Scuola Superiore di Neurologia Sin

V CORSO

Neuroimmagini nella Malattia di Parkinson e Parkinsonismi

Genova, 21-22 febbraio 2017

Accademia Nazionale di Medicina - Via M. Piaggio 17/6 - Genova

DIFFUSION MRI

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DIFFUSION MRI

Outline of the presentation

- ✓ Basic principles
- ✓ Parkinson’s disease
- ✓ Progressive supranuclear palsy
- ✓ Corticobasal syndrome
- ✓ Multiple system atrophy
- ✓ Differential diagnosis

DIFFUSION MRI

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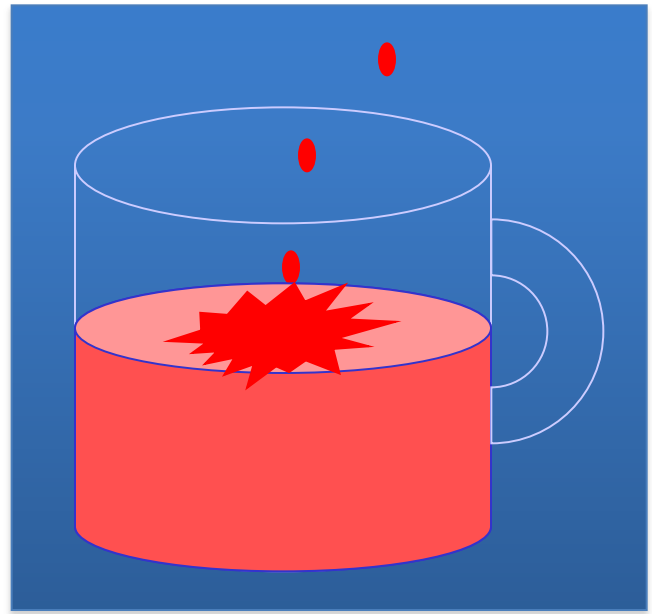
DIFFUSION MRI

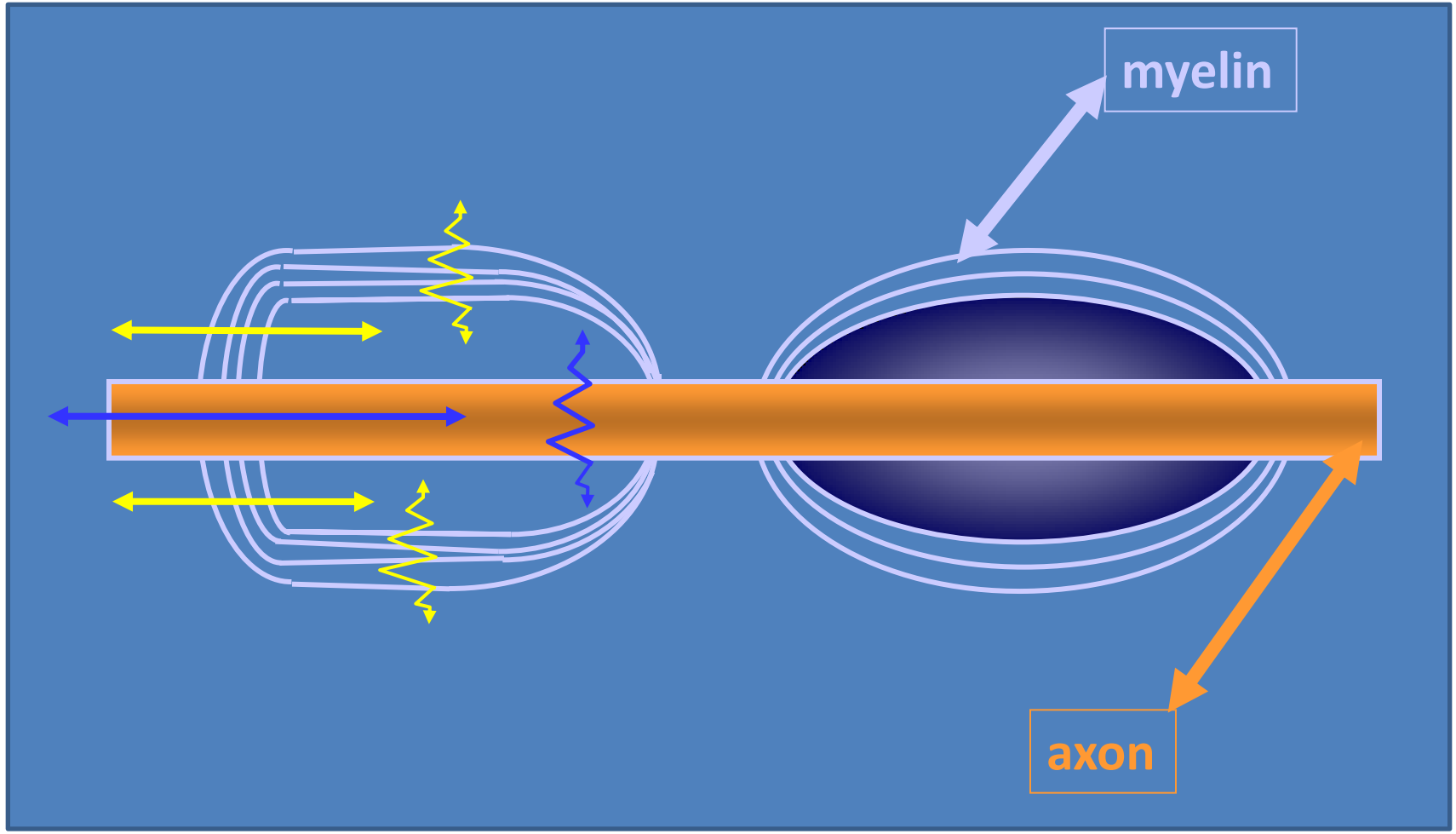
Basic principles



Diffusion results from a microscopic random motion known as Brownian motion

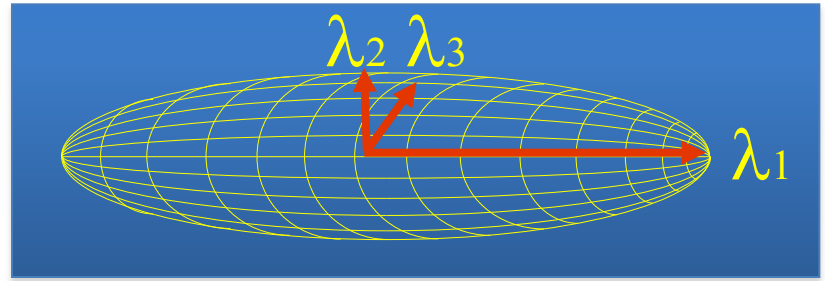
DIFFUSION MRI

Diffusion anisotropy in white matter



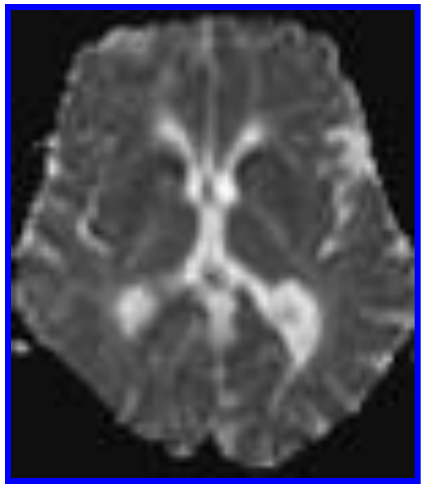
DIFFUSION MRI

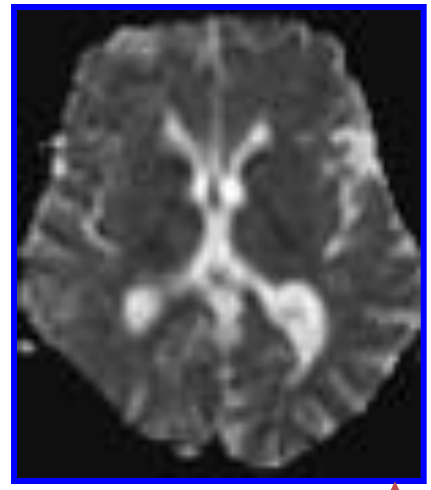
Tensor model

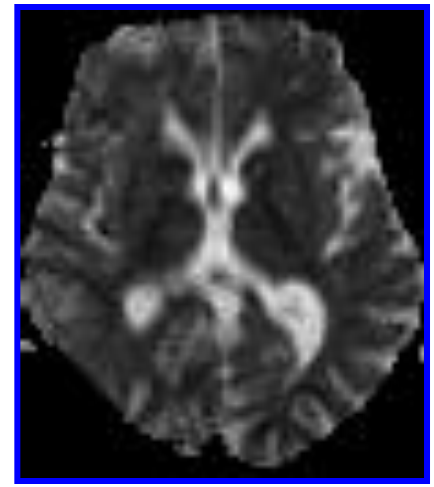


- Principal diffusivities:

diffusivities along the three principal directions







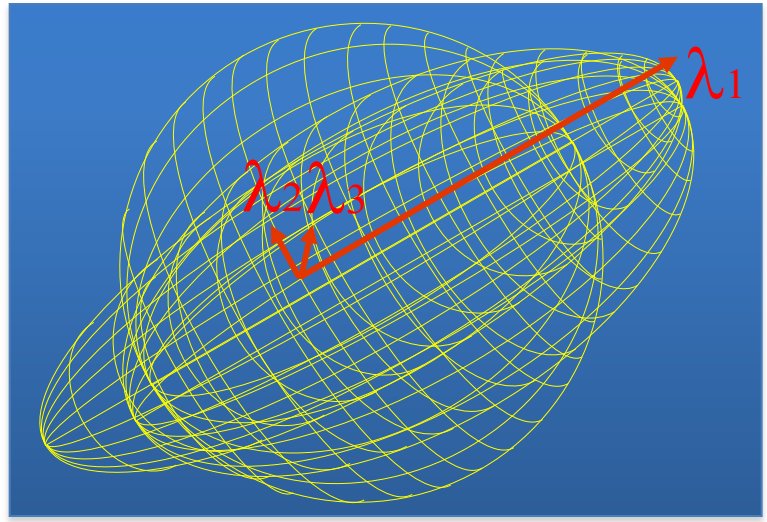
λ_1 λ_2 λ_3

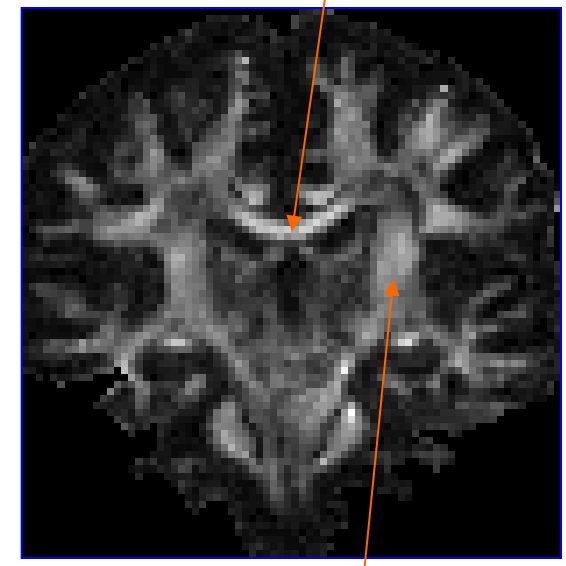
$MD=(\lambda 1+\lambda 2+\lambda 3)/3$

DIFFUSION MRI

Tensor model

- Shape





- Fractional anisotropy index (FA):

