



Thalamic parcellation for target identification in trans-cranial MR-guided focused ultrasound (tcMRgFUS) thalamotomies: A preliminary probabilistic tractography study

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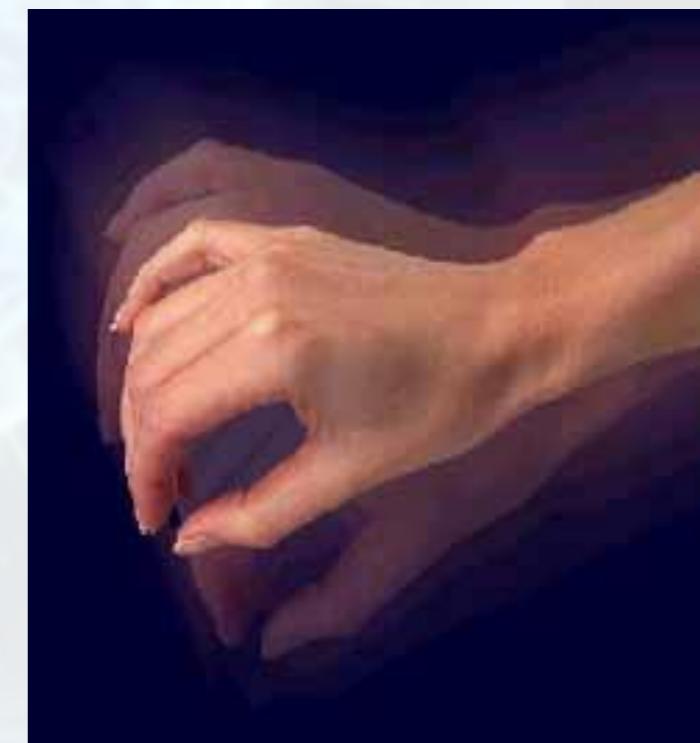
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What is Essential Tremor (ET)?

- Most common adult-onset movement disorder
- 5% general population
- Genetics: variable penetrance, no gene found (polygenic)
- Central generator: thought to represent cerebellar-thalamo-cortical outflow pathology
- Kinetic and postural, mainly arms; 4-12Hz
- Progressive
 - Arms head (“yes-yes” vs. “no-no”)
 - Voice / vocal cord, chin, tongue
 - Unilateral bilateral





Disability due to Essential Tremor

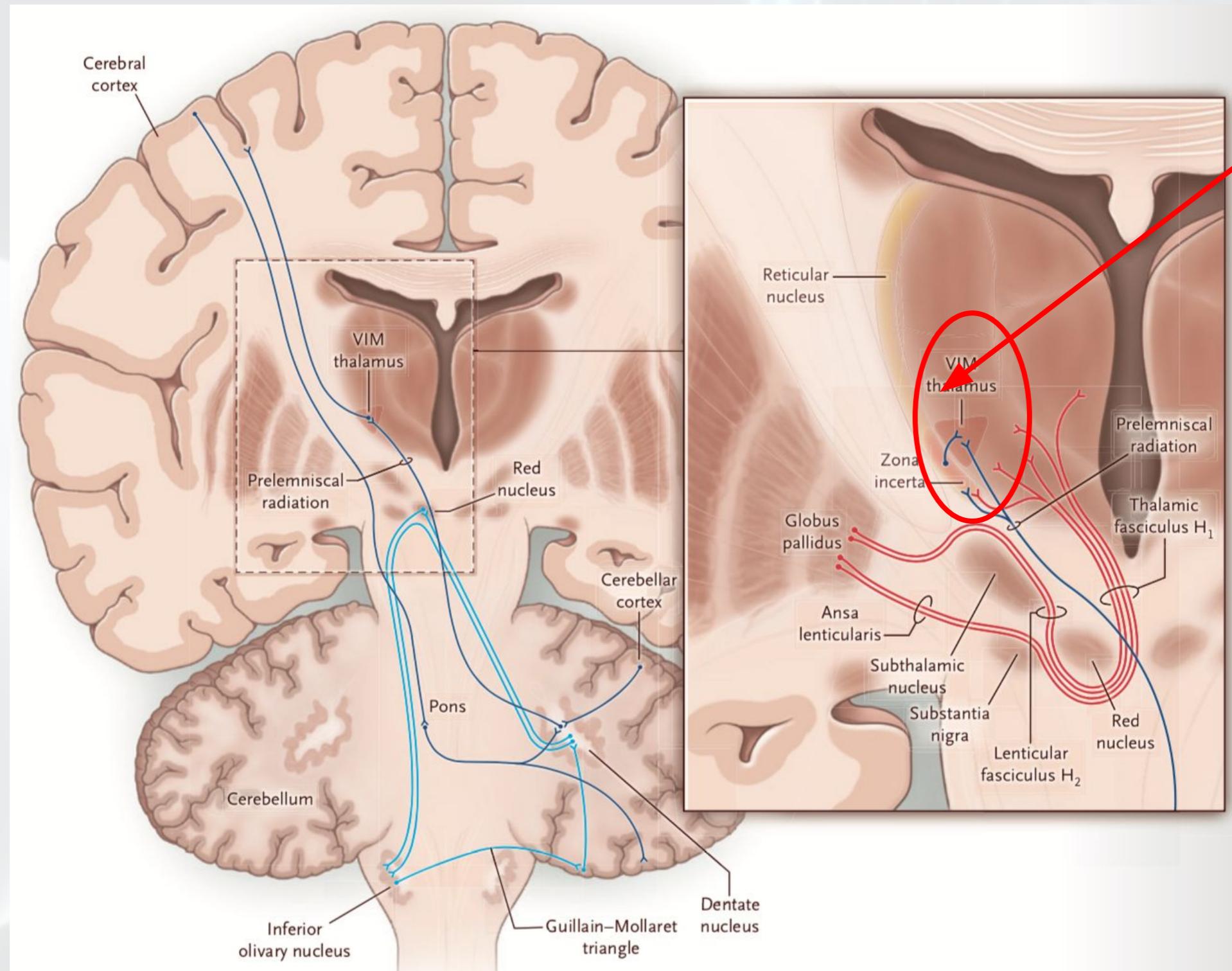
- **Interferes with activities of daily living (ADL)**
 - Feeding
 - Spoon, drinking from a cup
 - Writing
 - Typing
 - Personal hygiene

TREATMENT

- **Pharmacologic**
 - Mainly for not heavy tremors
- **Surgery**
 - Stereotactic Radiation Surgery (SRS)
 - Radiofrequency ablation (RFA)
 - Deep Brain Stimulation (DBS)
 - Magnetic Resonance guided Focused Ultrasounds Surgery (MRgFUS)



Cerebellar-thalamo-cortical tract



Ventral
InterMediate
(VIM)
nucleus:
target to be
ablated!



Trans-cranial Magnetic Resonance guided Focused Ultrasounds (tcMRgFUS)

- **Use of ultrasounds suitably focused on the thalamus**
- **Thermal Ablation of the target**
- **No surgery needed**
- **Guided by MRI**



Courtesy of Insightec, Israel

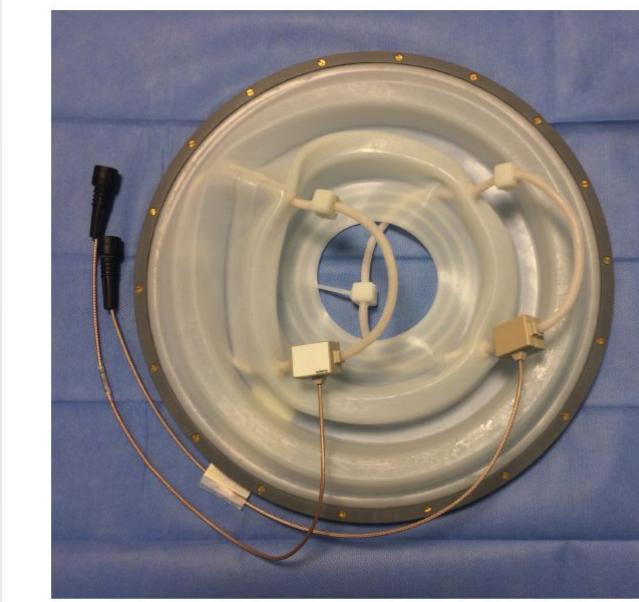
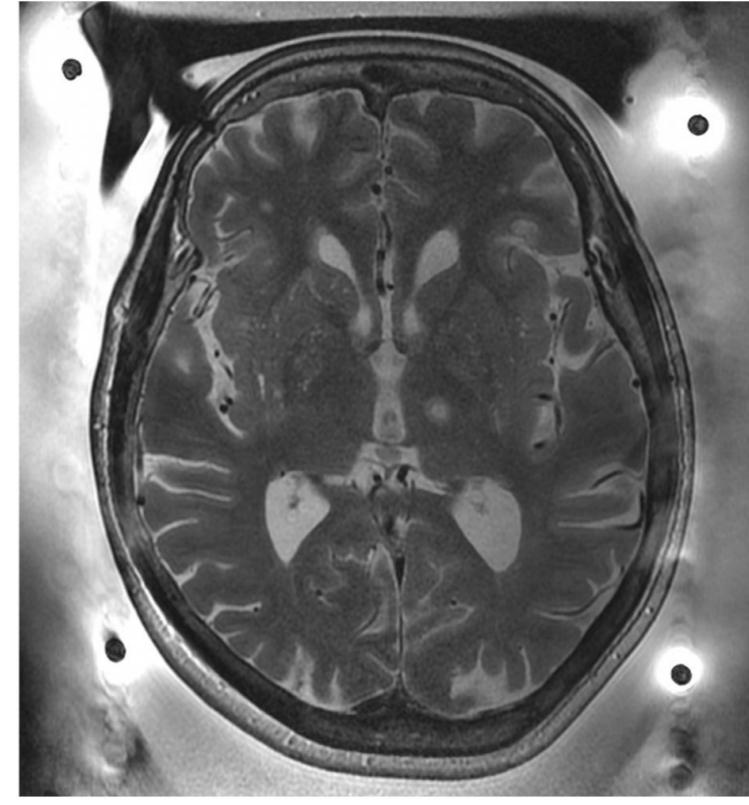
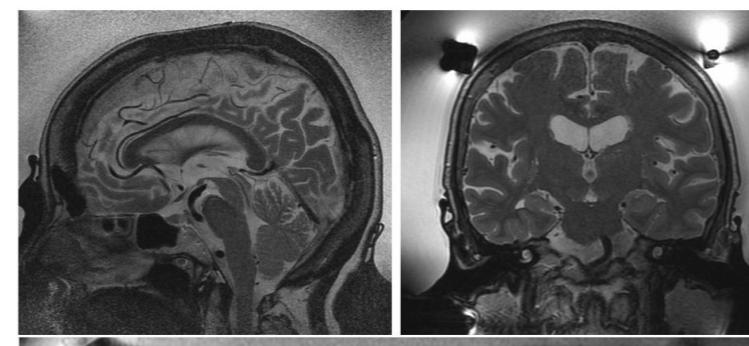


