Magnitude. A Wilcoxon signed-rank test showed T2W FSE and Magnitude have both a statistically significant superiority in detection of the plaques rather