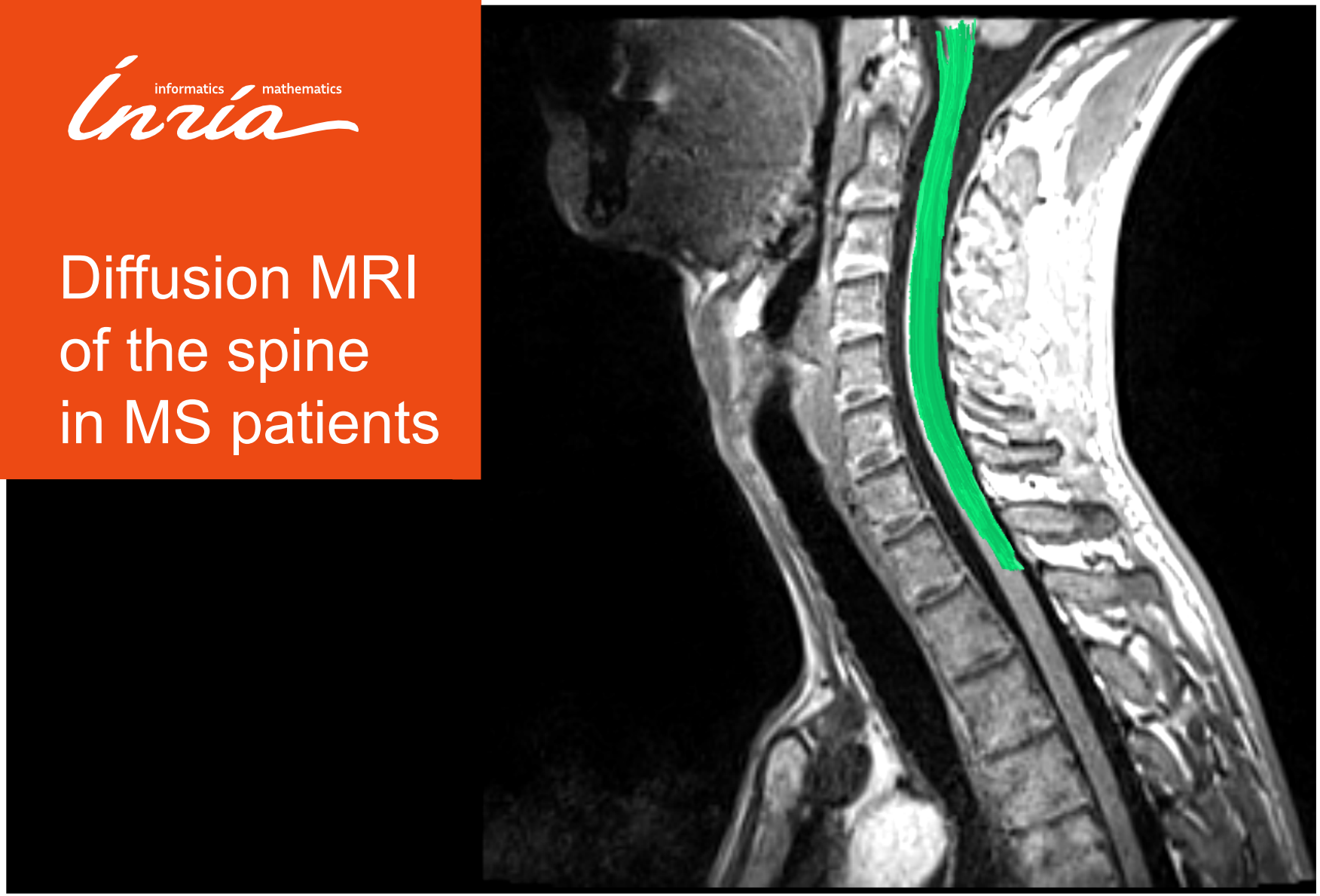
Diffusion MRI of the spine in MS patients



Overview of the project

Description of the “EMISEP” cohort

- Nearly 80 RRMS patients, with 3-5 years longitudinal follow-up (in progress)
- About 30 controls
- Brain and Spine MRI and clinical follow-up
- Multi-centric study in France (Rennes, Montpellier, Marseille, …)

Main scientific objectives

- Identify and follow early occurring lesions in the spinal cord
- Characterize predictive biomarkers of the EDSS score at 5 years

Key challenges in diffusion MRI processing

- How does inhomogeneity distortion affects diffusion analysis?
- How to cope with the inter-subject, inter-centre, intra-subject variability?
- Is fibre tracking informative/relevant in the context of spine imaging?