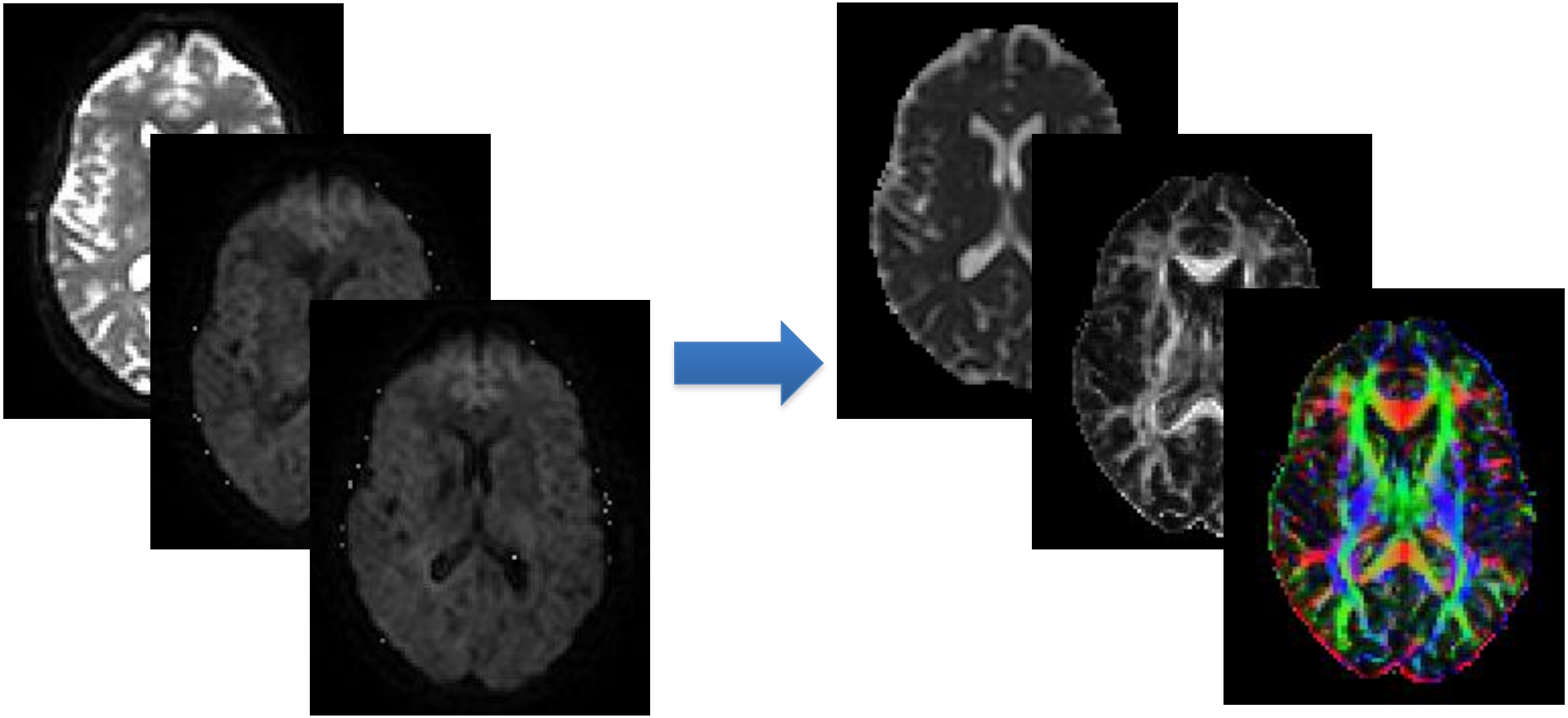
$$\mathrm{FA} = \sqrt{\frac{1}{2}}\frac{\sqrt{(\lambda_1-\lambda_2)^2+(\lambda_2-\lambda_3)^2+(\lambda_3-\lambda_1)^2}}{\sqrt{\lambda_1^2+\lambda_2^2+\lambda_3^2}}$$

AxD=λ1

RD=(λ2+λ3)/2

DIFFUSION MRI

Diffusion tensor estimation



DIFFUSION MRI

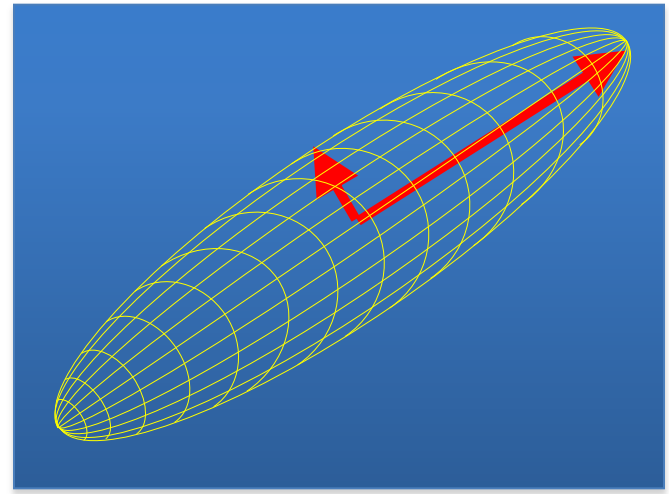
Diffusion techniques

- ROI-based approaches
- Tractography-based approaches
- Voxel-wise approaches
  - Tract-based spatial statistics (TBSS)
  - Statistical parametric mapping (SPM)

DIFFUSION MRI

Tractography

Assumption: only one direction is predominant in each voxel and diffusivity is greatest in this direction



3D vector field representing fibre orientation in each voxel can be obtained through diagonalization of DT

Tracts are reconstructed by changing the fibre's direction as soon as a new pixel with a new information about direction is encountered.

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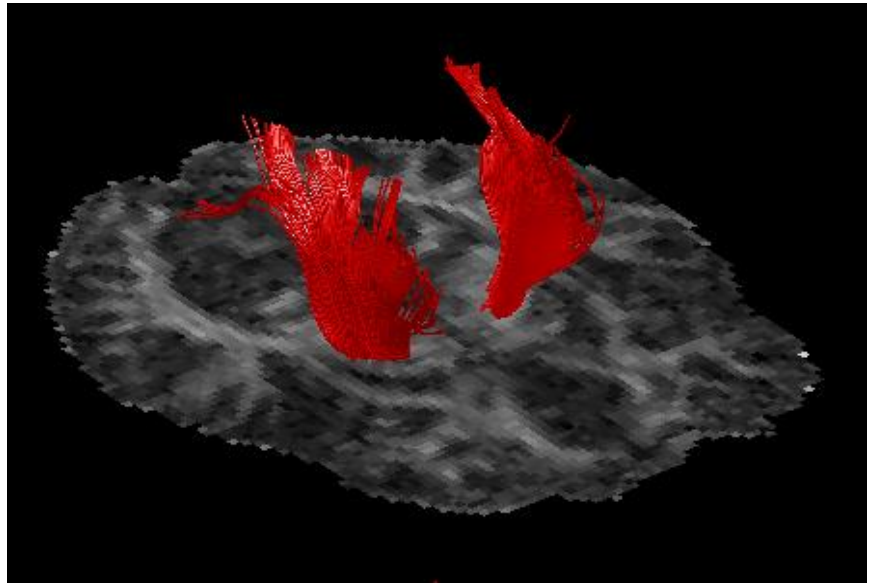
Tractography



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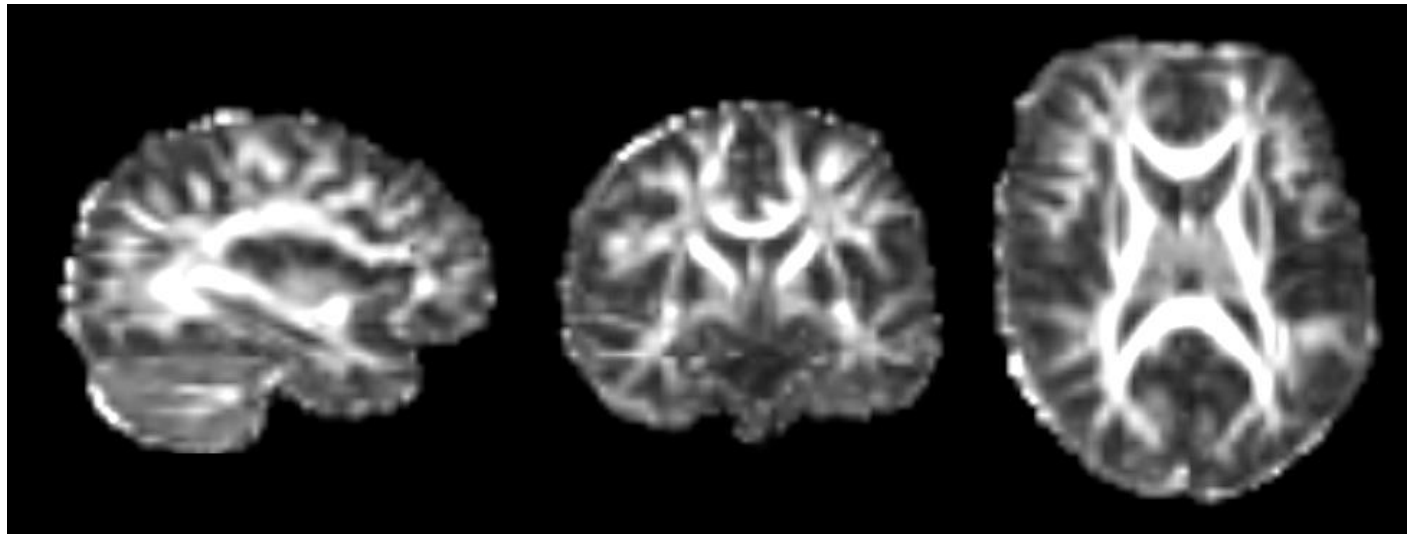
TBSS

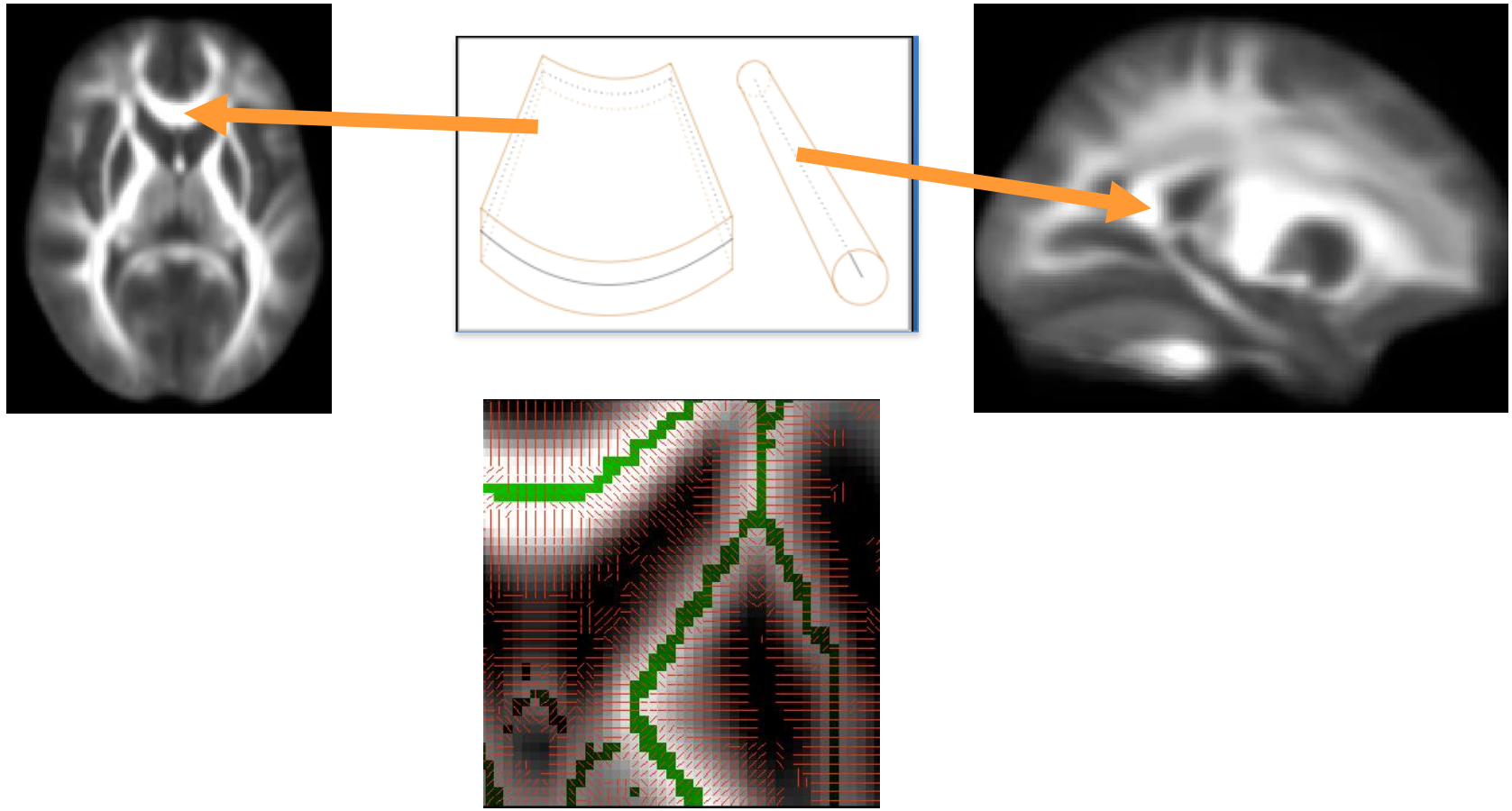
Use nonlinear registration to pre-align all subjects' FA (nonlinear reg: FNIRT)



