Phase sensitive inversion recovery imaging of the spinal cord in clinical scan times

Nico Papinutto[1], Valentina Panara[1,2], Sinyeob Ahn[3], Kevin Johnson[3], Regina Schlaeger[1,4], Eduardo Caverzasi[1], William Stern[1], Bruce Cree[1], Stephen Hauser[1], and Roland G Henry[1]

[1]*Dept. of Neurology, UCSF, San Francisco, CA, United States,* [2]*ITAB - Institute of Advanced Biomedical Technologies, University "G. D'Annunzio", Chieti, Italy,* [3]*Siemens Healthcare USA, San Francisco, CA, United States,* [4]*Dept. of Neurology, University Hospital Basel, University of Basel, Basel, Switzerland*

Introduction

Magnetic Resonance Imaging (MRI) of spinal cord represents a key tool for the study and diagnosis of multiple sclerosis (MS), but it is challenging due to the small dimension of the cord, susceptibility effects, subject and physiological motion. Although 2D sagittal and axial turbo spin echo (TSE) sequences are the standard for lesion detection in MS, they are vulnerable to motion and have a very low white matter (WM)/grey matter (GM) contrast. 3D gradient echo (GRE) sequences have been used since they provide good WM/GM contrast useful to segment GM and they showed to be very efficient for area measurements [1]. Very recently, 3D phase-sensitive inversion recovery (PSIR) images, initially developed in cardiac imaging [2,3], have started to be used in MS studies [4,5,6], since they can provide at the same time the best canal/cord, GM/WM and lesion/cord contrasts. However, most protocols in the cited papers have scan times not compatible with clinical purposes. Here we present two protocols that not only provide consistent measurement of cord and GM area and efficient lesion detection, but also reduce significantly scan times.

Materials and methods

We propose two PSIR protocols optimized on a Siemens 3T Skyra scanner: **1)** A 1:50 minute axial 2D protocol with very good canal/cord, WM/GM and lesion/cord contrasts and no need for re-slicing (in Fig.1 we report an example of an acquisition at the C2-C3 disc level). This protocol was conceived to obtain reliable and reproducible measurements of cord areas and diameters at precise cord levels, similarly to what was shown in [4], but with much shorter acquisition times. **2)** The 3D version of the same protocol that covers a slab of 60 mm in 4:30 minutes, mainly conceived for lesion detection.

The sequence parameters are: **1)** In plane resolution of 0.78*0.78 mm^2, slice thickness 5 mm, matrix 256x256, TR/TE/TI=4000/3.22/400 ms, angle=10°, 3 averages. **2)** 3D axial acquisition built to match the resolution of the 2D version with 12 slices per slab, TR/TE/TI=4000/1.87/370 ms, angle=13°, linear encoding. Magnitude and phase-sensitive images are reconstructed for both protocols.

A series of evaluations was performed: **a)** scan-rescan reproducibility, intra- and inter-operator reproducibility of cord area measurement on 2D images:

a1) 1 healthy subject was scanned 4 times with full repositioning between scans and cord area measured by 3 different operators (NP, VP, RS) at the C2-C3 disc level. **a2)** For 8 healthy subjects the area of the cord was independently measured at the C2-C3, C3-C4, T8-T9, T9-T10 levels by the same 3 operators.

b) Intra- and inter-operator reproducibility of GM area measurement on 2D images: for 8 healthy subjects GM area at the same 4 disc levels was separately measured by 2 experienced operators (VP, RS). **c)** Comparison of area measurement on the 2D and 3D protocols: on 10 MS patients (Relapsing-Remitting, 5 males, 5 females, average age 37±8 years, time from disease onset 13±6 years) cord area was measured on 2D and 3D images at C2-C3 and C3-C4 level (NP). **d)** Lesion detection and localization efficiency of the 3D protocol: using phase and magnitude contrasts together, two neuro-radiologists (VP and EC, 5 and 8 years of experience, respectively) counted and evaluated in consensus the lesion load and localization on the 10 patients comparing results with a standard axial T2 acquisition (0.62x0.62x3 mm^3 resolution).

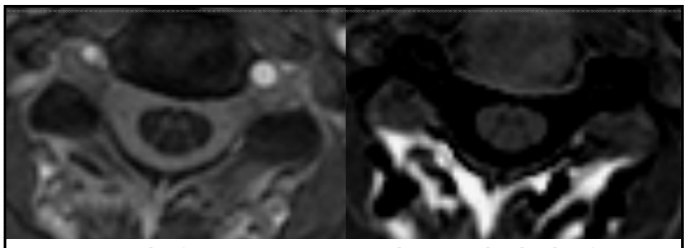

Fig.1*: Example of 2D PSIR acquisition at the C2-C3 disc level. Left: magnitude reconstruction. Right: phase-sensitive reconstruction.*

Area of the spinal cord and of the GM were measured on the phase-sensitive reconstructed images with the software Jim (www.xinapse.com). For total area the software was used in a semi-automated way [7], while GM was manually delineated by the operators 3 times and the average calculated. Reproducibility was expressed as coefficient of variation (COV) defined as standard deviation/mean of the values.

Results

a1) Cord area test-retest reproducibility COVs for the 3 operators were 0.40%, 0.51% and 0.32%, respectively. On the 4 separated acquisitions the inter-operator COV was, on average for the 3 operators, 0.25%. **a2)** On the 8 subjects the inter-operator COV was 0.30% averaging the 2 cervical levels and 0.57% averaging the thoracic levels. **b)** For GM on the 8 subjects the average inter-operator COV was 3.51% on cervical levels and 4.81% on thoracic levels.

c) At both levels, measurements performed on 2D and 3D images strongly correlated (C2-C3: r Pearson coefficient 0.971, $p<0.001$, C3-C4: r Pearson coefficient 0.977, $p<0.001$).

d) On the 10 MS patients 51 lesions were detected on 3D PSIR while 36 on T2 images.

It was possible to localize 30 pure WM or mixed WM/GM lesions (59% of total) on 3D PSIR images, whereas none on T2. We report an example in Fig.2 showing the difference of performance of T2 and 3D PSIR. On the PSIR an arrow points a lesion not detected on the T2.

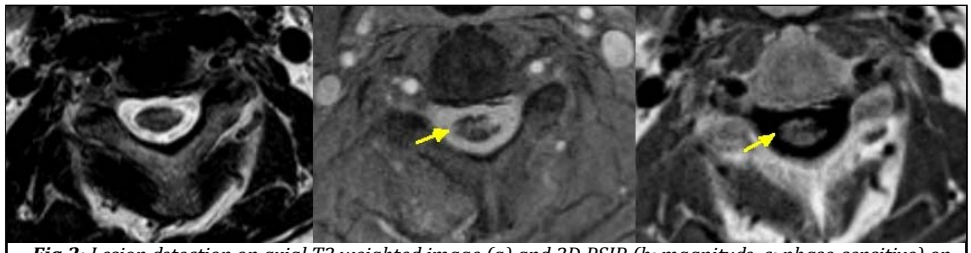

Fig.2*: Lesion detection on axial T2 weighted image (a) and 3D PSIR (b: magnitude, c: phase-sensitive) on a MS patient. The yellow arrow on the 3D PSIR points a lesion not detected on the T2 image.*

Discussion and conclusions

In this study we present 2D and 3D PSIR protocols that have short acquisition times but retain good in plane resolution and great canal/cord, GM/WM and lesion/cord contrasts making them candidates to become broadly implemented in clinical MS centers.

References

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