Trans-cranial Magnetic Resonance guided Focused Ultrasounds (tcMRgFUS) at University Hospital Palermo



First Italian site for neurological surgery through tcMRgFUS

World First site for neurological surgery through tcMRgFUS at 1.5T





Trans-cranial Magnetic Resonance guided Focused Ultrasounds (tcMRgFUS)

As above stated there are many advantages!

...but there is also an disadvantage:

Since the treatment is based on the patient's feedback by varying the focus point the procedure could last 3 or more hours!



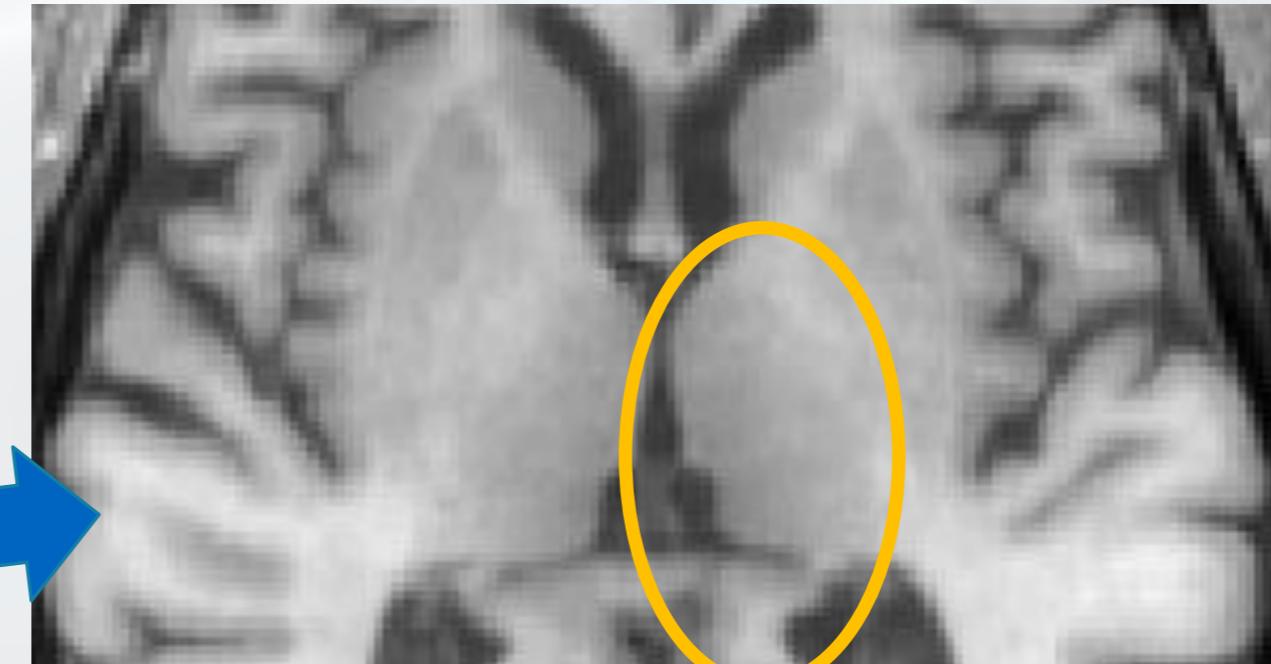
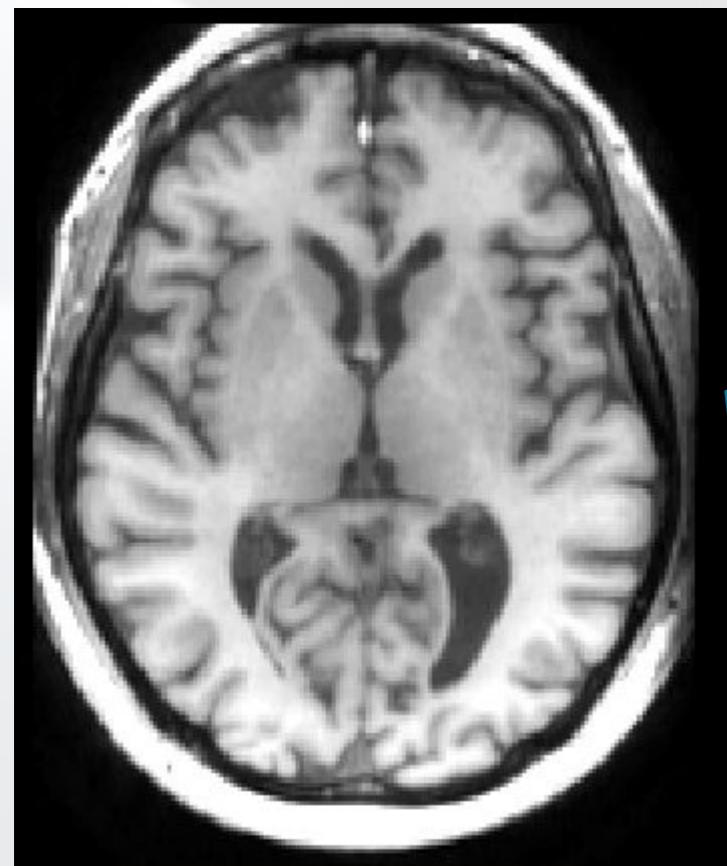


Target of this work

The aim of this work is to retrospectively evaluate the possible role of thalamic parcellation for the identification of the ventral intermediate nucleus (VIM) in patients undergoing tcMRgFUS.