www.fmrib.ox.ac.uk/fsl/tbss/index.html

DIFFUSION MRI

TBSS/Skeletonise

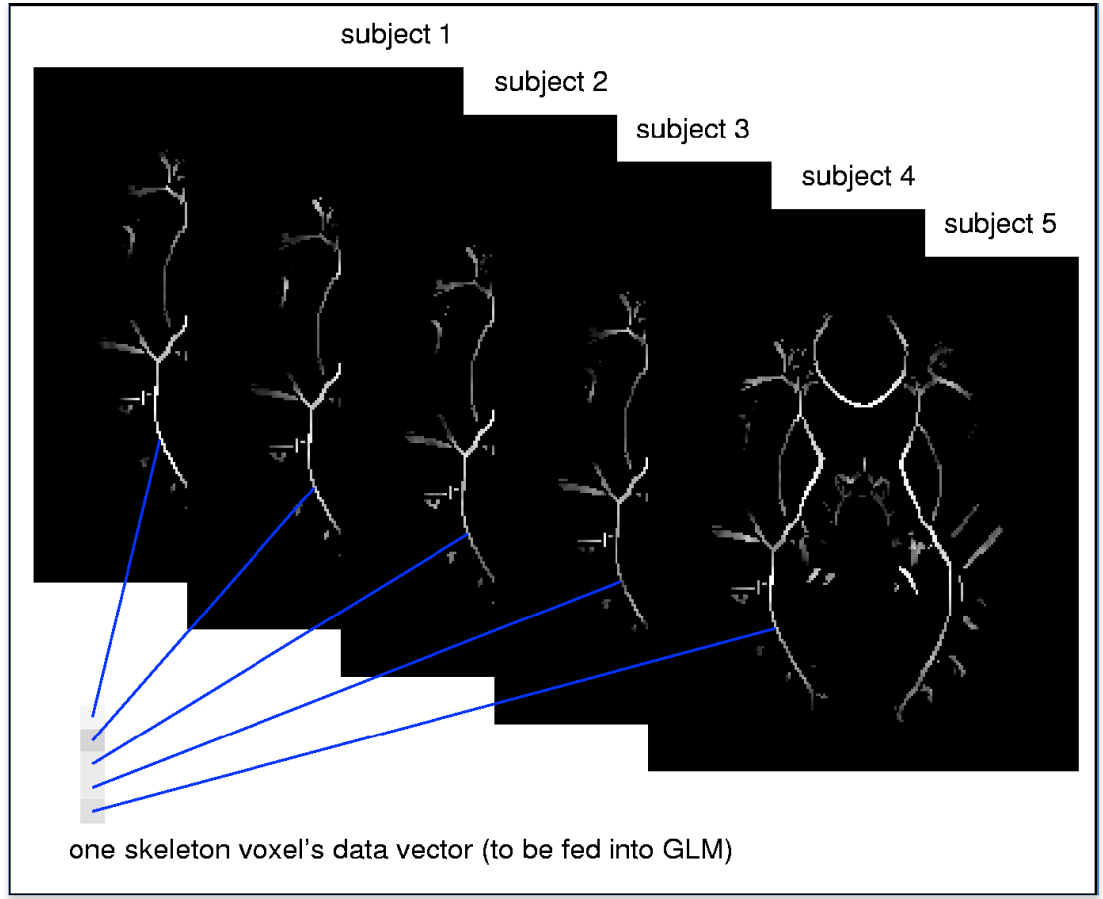


www.fmrib.ox.ac.uk/fsl/tbss/index.html

DIFFUSION MRI

TBSS

Do cross-subject voxelwise stats on skeleton-projected FA Threshold, (e.g., permutation testing, including multiple comparison correction)



www.fmrib.ox.ac.uk/fsl/tbss/index.html

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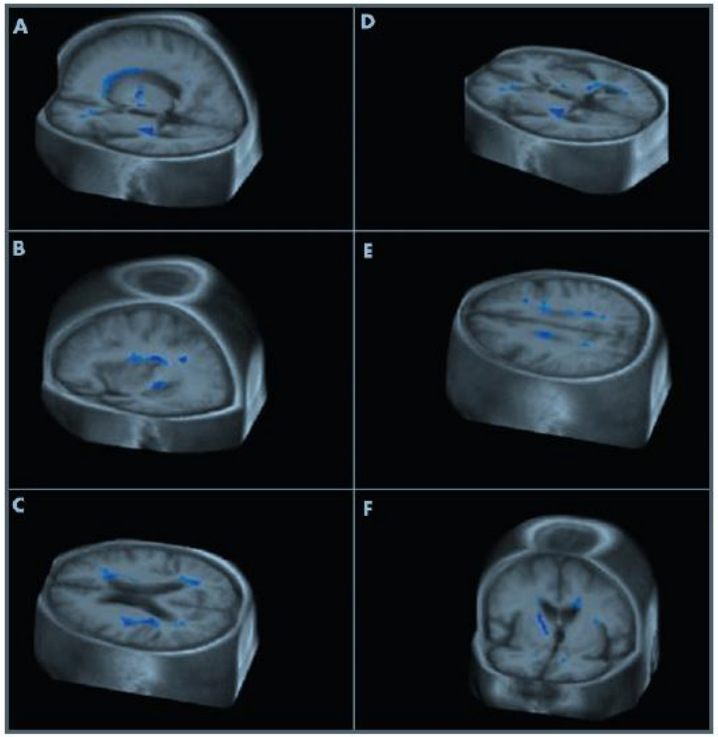
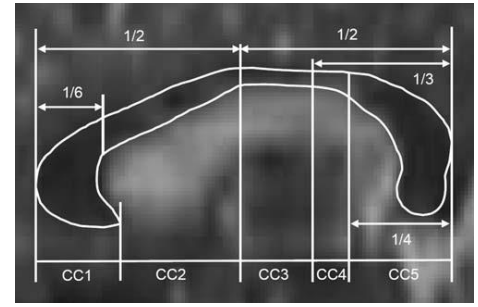
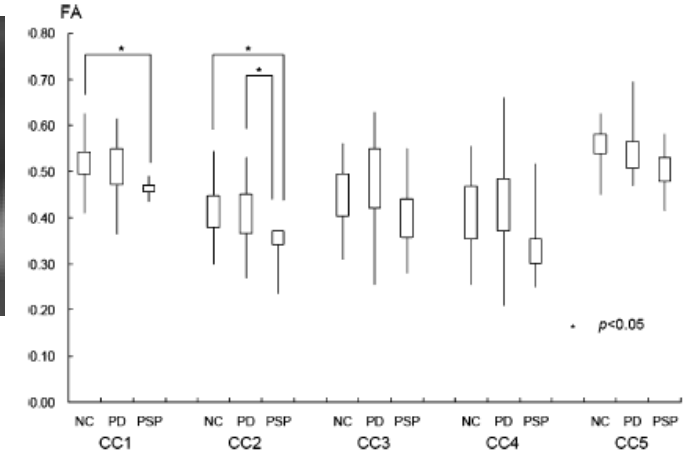
DIFFUSION MRI

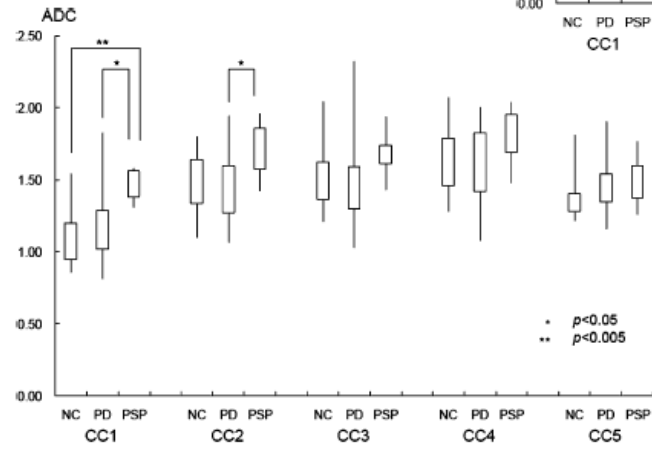
PSP



Padovani et al. JNNP 2006



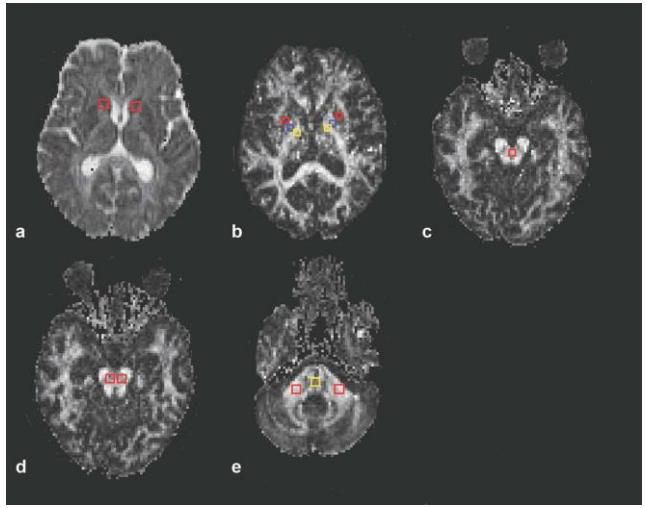


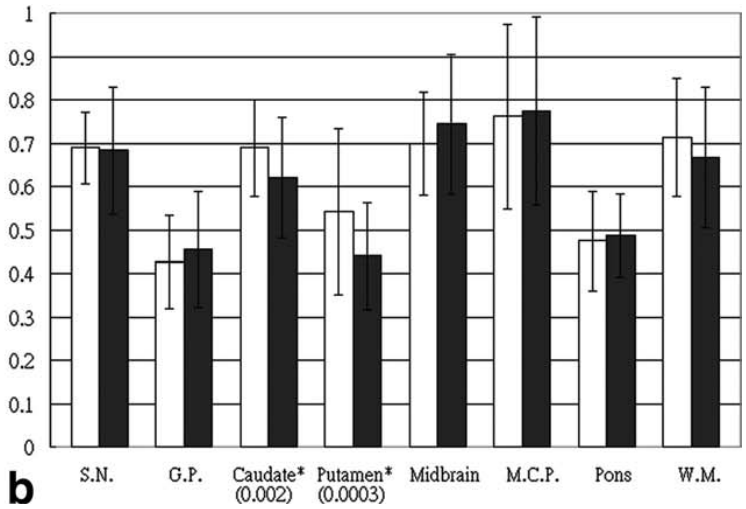


Ito et al. Neuroradiology 2008

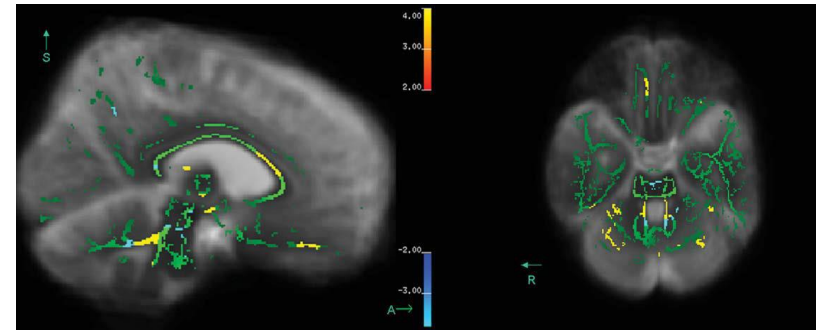
DIFFUSION MRI

PSP





Wang et al. JMRI 2010



Knake et al. Mov dis 2010

Kvickström et al. BMC Neurology 2011

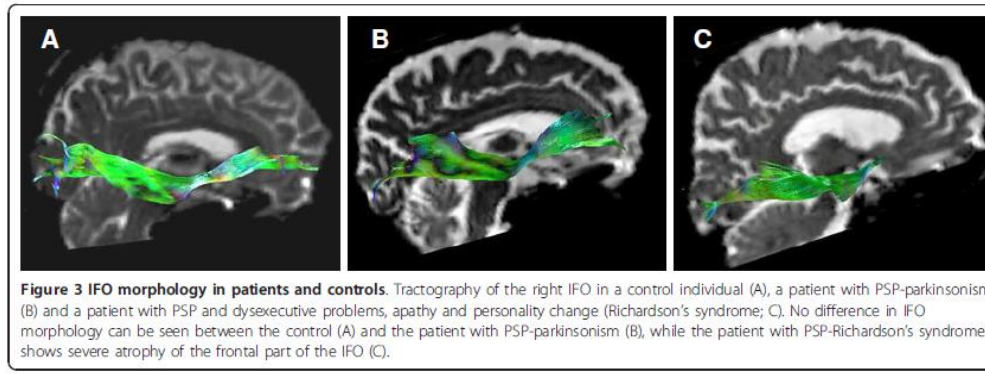


Figure 3 IFO morphology in patients and controls. Tractography of the right IFO in a control individual (A), a patient with PSP-parkinsonism (B) and a patient with PSP and dysexecutive problems, apathy and personality change (Richardson's syndrome; C). No difference in IFO morphology can be seen between the control (A) and the patient with PSP-parkinsonism (B), while the patient with PSP-Richardson's syndrome shows severe atrophy of the frontal part of the IFO (C).