A focus on distortion correction

Several sources of distortion in diffusion MRI of the spine

- Subject/physiological motion
- Eddy-current induced distortions
- B0 field inhomogeneity (susceptibility-induced)

Strategies to correct inhomogeneity distortions

- Co-registration with a reference image (image-based)
- Point spread function mapping
- Phase field map
- Reverse gradient polarity (RGP) methods

Comparison of RGP methods (1)

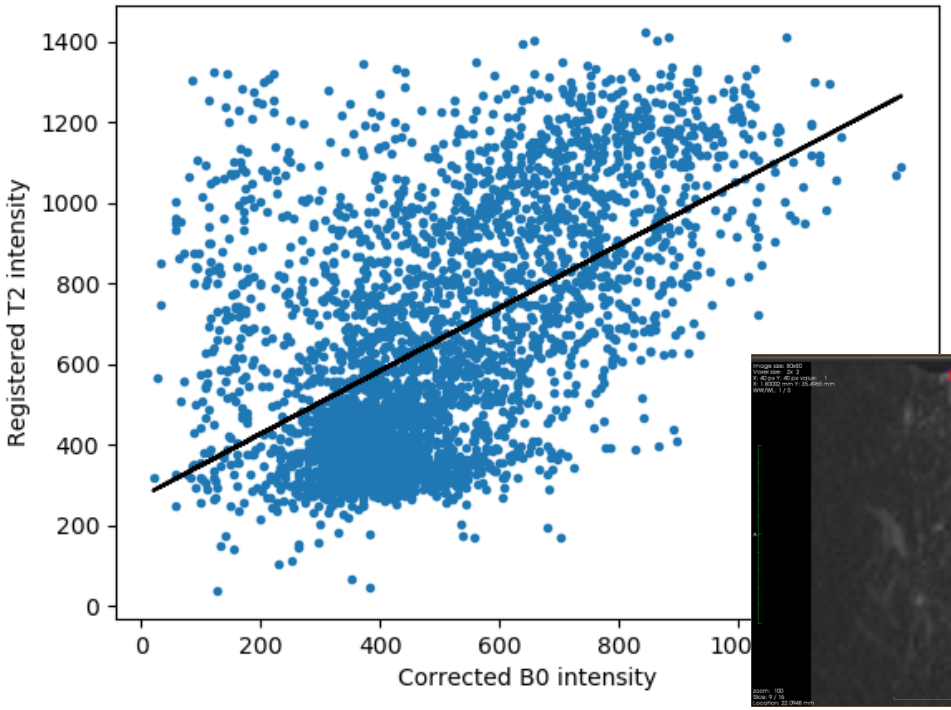
We benchmarked state-of-the-art methods on our dataset

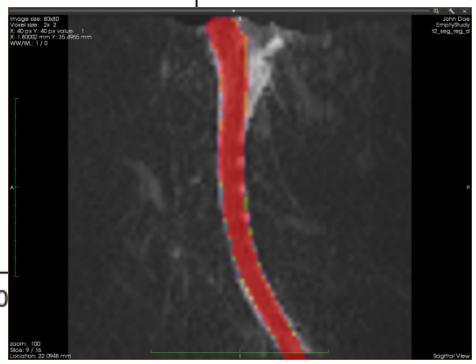
- Block-matching [1], as implemented in Anima
- Hysco[2], as implemented in ACID-SPM
- Voss[4], as implemented in Anima
- Topup[3], as implemented in FSL
- No correction (as a reference)

1. R Hédouin *et al*, IEEE T Med Imaging, 36 (5): 1106-1115, 2017.
2. L Ruthotto *et al*, Phys Med Biol, 57(18): 5715-5731, 2012.
3. HU Voss *et al*, Magn Reson Imaging, 24(3): 231-239, 2006.
4. JLR Andersson et al, Neuroimage, 20(2): 870-888, 2003.

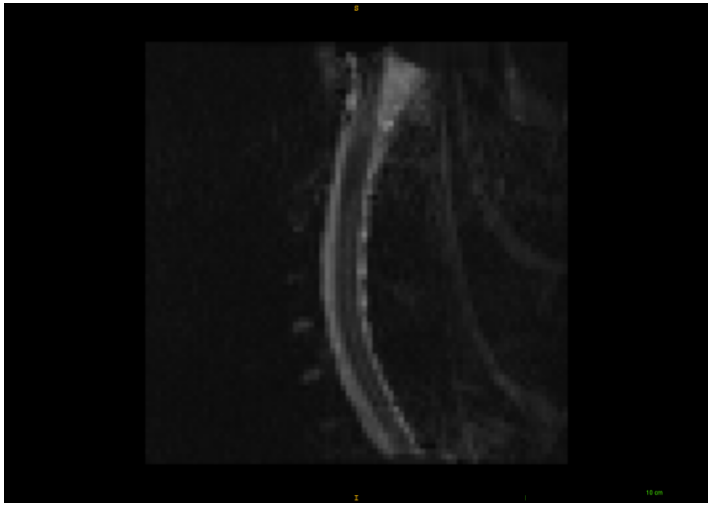
Comparison of RGP methods (2)