The VIM nucleus is not easily visible with conventional MR imaging



THALAMUS

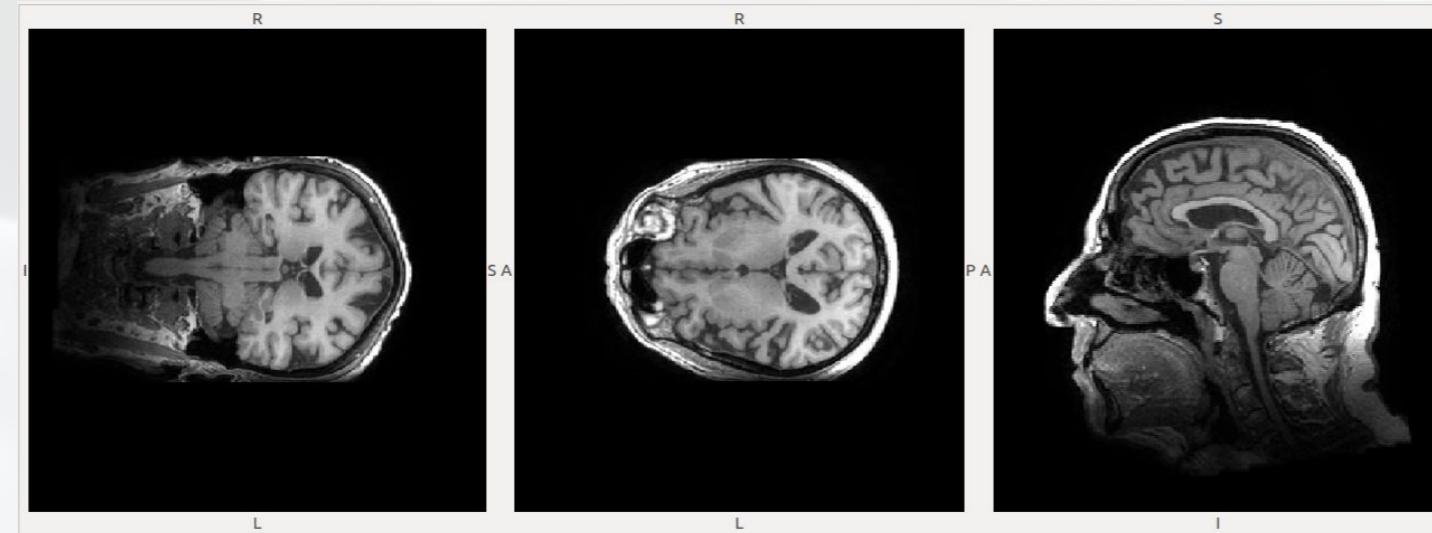


FLOW CHART OF ANALYSIS PERFORMED

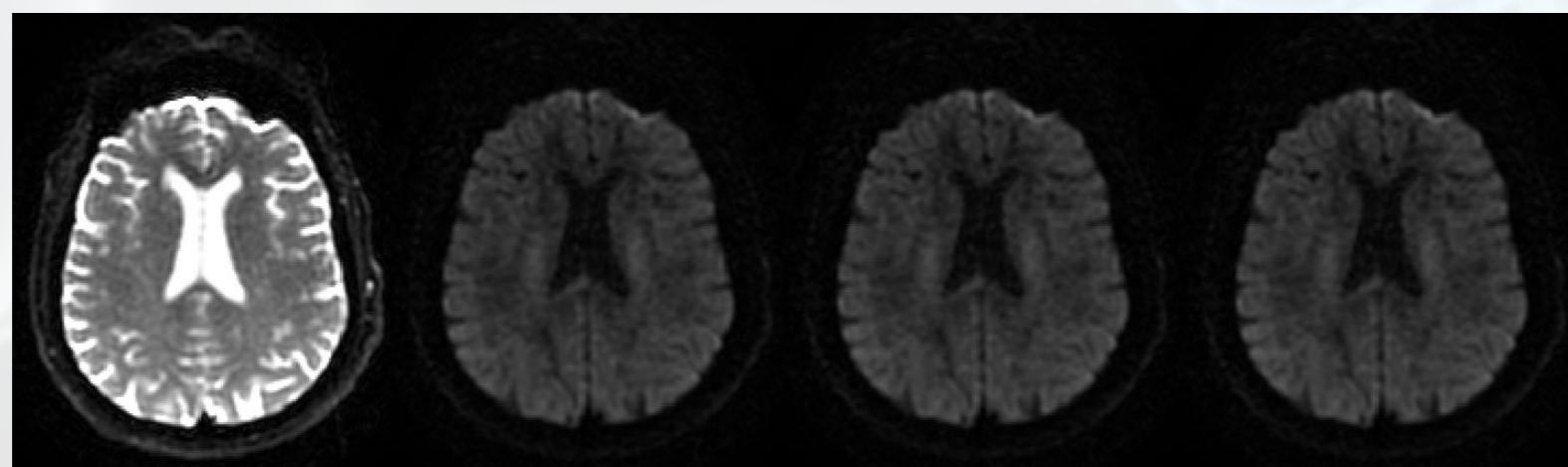
- **SEGMENTATION OF THE CEREBRAL CORTEX**
- **PROBABILISTIC TRACTOGRAPHY**
- **THALAMIC PARCELLATION**
- **COMPARISON *A POSTERIORI* BETWEEN LESION AND PARCELLATION**

SCREENING

- T_1 weighted MR images



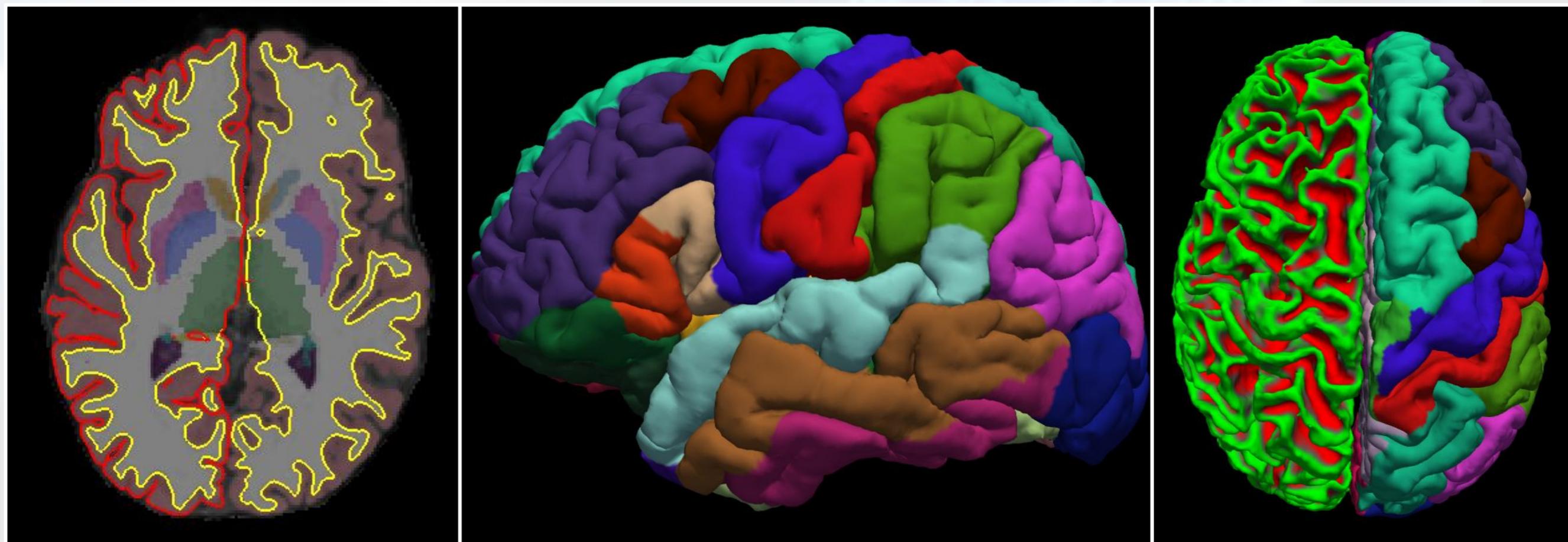
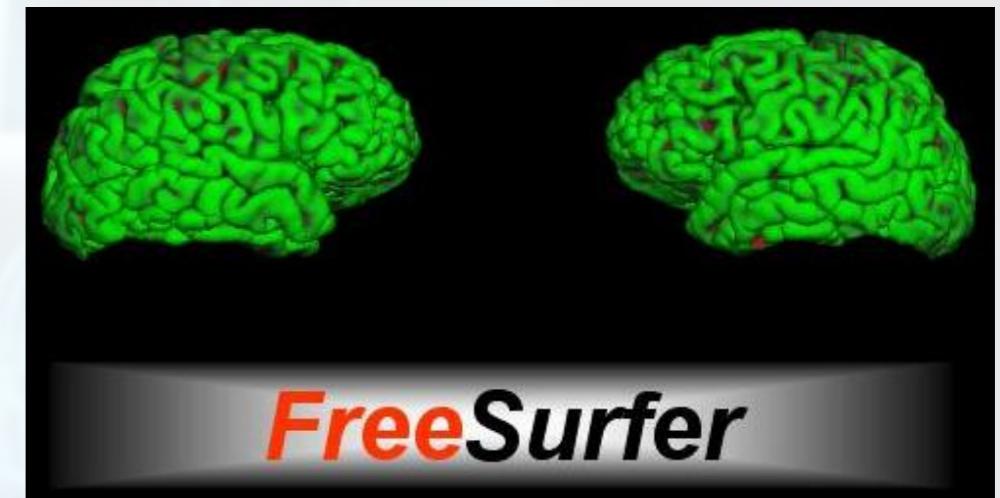
- Diffusion weighted MR images