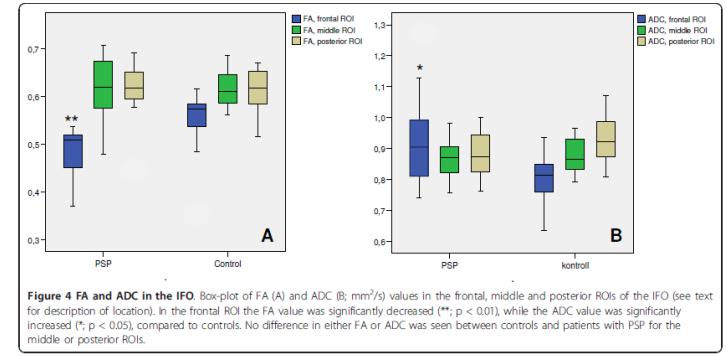
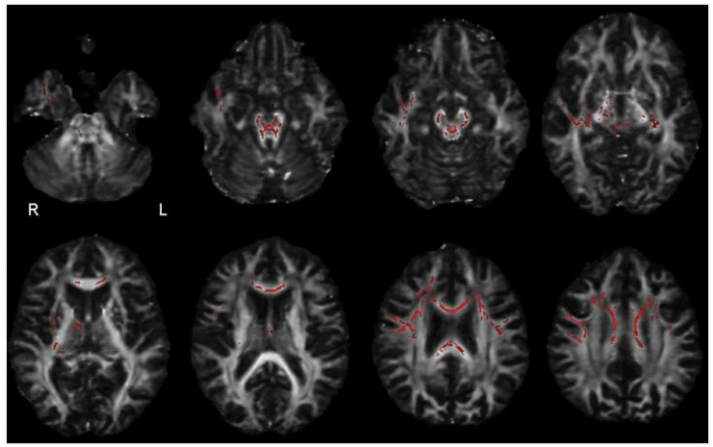
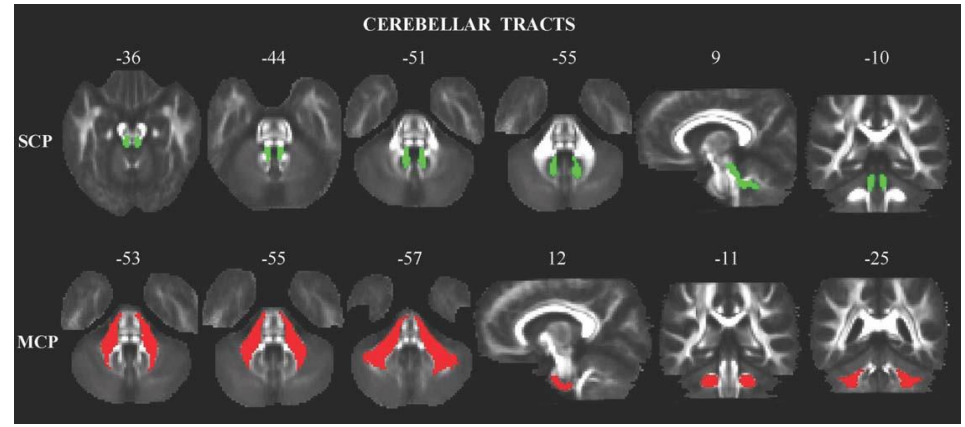


Figure 4 FA and ADC in the IFO. Box-plot of FA (A) and ADC (B; mm^2/s) values in the frontal, middle and posterior ROIs of the IFO (see text for description of location). In the frontal ROI the FA value was significantly decreased (**; $p < 0.01$), while the ADC value was significantly increased (*; $p < 0.05$), compared to controls. No difference in either FA or ADC was seen between controls and patients with PSP for the middle or posterior ROIs.