Correlation with anatomical image as a measure of



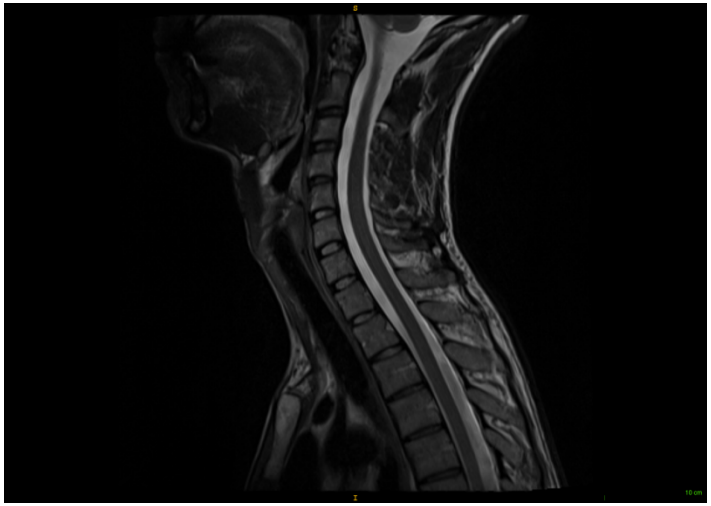


Diffusion acquisitions



- Sagittal acquisition
- Continuous sampling
- 2mm isotropic resolution
- 30 gradient directions (b = 900s/mm²) + 6 b = 0
- Acquisition in reverse phase encoding direction (F > H) for 1 additional b = 0

Anatomical reference



- Sagittal acquisition
- In-plane resolution: 0.67 mm
- Slice thickness: 2.75 mm
- T2-weighted anatomical image

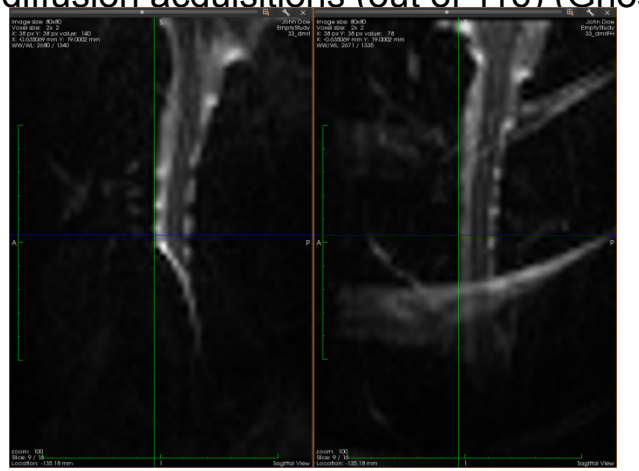
Description of the dataset

Before QC

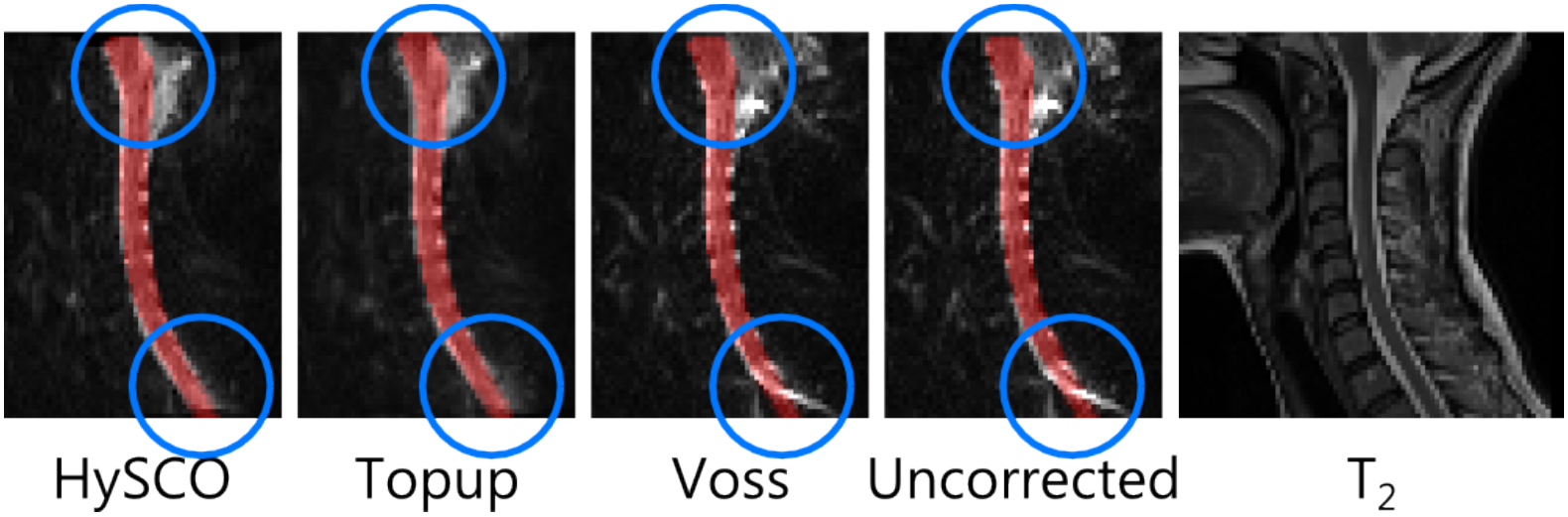
- 116 diffusion acquisitions (61 MS patients + 9 controls)
- 2 imaging centres (Rennes and Montpellier university hospitals) with 3T Siemens scanners