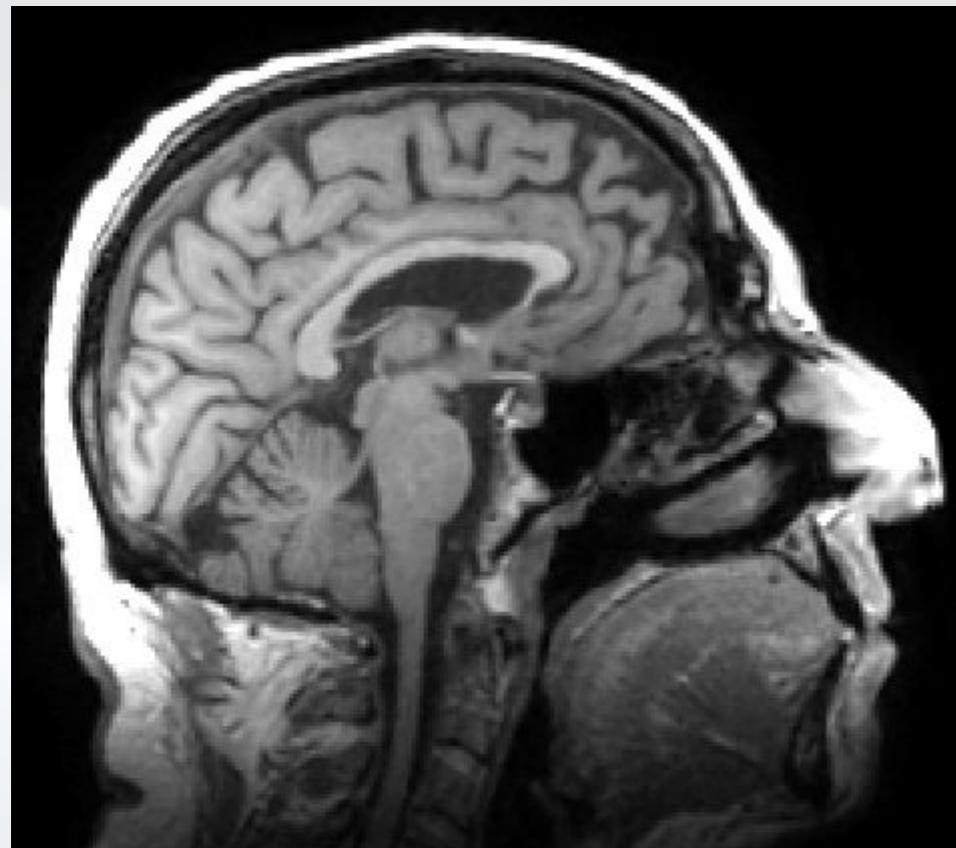
Segmentation

The T₁w FSPGR 3D datasets (1x1x1mm³) were used. The FreeSurfer 6.0 workflow was used to segment both the cortical and deep gray matter.