DIFFUSION MRI

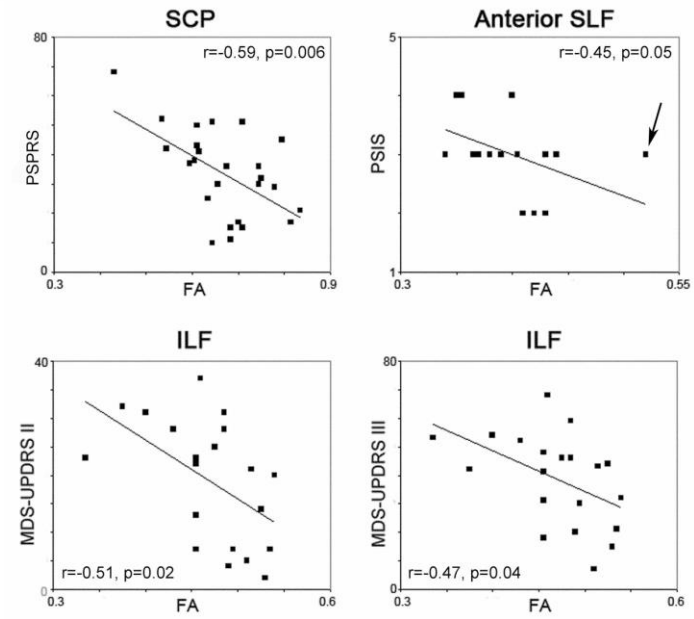
PSP



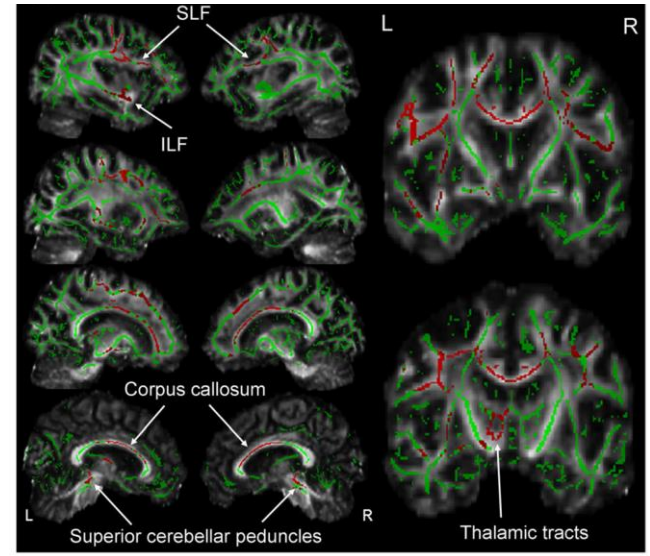


Selective damage of SCP

Canu et al. Mov Dis. 2011



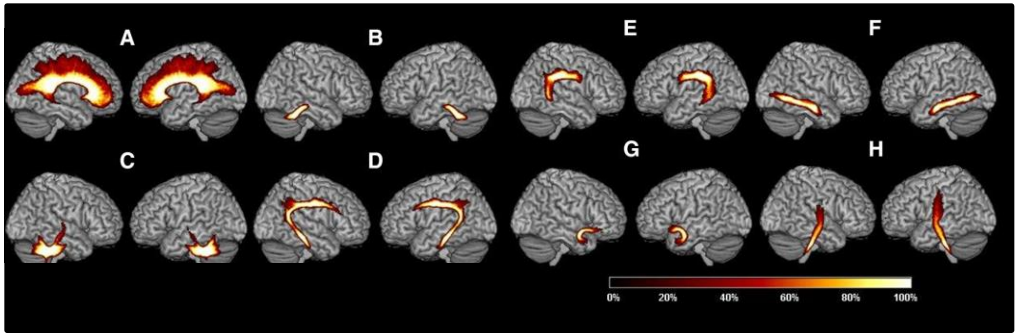
Whitwell et al. Arch Neurol. 2011

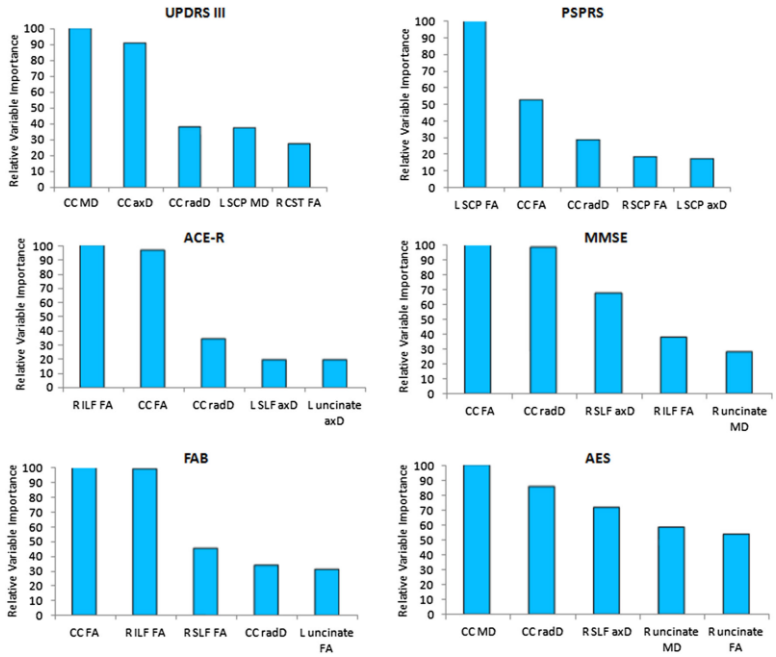


Whitwell et al. Parkinsonism Relat Disord. 2011

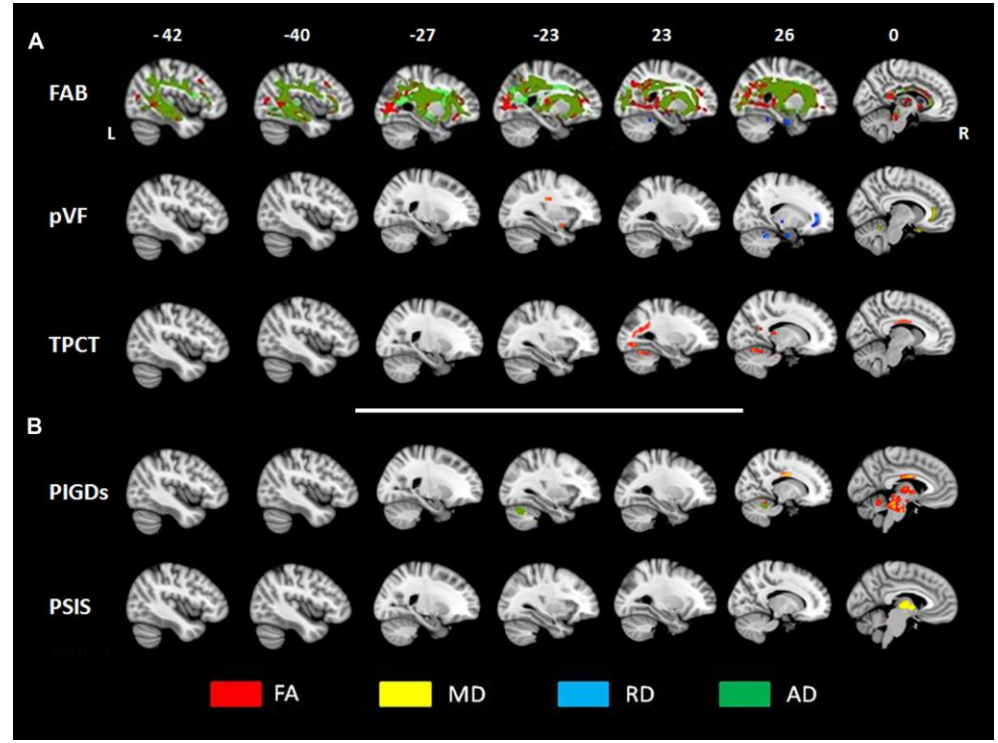
DIFFUSION MRI

PSP/Correlations





Agosta et al. J Neurol. 2014



Tessitore et al Neurobiol Aging. 2014

DIFFUSION MRI

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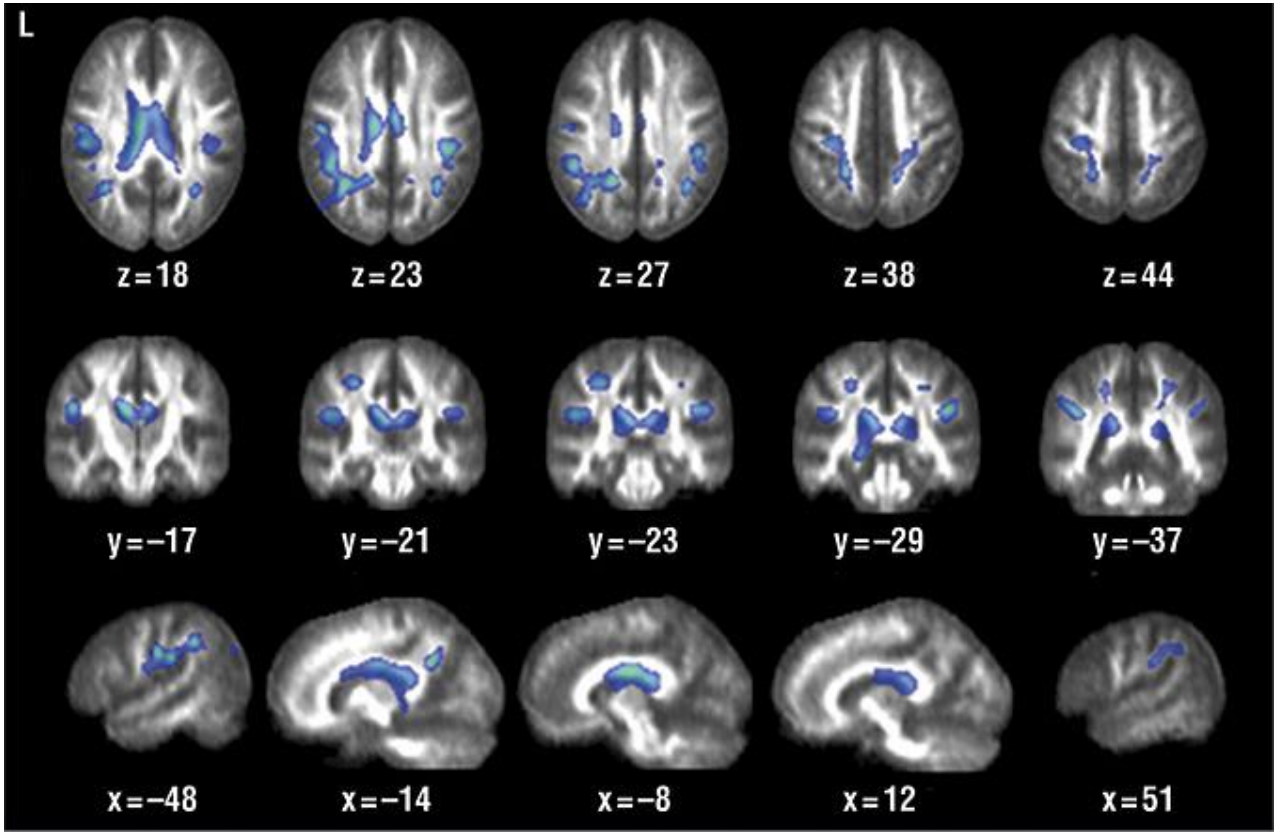
DIFFUSION MRI