After QC

- 69 diffusion acquisitions (out of 116) (Ghosting/motion, failed registration)



Comparison of distortion correction methods (1)



- T2 image is segmented (using Spinal cord toolbox[1,2])
- Diffusion image is corrected (H>F b = 0 image)
- T2 image is rigidly registered to the corrected diffusion

1. B De Leener *et al*, Neuroimage, 145(A):24-43, 2017.
2. http://sourceforge.net/p/spinalcordtoolbox

Comparison of distortion correction methods (2)

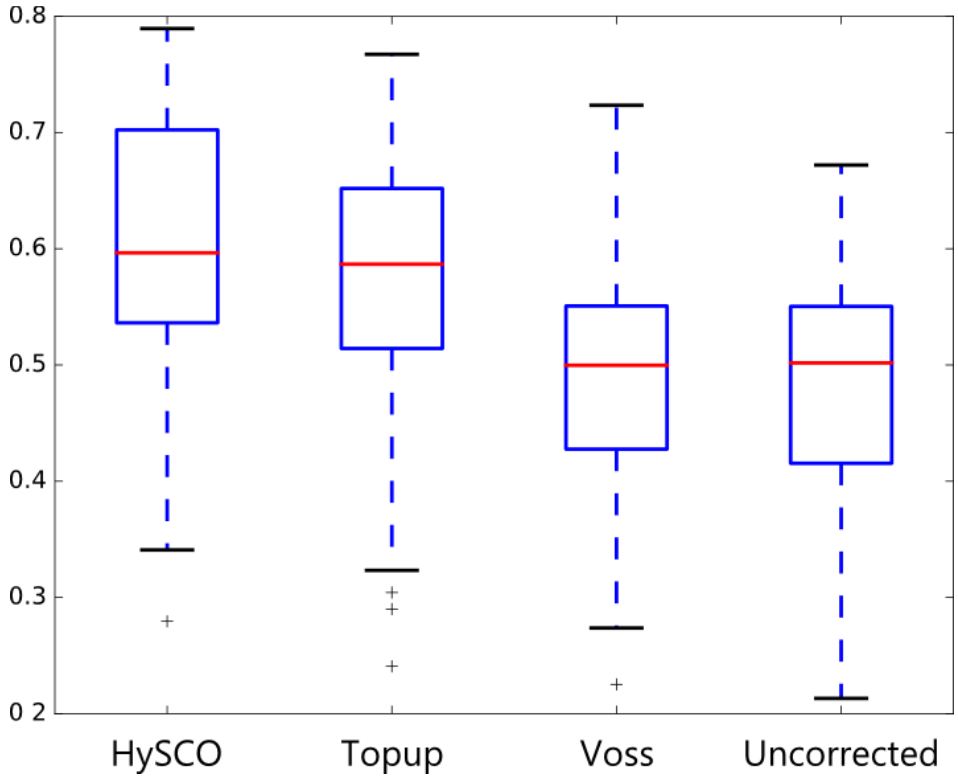


Figure: cross-correlation between T2 and corrected b = 0 image

- Significant difference corrected/uncorrected (ANOVA $F = 19.8$, $p < 10^{-10}$)
- Significant improvement for Topup and HySCO ($p < 2 \times 10^{-4}$)
- No significant improvement for Voss over no-correction

Conclusions / perspectives

Inhomogeneity-induced correction of distortions

- A careful choice of correction method is important
- Topup/HySCO provide best results for alignment of the spinal cord

Main objective: stats on diffusion-derived indices

- How to define anatomical “landmarks” in the spine?
  - Atlas-based methods? E.g. PAM50
  - Tractography?
- How to account for variability in the data?
  - Intra-subject, inter-subjects, inter-scanners, etc.

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