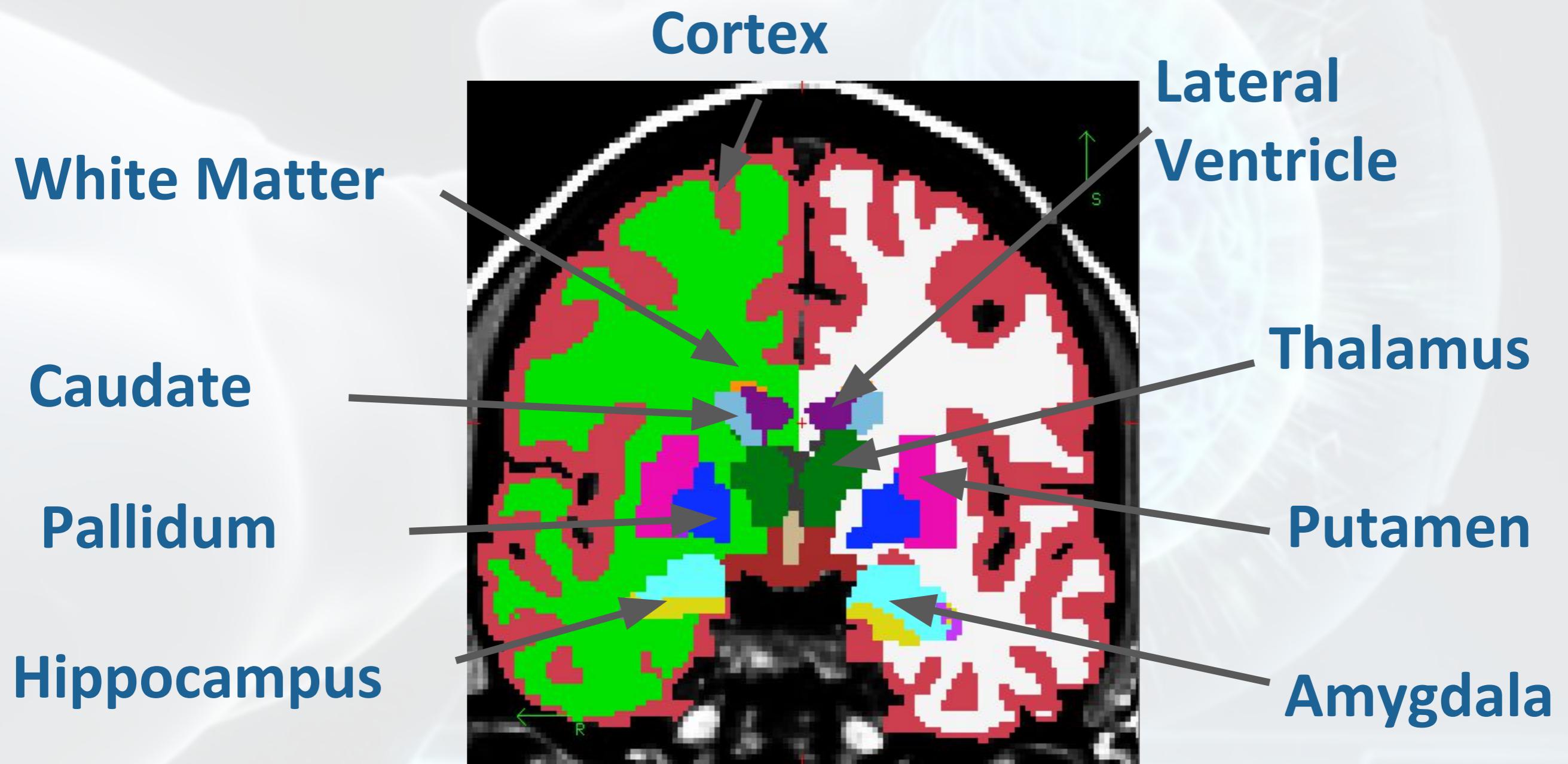


SEGMENTATION



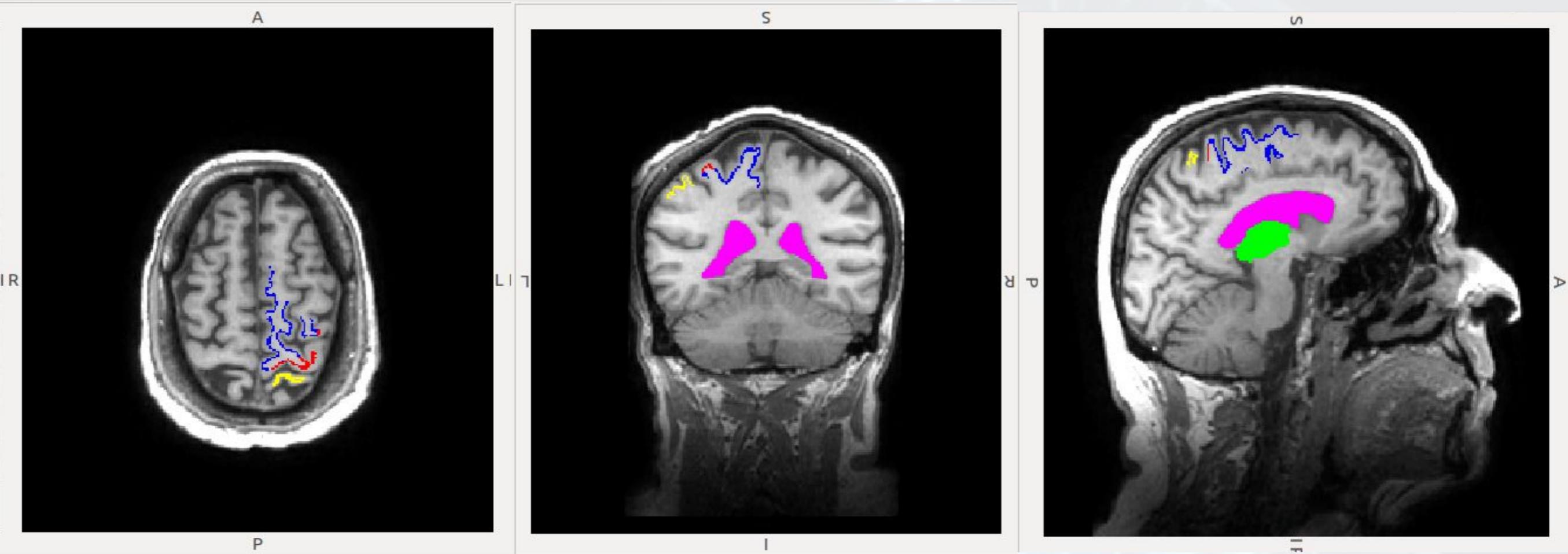


Subcortical Segmentation





SEGMENTATION



- VENTRICLES
- RIGHT THALAMUS
- BRODMAN AREA 6
- PRECENTRAL GYRUS
- POSTCENTRAL GYRUS

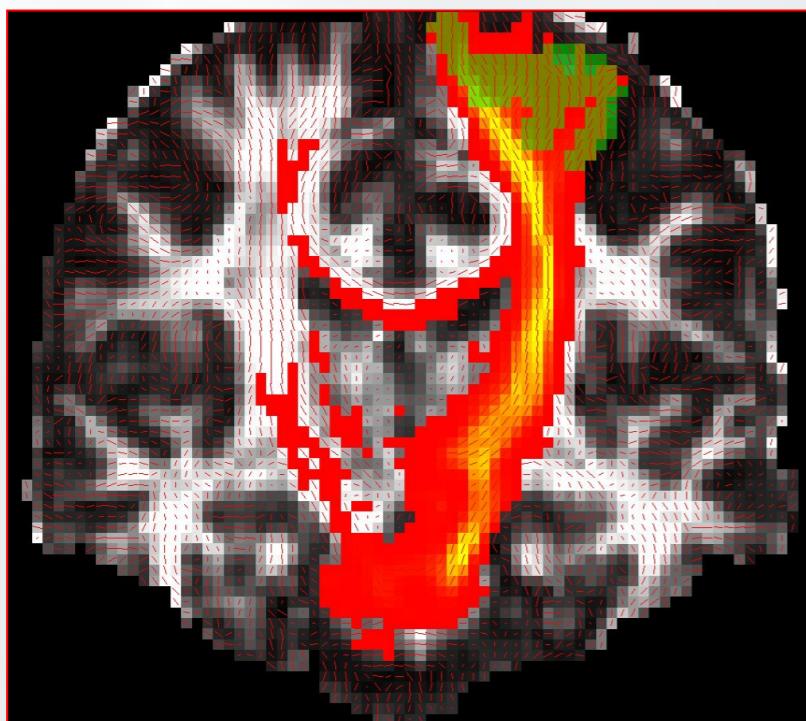
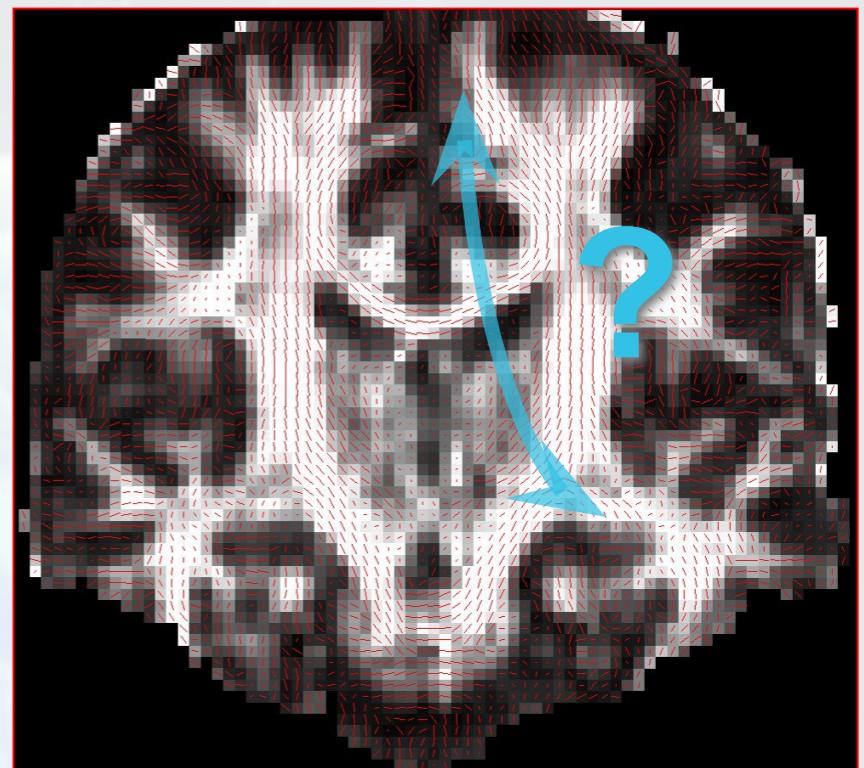


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- SEGMENTATION OF THE CEREBRAL CORTEX
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Probabilistic Tractography

- Use local diffusion orientation at each voxel to determine pathway between distant brain regions
- Local orientation comes from diffusion model fit (tensor, ball-and-stick, etc.)

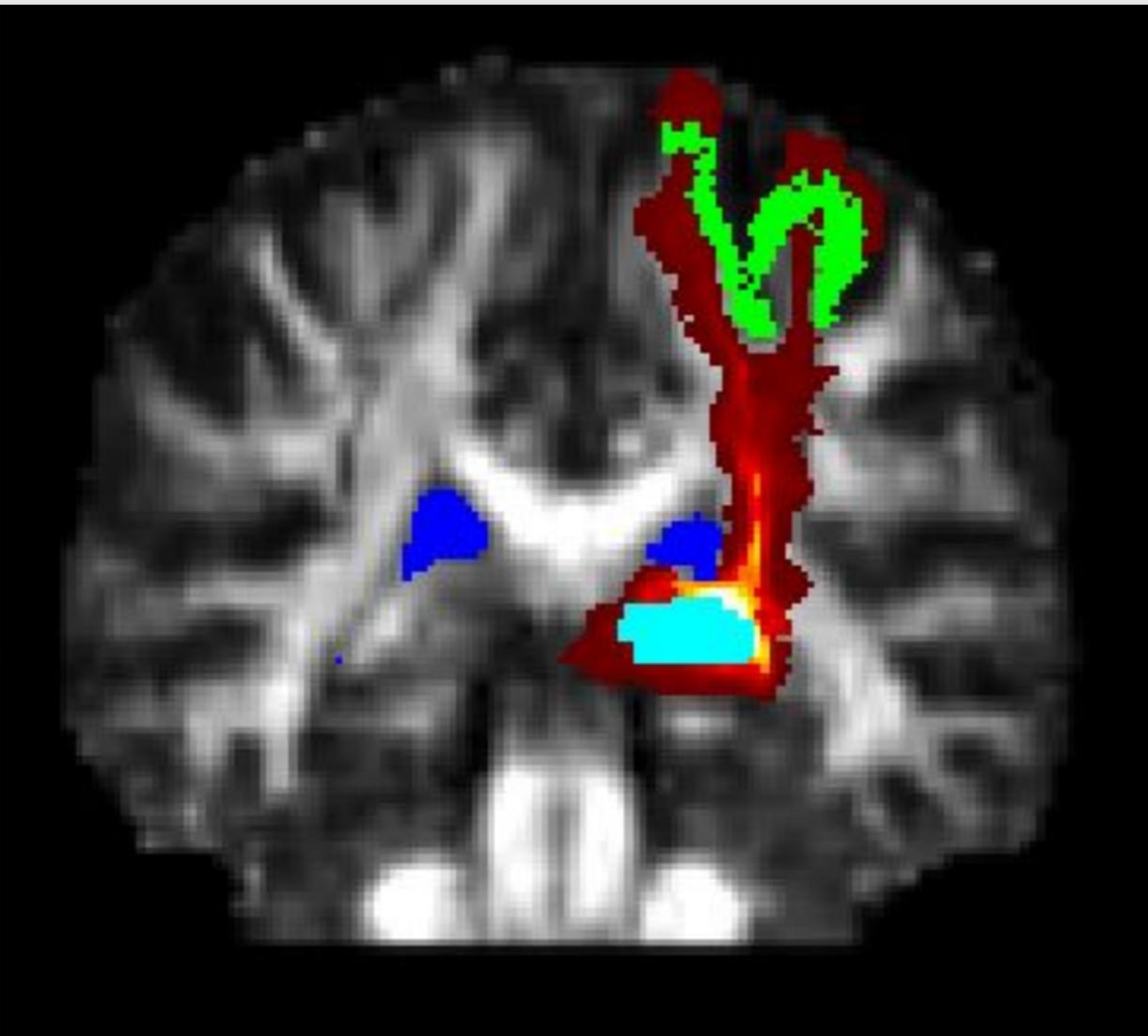


A probability distribution
(sum of all streamline samples from all seed voxels)

Anastasia Yendiki – FSL TRACULA HMS/MGH/MIT
Athinoula A. Martinos Center for Biomedical Imaging



Global tractography



- ❖ Fits the entire pathway, using diffusion orientation at all voxels along pathway length
- ❖ Constrained to connection of two specific end regions