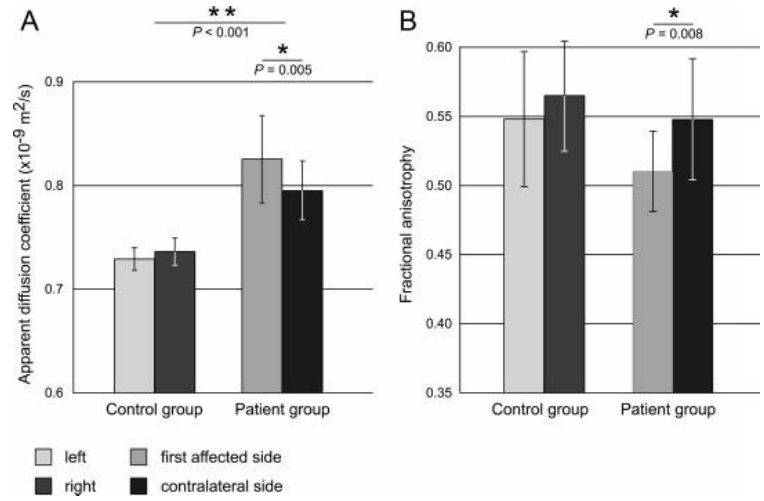
CBS

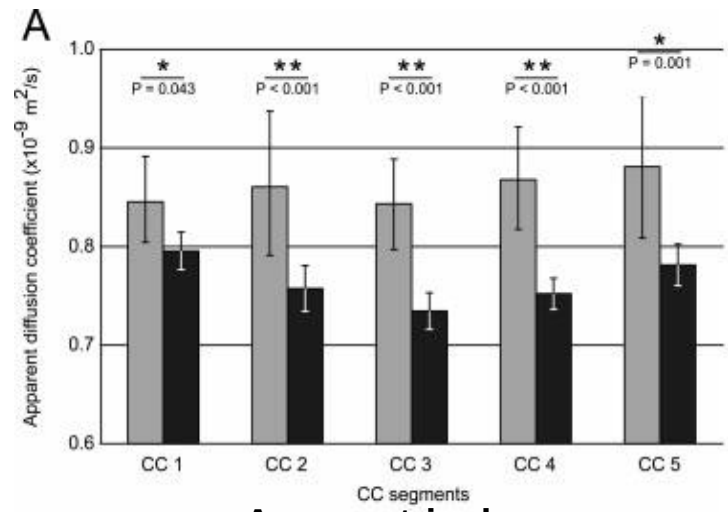
FA: CBS patients *vs.* controls



Corpus callosum, fronto-parietal connections

Borroni et al., Arch Neurol. 2008





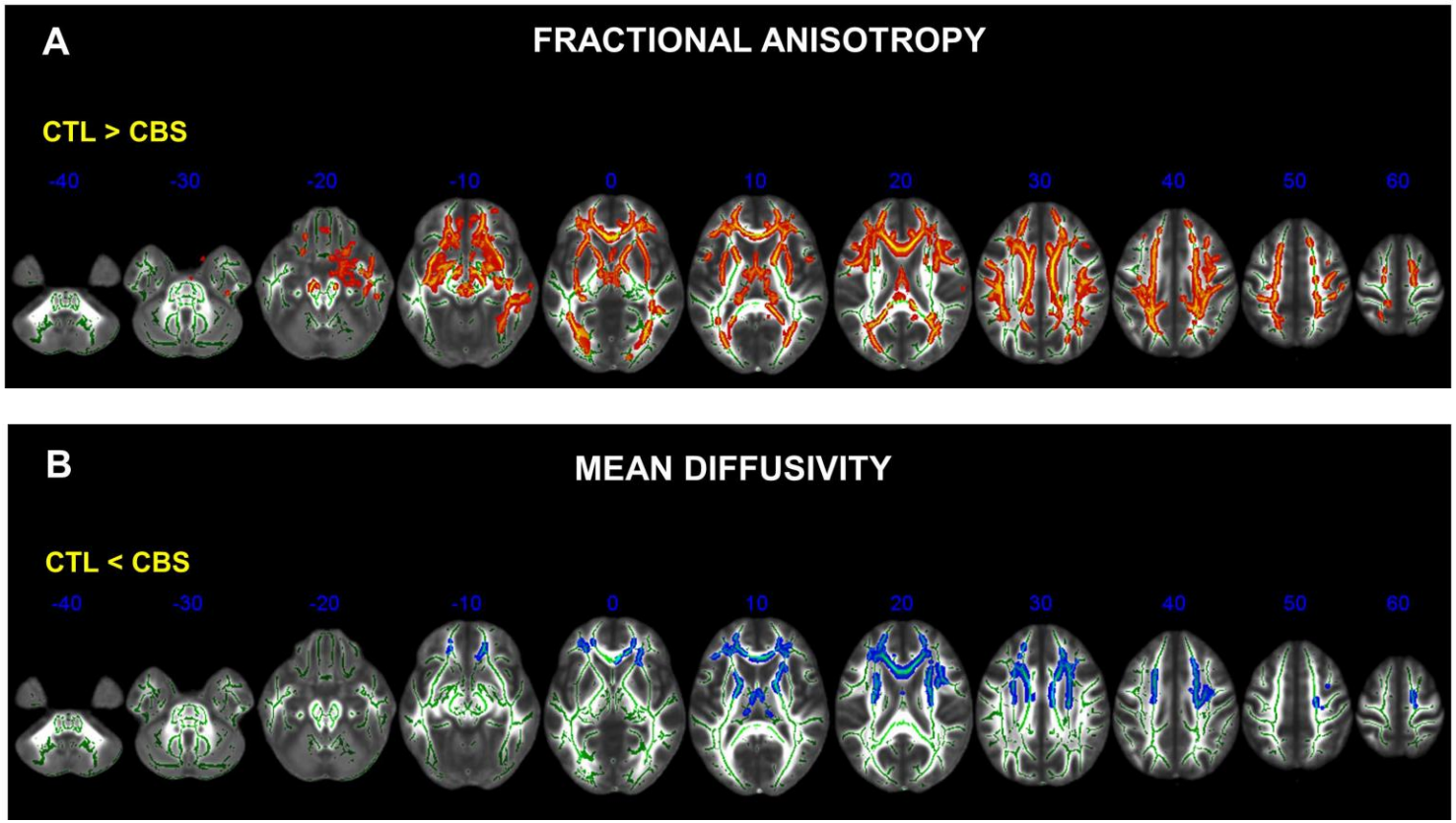
Asymmetric damage

Boelmans et al. Mov Dis. 2009

DIFFUSION MRI

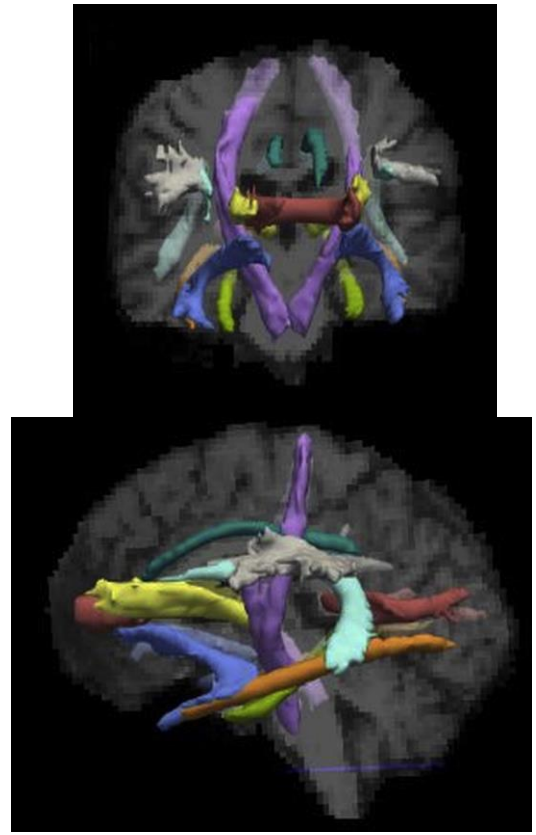
CBS

DTI metrics changes in CBS



Tovar-Moll et al. Plos One. 2014

Most tracts are altered in CBS

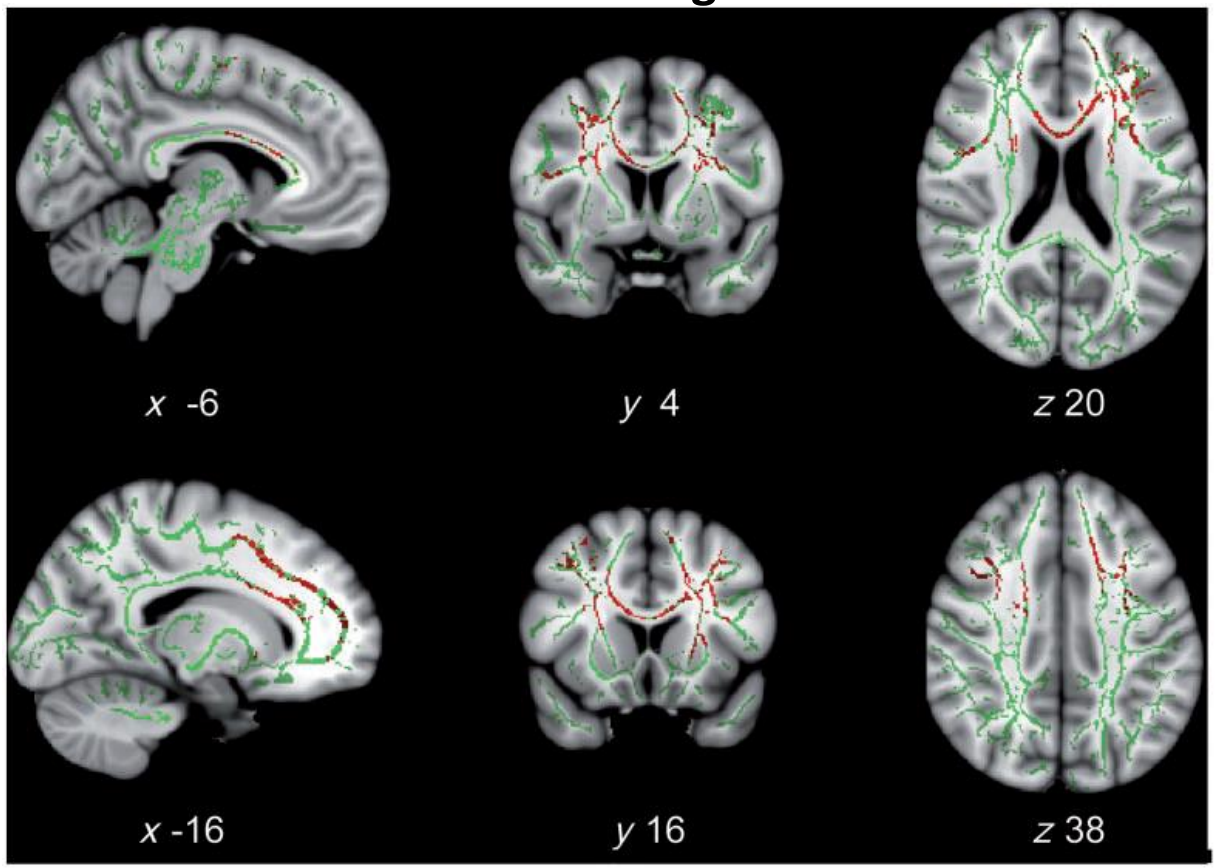


Upadhyay et al. Neurobiol Aging. 2016

DIFFUSION MRI

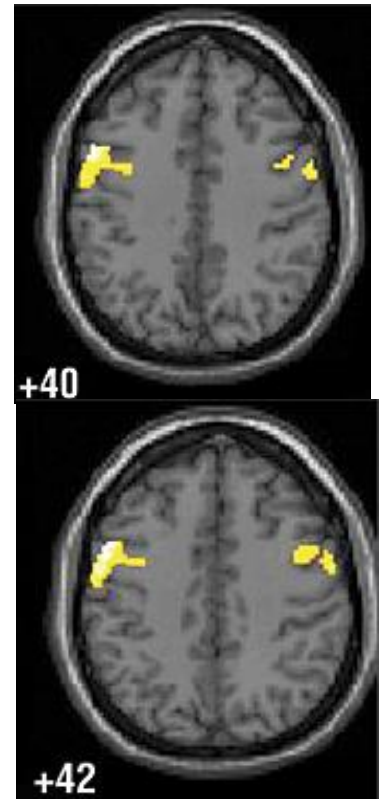
CBS/Correlations

MD correlates to action binding in CBS



Wolpe et al., Brain. 2014

Sensorimotor WM FA decrease *vs.* limb apraxia



Borroni et al., Arch Neurol. 2008

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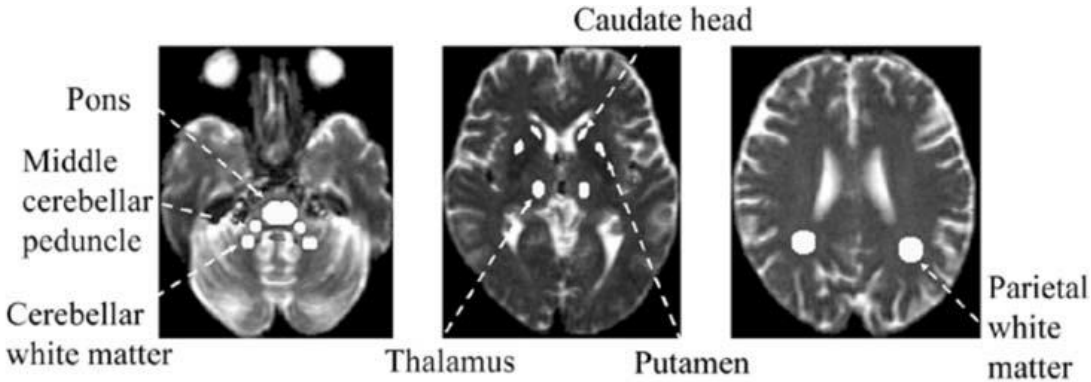
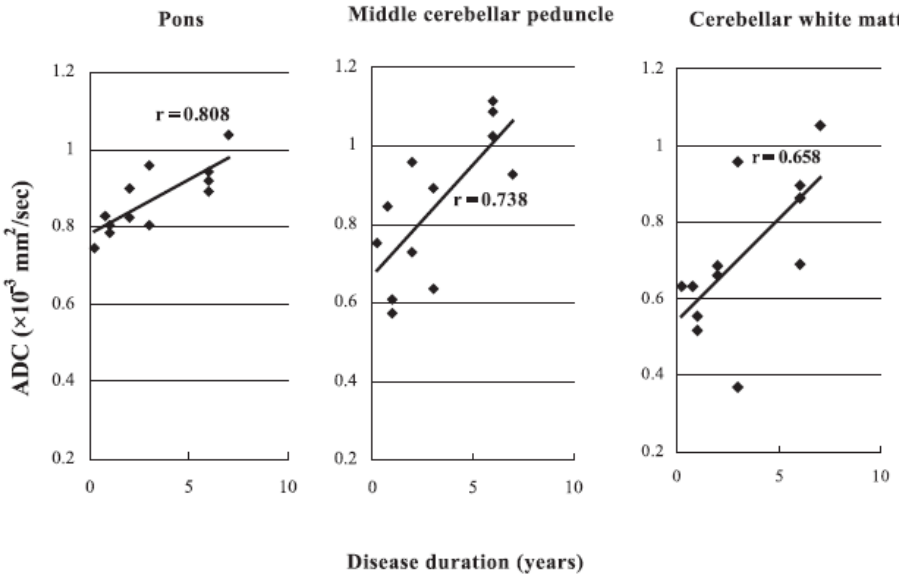
DIFFUSION MRI

MSA

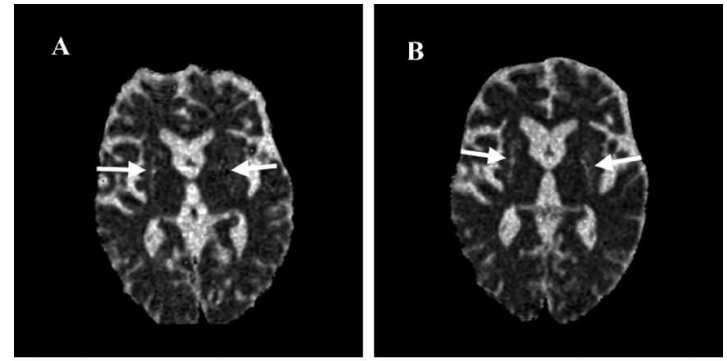
Altered ADC in the pons and MCP of MSA-C patients



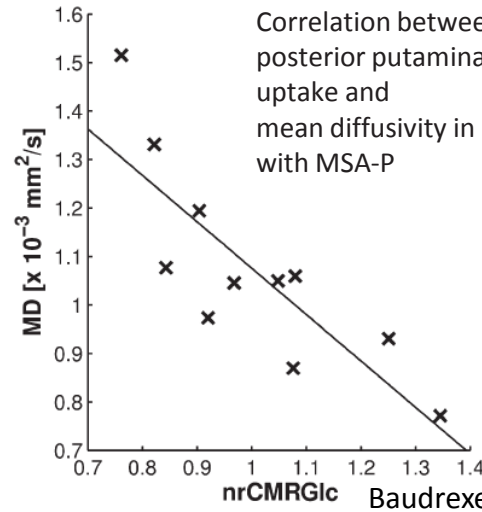


Kanazawa et al. J Neurol. 2004

Putaminal degeneration in MSA-P



Seppi et al. Neuroimage 2006



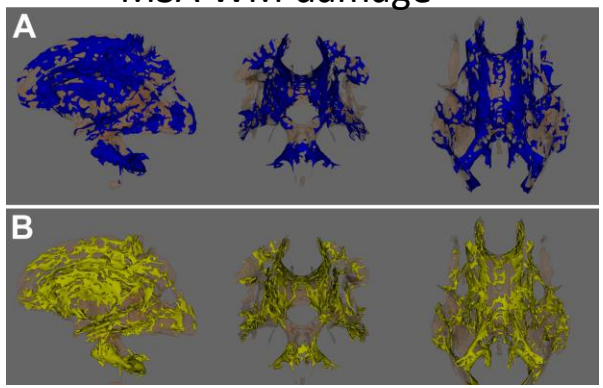
Correlation between posterior putaminal FDG-uptake and mean diffusivity in patients with MSA-P

