Symmetry-based reorientation algorithm for spinal cord 3T MR images

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Abstract –Imaging the spinal cord of spinal cord injury (SCI) patients is challenging due to pain and sores problems that could be caused by a prolonged lying position in the scanner. Once positioned within the MRI the subject cannot be displaced and therefore subject centering within the scanner (A-P and L-R directions) is not ensured. Thus, centering spinal cord images in the A-P and L-R directions is necessary to make group analysis and accurately quantifying cord atrophy in SCI patients. A Symmetry-based reorientation algorithm for the spinal cord 3T R images was proposed and evaluated on 32 data using both an imposed rotation angle and visual strategies. The proposed reorientation algorithm was proven to be efficient at C2 vertebral level.

Index terms - Disability, Image Processing, Magnetic Resonance Imaging.

I. INTRODUCTION

Imaging the spinal cord of spinal cord injury (SCI) patients is challenging due to pain and sores problems that could be caused by a prolonged lying position in the scanner. Once positioned within the MRI the subject cannot be displaced and therefore subject centering within the scanner (A-P and L-R directions) is not ensured. Thus, centering spinal cord images in the A-P and L-R directions is necessary to make group analysis and accurately quantifying cord atrophy in SCI patients [1].

II. MATERIALS AND METHODS

II.1. Subjects

Patients with SCI (n=16, age: 45.25±16.46, 4 females) and age/gender matched healthy controls (n=16, age: 45.38±16.10, 4 females) were recruited. A written informed consent was obtained from each participant and the local Ethics Committee of our institution approved all experimental procedures.

II.2. MRI acquisition

Subjects were scanned at 3T MRI system (Tim Trio, Siemens Healthcare). Spinal cord was imaged using a 3D T2-weighted turbo spin echo (TSE) sequence. Imaging parameters were: FOV = 280×280 mm^2; voxel size = $0.9\times0.9\times0.9$ mm^3; 52 sagittal slices; TR/TE = 1500/120 ms; acquisition time ≈ 6min [2].

II.3. Reorientation algorithm

The spinal cord, CSF, vertebrae and nerves roots are symmetrical with regards to the L-R direction. This property was used to correct the R-L and A-P orientation of the spinal cord from MR images. *<u>Preprocessing:</u>* B_1 non uniformity intensity correction using Minc-Toolkit N3 [3]. Images at C2 vertebral level were cropped and resampled to a resolution of $0.3\times0.3\times0.3$ mm^3 (FOV = 90×110 pixels), then segmented using an automated version of the well-established Losseff's segmentation method [4]. Images were straightened in planes perpendicular to the centreline and standardize in length to the median cord length (120 slices) [5]. Axial slices were resampled to a resolution of $0.3\times0.3\times3$ mm^3 [6, 7]. For some subjects, the 12th axial slice was not imaging spinal cord but the pons. Therefore, the 12th axial slice was removed from all data. *<u>Reorientation algorithm:</u>* Axial slices were rotated successively by an angle between -30° and 30° with a step of 0.5°. The rotated slice and the flipped rotated slice in the L-R direction were reshaped into vectors. Zero values were removed from the two vectors. Pearson's correlation coefficient between the two vectors was computed. The angle maximizing the correlation coefficient was used to reorient the 11 slices. It allows an identical reorientation of the spinal cord along the same vertebrae, C2 in this case.

II.4. Reorientation algorithm validation

Correction of orientation in case of an imposed angle: Thirteen MR images perfectly centred in the in the A-P and L-R directions were selected from our database. Rotations between -10° and 10° with a step of 0.5° were applied to all the images (41 rotations), and the error of orientation made by the algorithm was assessed. The human eye cannot see an error orientation under 1°, therefore all results between -1° and 1° were considered perfect. *Visual validation:* MR images from all subjects were used for validation of our algorithm. Images were reoriented via the algorithm given in II.3. Angles resulting from the algorithm were compared to the visually estimated angles. Bland-Altman plots were used for validation [8].

III. RESULTS

Correction of orientation in case of an imposed angle: The mean (SD) error made by our algorithm was -0.01° (0.14°) (Figure 1).

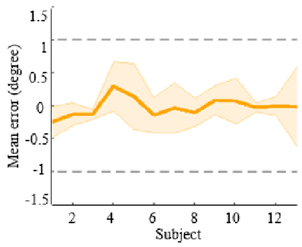

Figure 1: Mean ± SD error of correction in degree over the 41 imposed rotations for each subject. The dotted lines represent the limits of human eye angular resolution.

Visual validation: The mean (SD) difference between the visually estimated angle and the computed angle by our algorithm was 0.17° (0.78°). Bland-Altman plots are given in Figure 2.

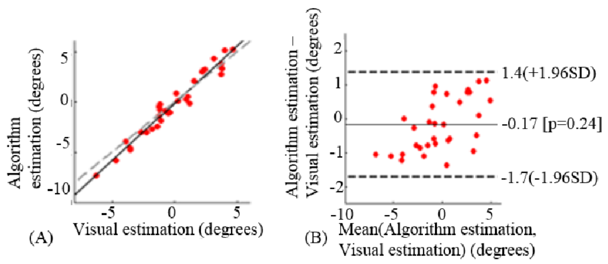

Figure 2: Bland-Altman plot between the visually estimated angle and the computed angle, (A) correlation of computed angle and estimated angle, (B) and the amplitude of agreement.

All samples lied strictly between ±1.96×SD. Pearson's correlation coefficient R was 0.98.

Therefore, there was a perfect agreement between the visually estimated rotation angle and the computed rotation angle by our algorithm (p=0.24).

Reorientation algorithm example: One example of reorientation can be seen in Figure3.

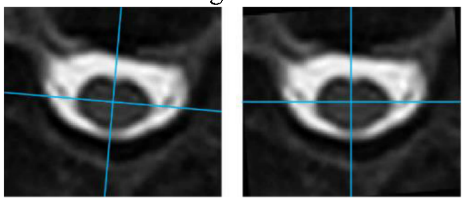

Figure 3: Orientation algorithm applied to a SCI subject. Slice before correction (left) and slice after correction (right).

IV. DISCUSSION-CONCLUSION

The proposed reorientation algorithm was proven to be efficient at C2 vertebral level. The algorithm could be integrated as a part of data processing before atrophy quantification in SCI patients [1]. As a perspective, our algorithm could be tested in other spinal cord regions as cord atrophy in SCI patients is potentially not limited to C2 vertebral level [9].

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