Seeds

- pre-central gyrus
- post-central gyrus
- Brodmann Area 6

Target

- Thalamus

Regions excluded

- Ventricle



FLOW CHART OF ANALYSIS PERFORMED

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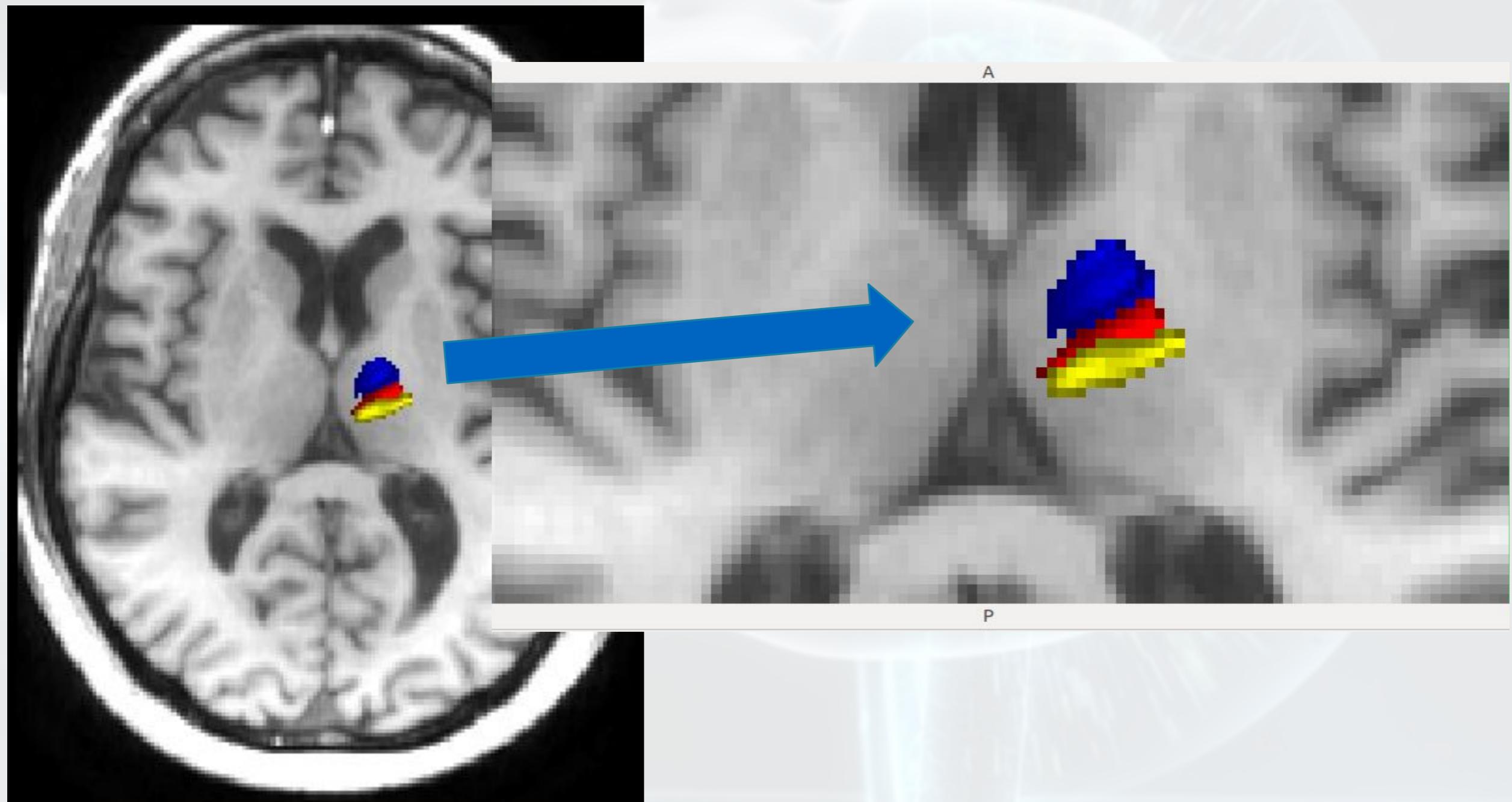


Thalamic segmentation for the first patients



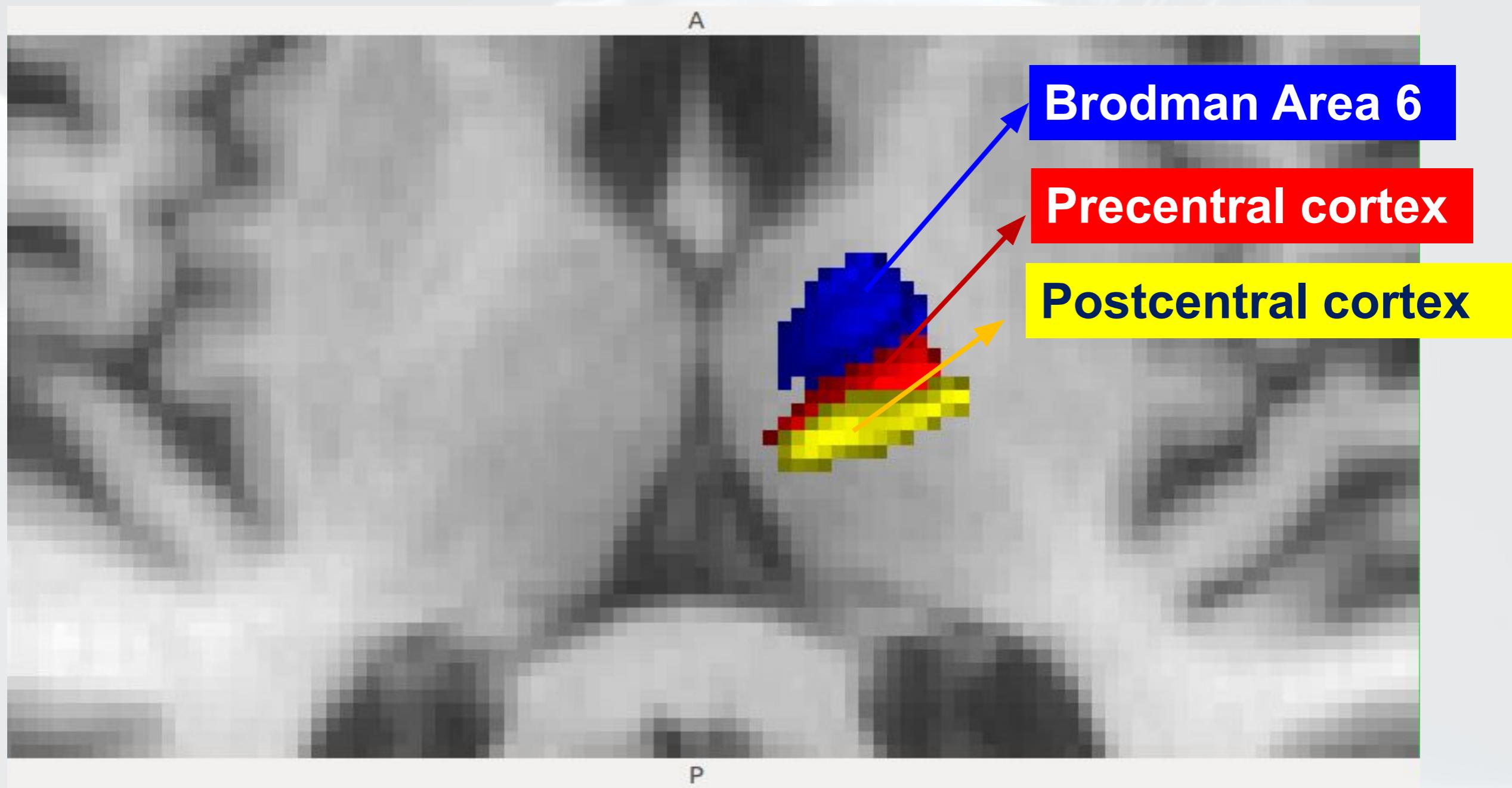


Thalamic segmentation for the first patients





Thalamic segmentation for the first patients





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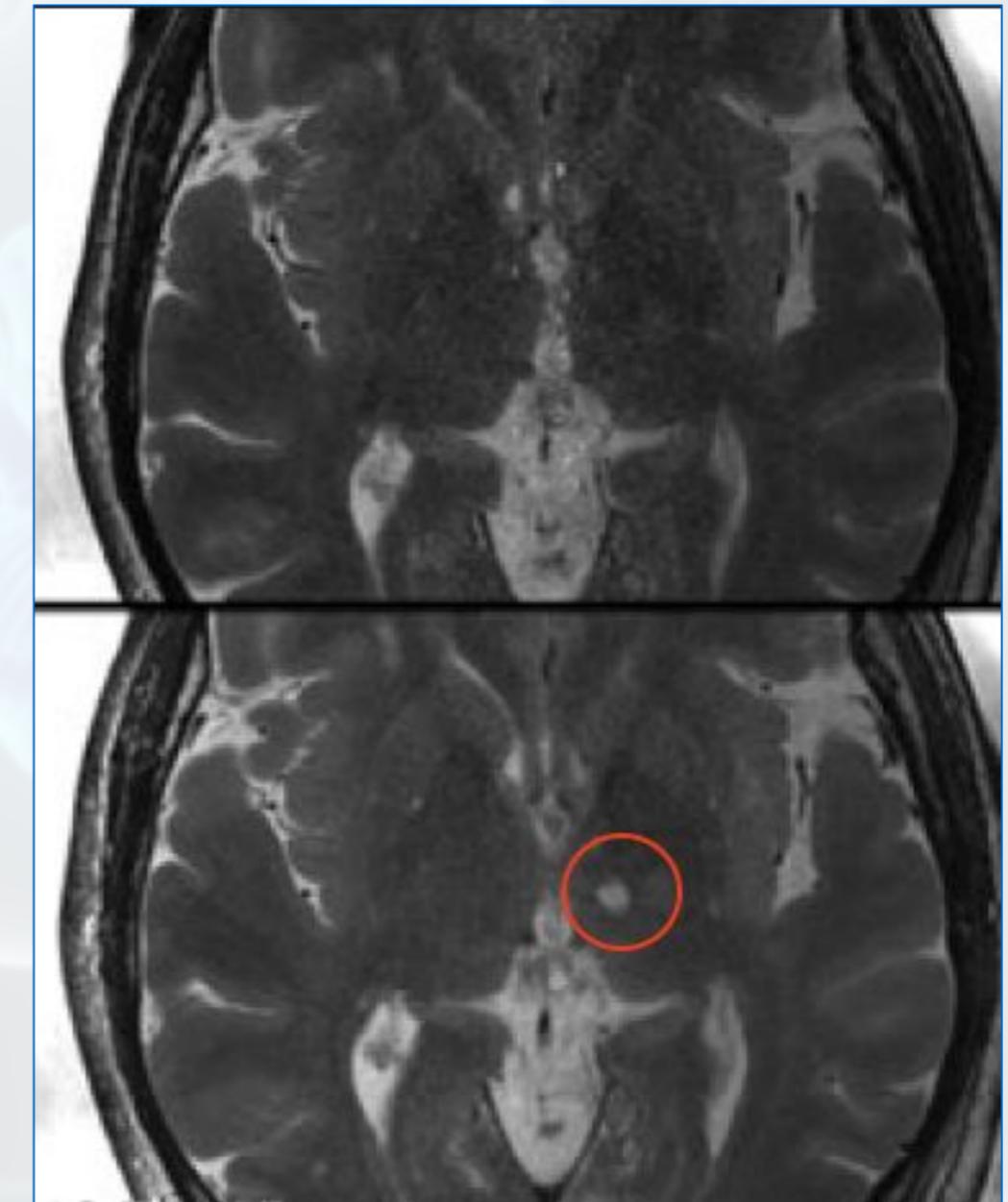
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FOLLOW-UP