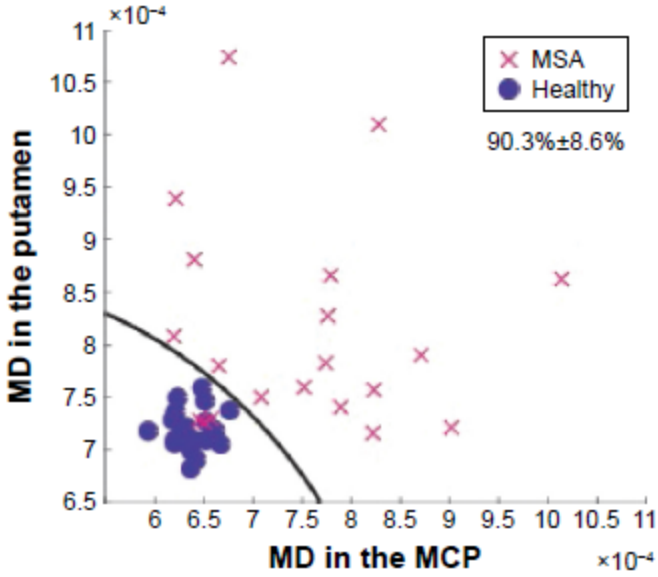
Baudrexel et al. Mov Dis. 2014

DIFFUSION MRI

MSA

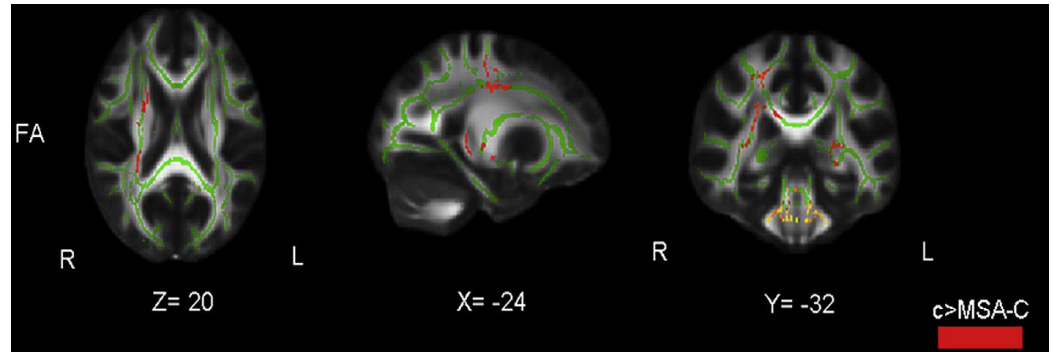
MSA WM damage



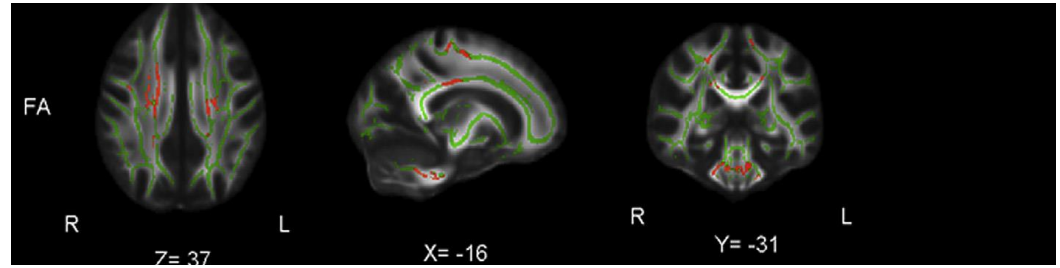


Rulseh et al. Neuropsychiatr Dis Treat. 2016

MSA-C vs HC



MSA-P vs HC



Ji et al. Parkinsonism Relat Disord. 2014

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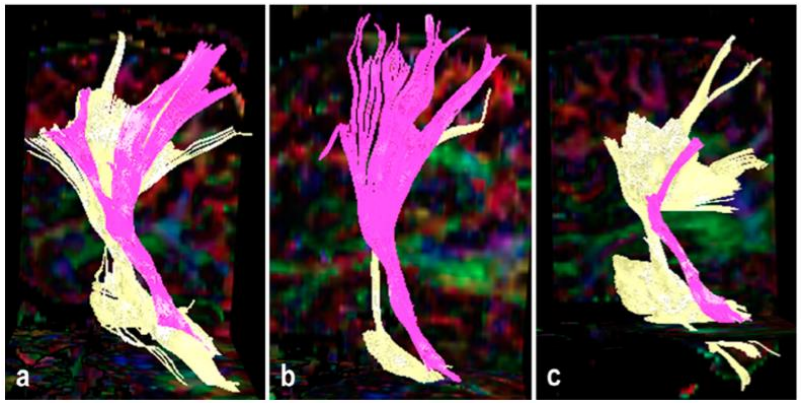
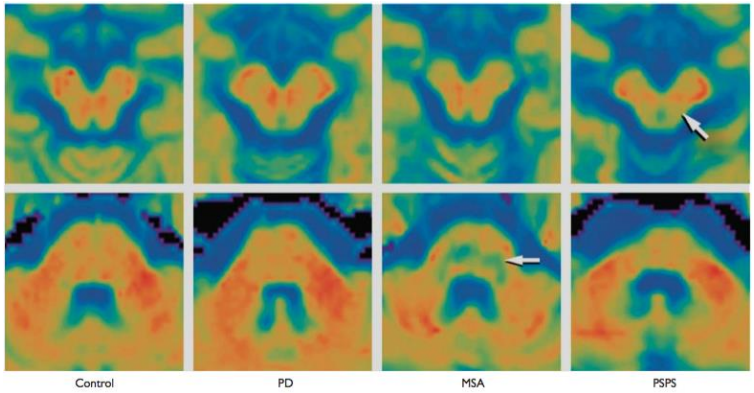
Differential diagnosis

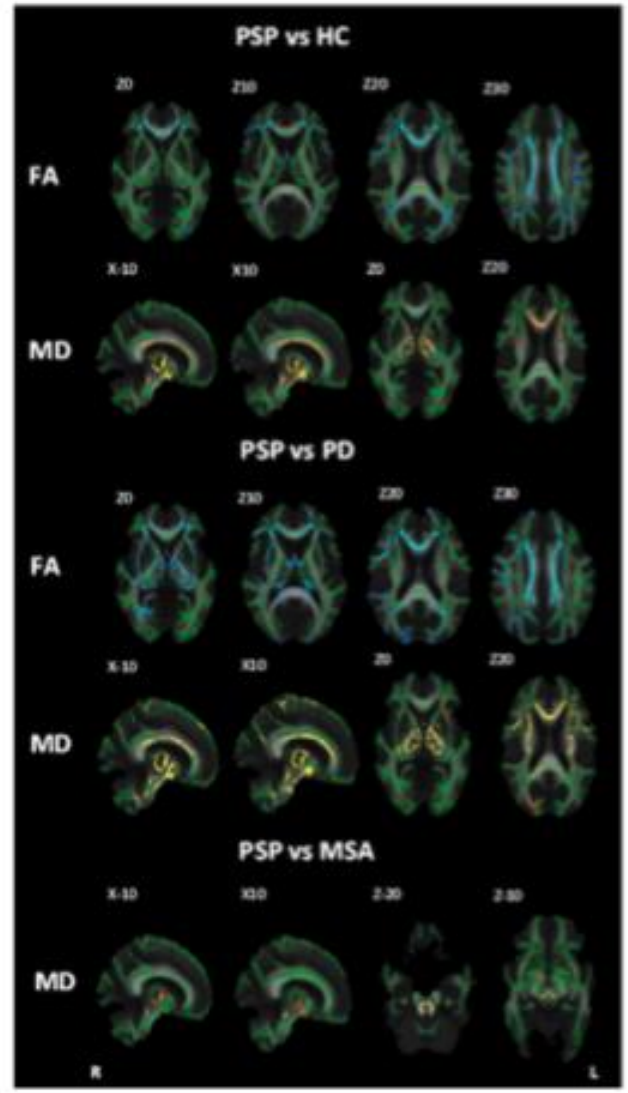
PD MSA PSP



Nilsson et al. Neuroradiology. 2007



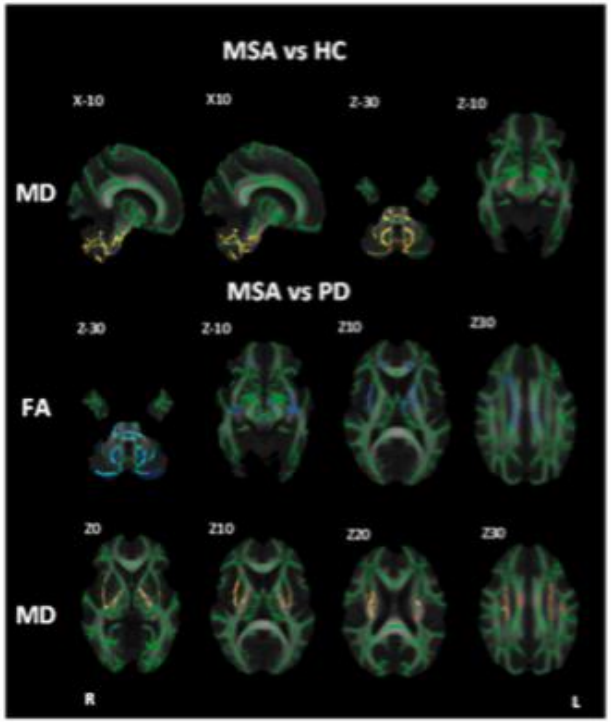
Ito et al. Neuroreport. 2015



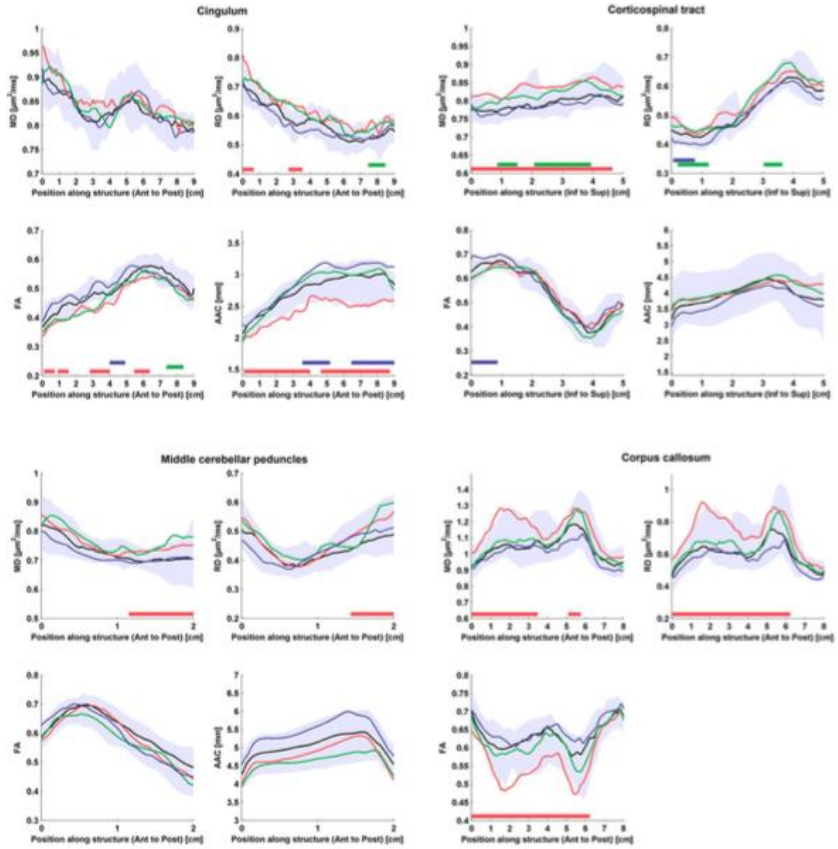
Worker et al. Plos one. 2014

DIFFUSION MRI

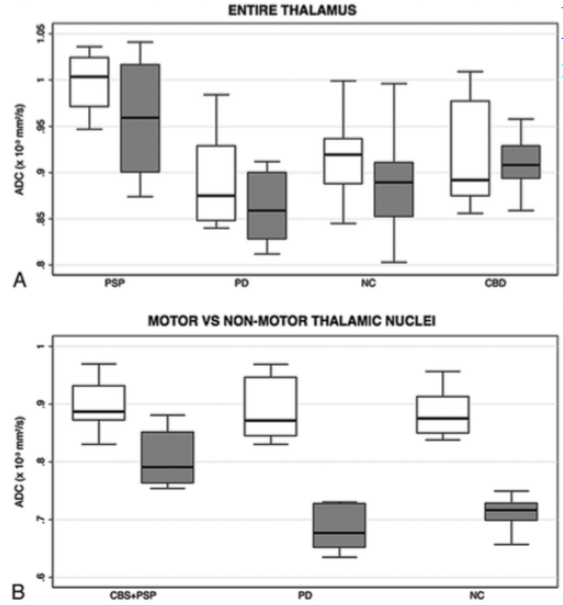
Differential diagnosis



Worker et al. Plos one. 2014



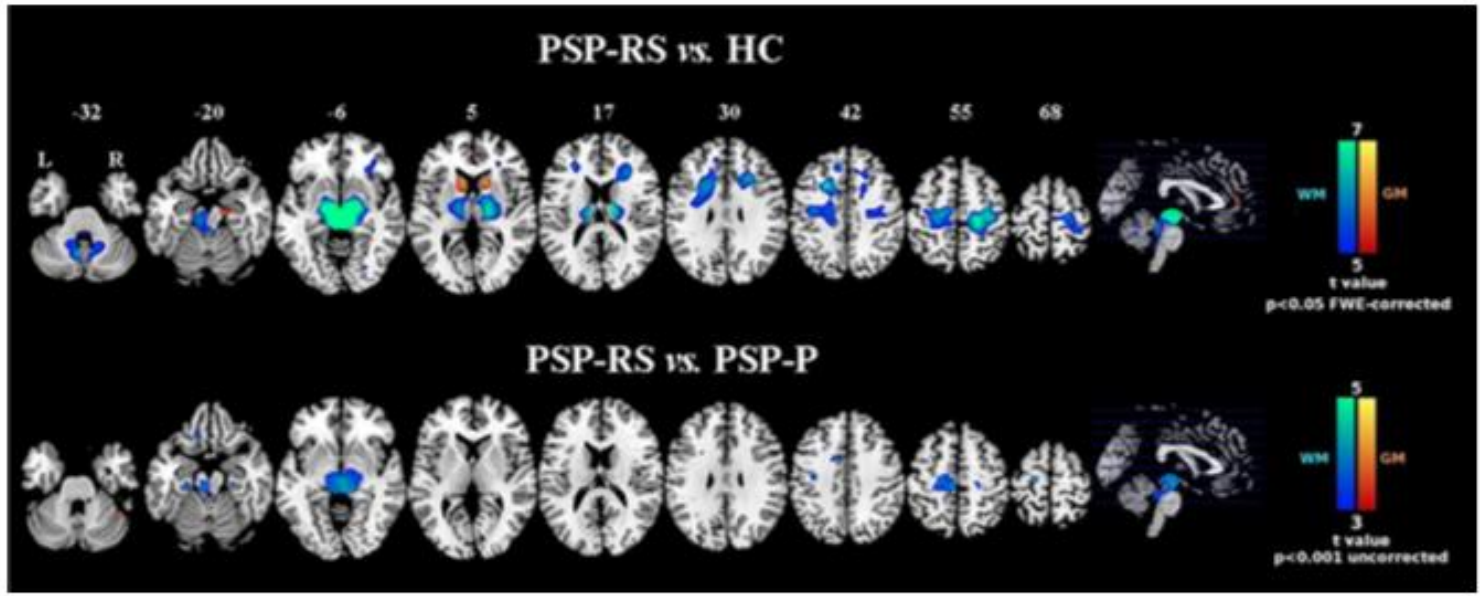
Surova et al. Plos one. 2013



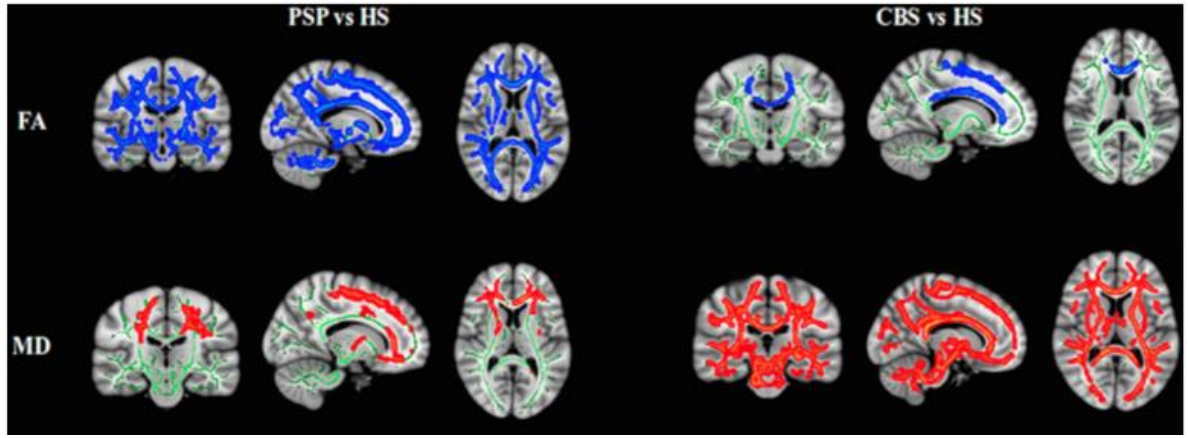
Hess et al. Brain. 2014

DIFFUSION MRI

Differential diagnosis



Agosta et al. Neurobiol Aging. 2012

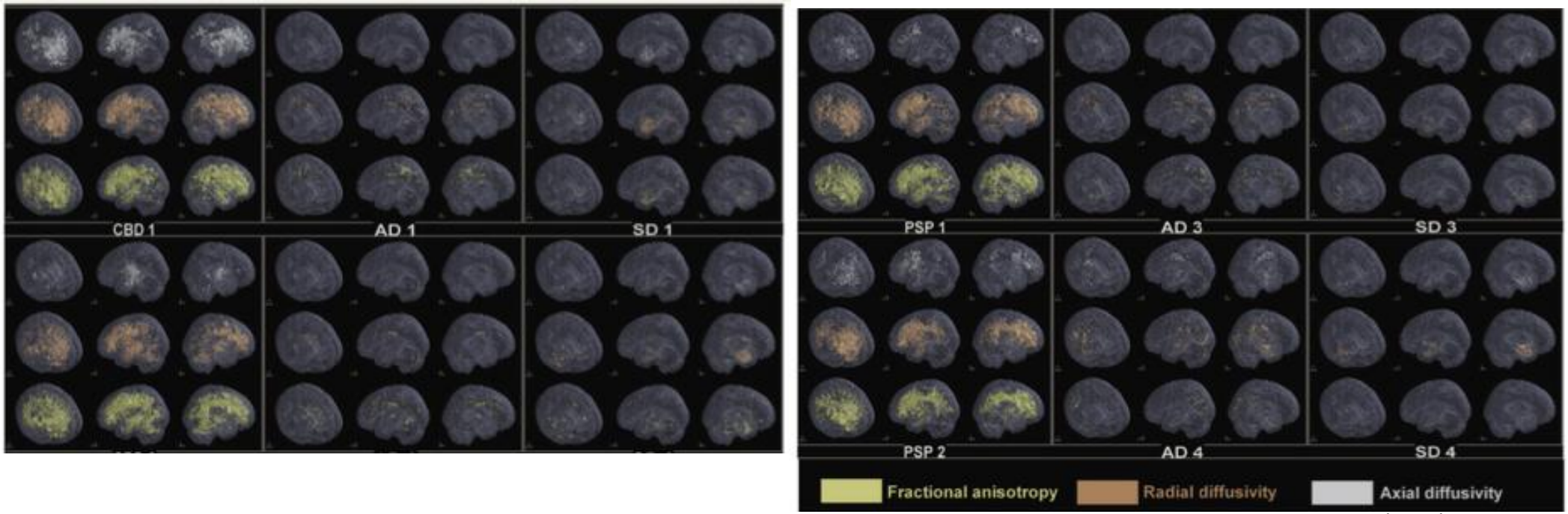


Upadhyay et al. J Neurol. 2016

DIFFUSION MRI

Differential diagnosis/Single subject

Single subject diagnosis of PSP or CBD

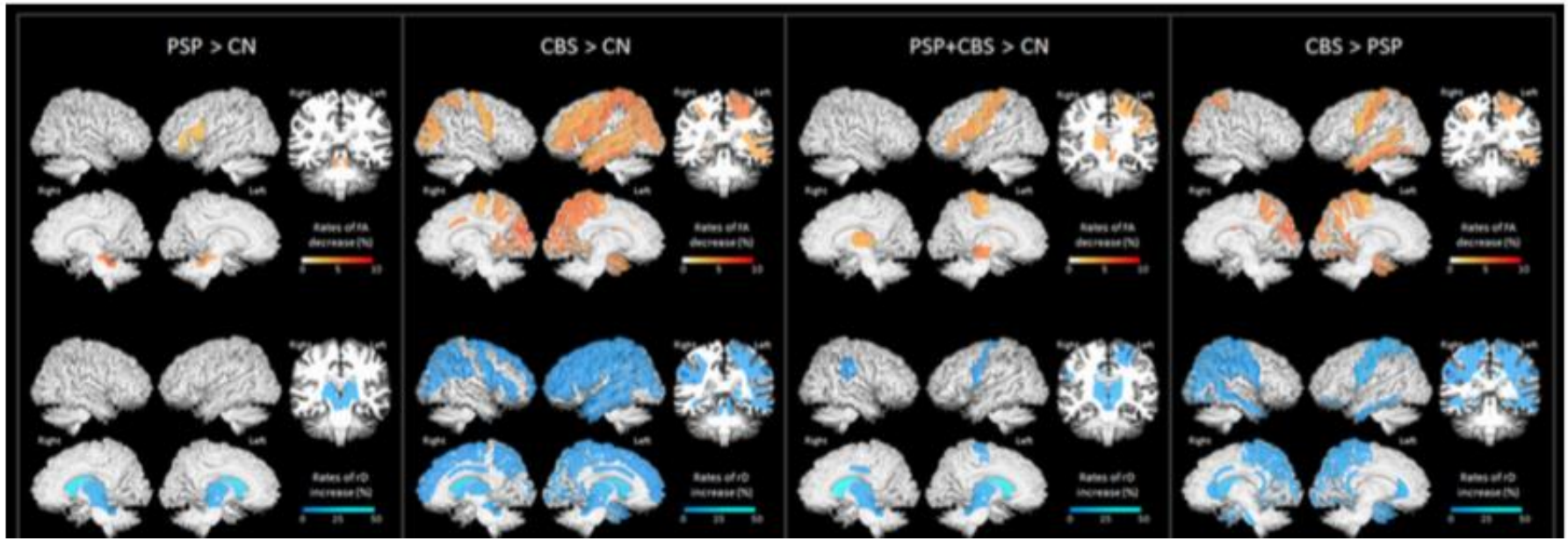


Sajjadi et al. Brain. 2013

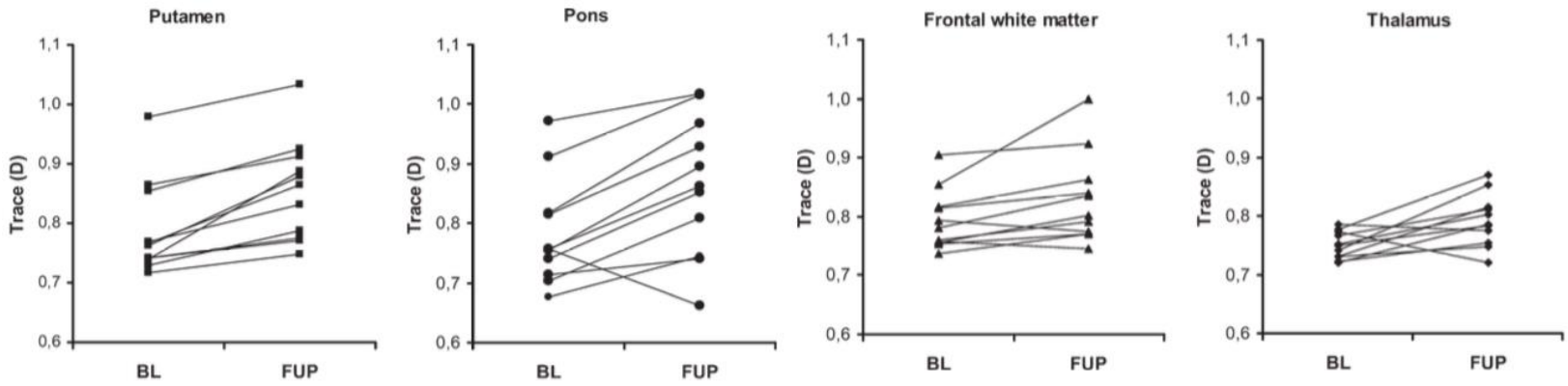
DIFFUSION MRI

Monitoring disease progression

Zhang et al. Plos one. 2016



Pellecchia et al. Mov Dis. 2011



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