**T₂-weighted images in which
the lesion
appears
hyperintense**

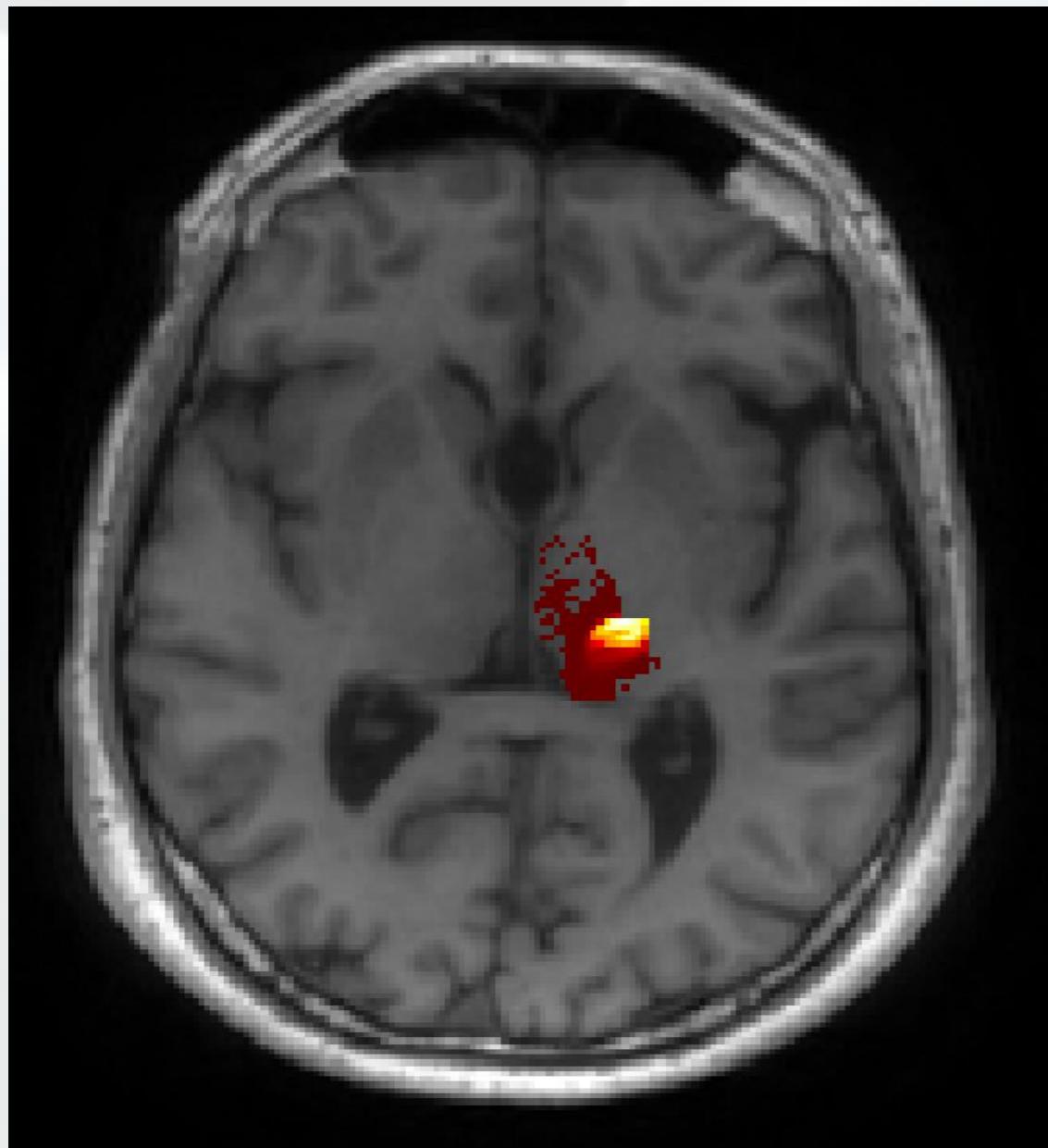
**Neurological control of the
severity of the tremor and of
the variation in the number
of waking hours in which the
subject trembles**



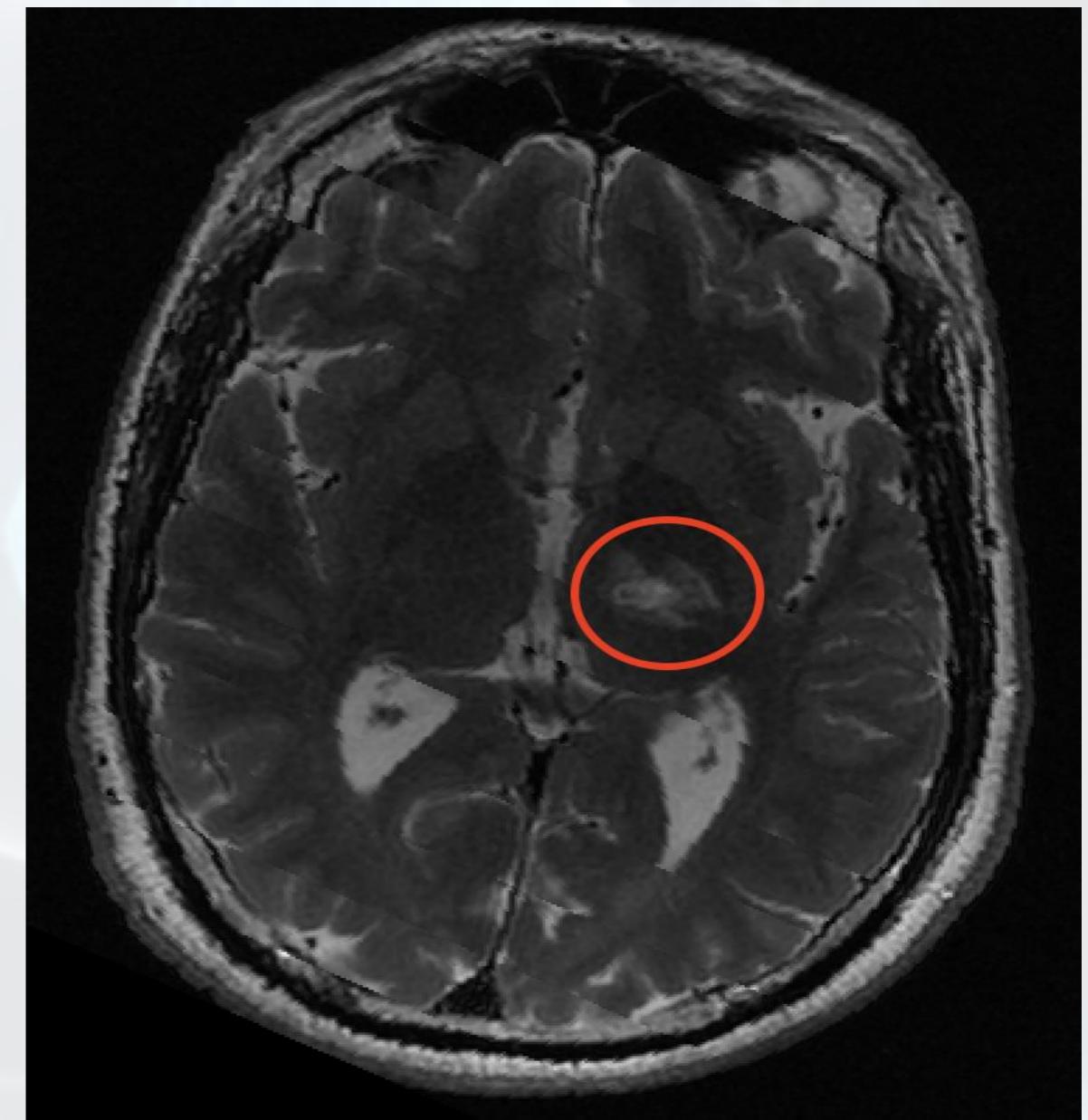


COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

TARGET DETERMINED THROUGH
PROBABILISTIC TRACTOGRAPHY



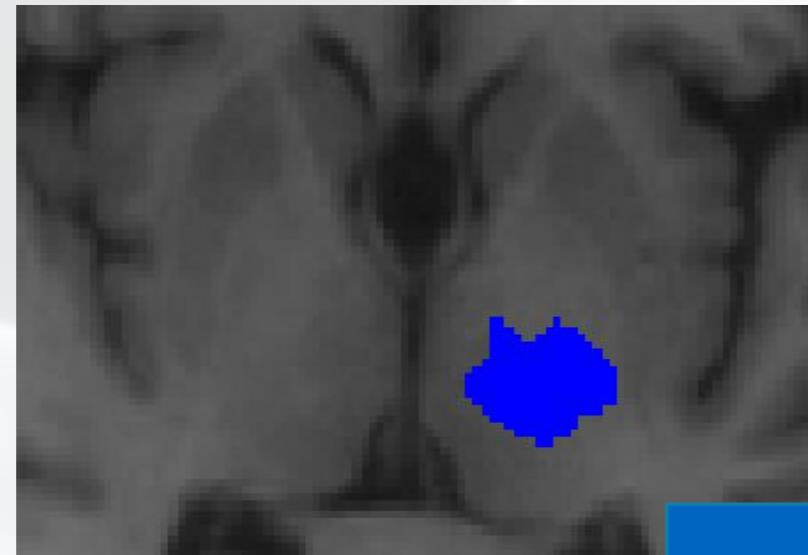
LESION INDUCED BY TREATMENT



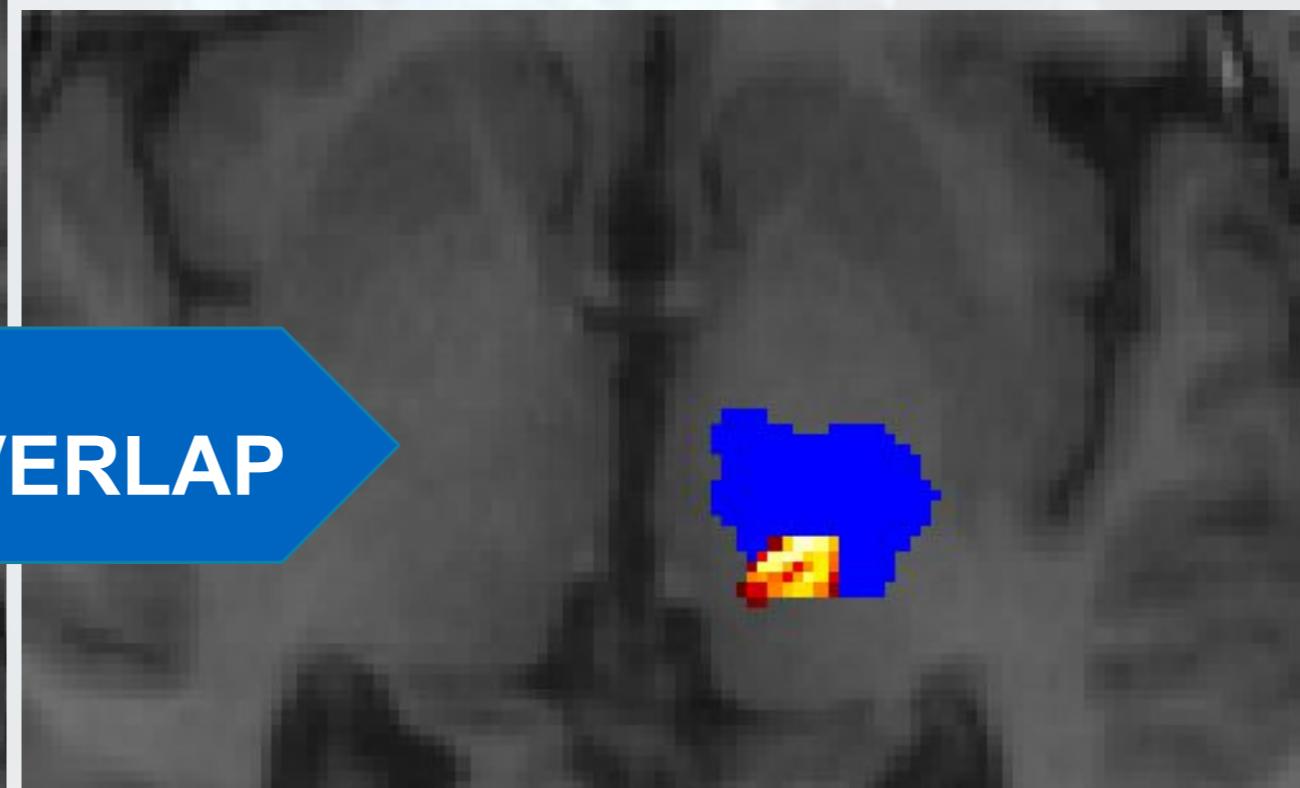


COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

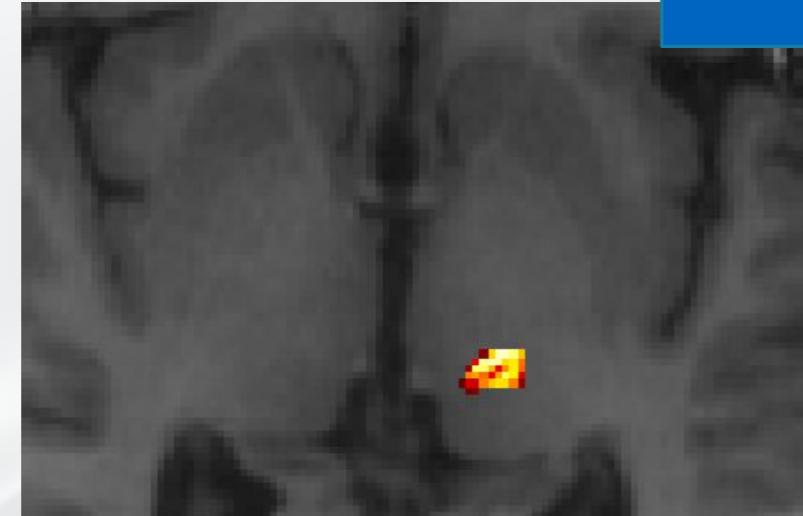
MASK OF THE
LESION
OBTAINED FROM
 T_2 -WEIGHTED
IMAGE



OVERLAP



PROBABILITY
DISTRIBUTION
OF
PRECENTRAL
GYRUS

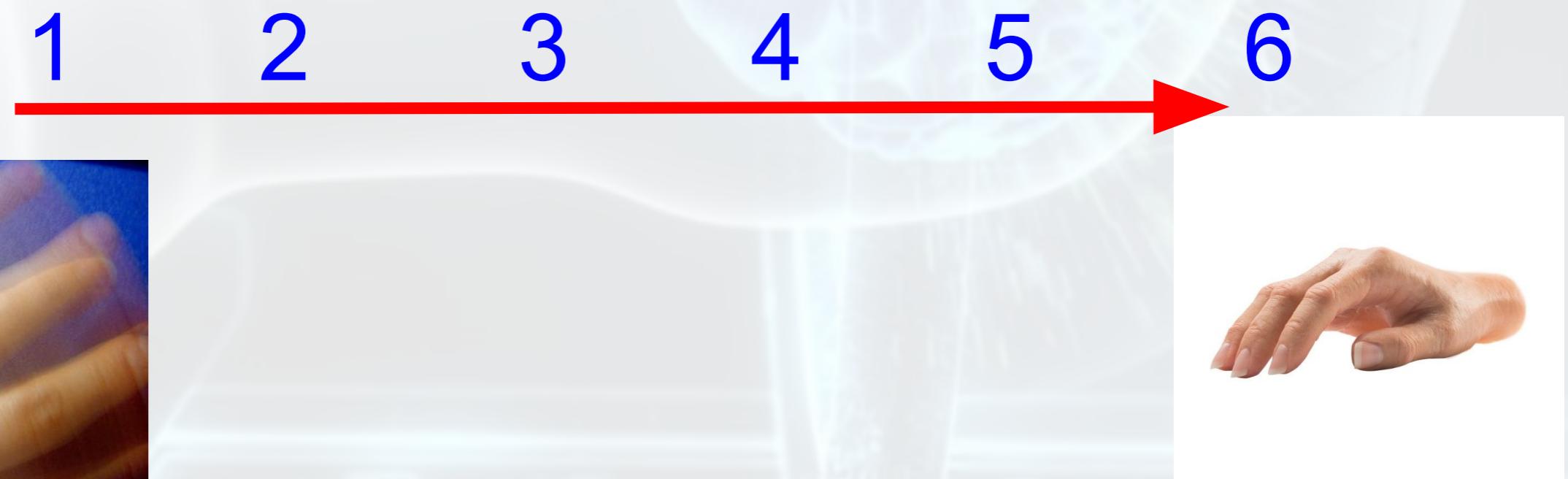




PRELIMINARY RESULTS OF THE QUANTITATIVE COMPARISON

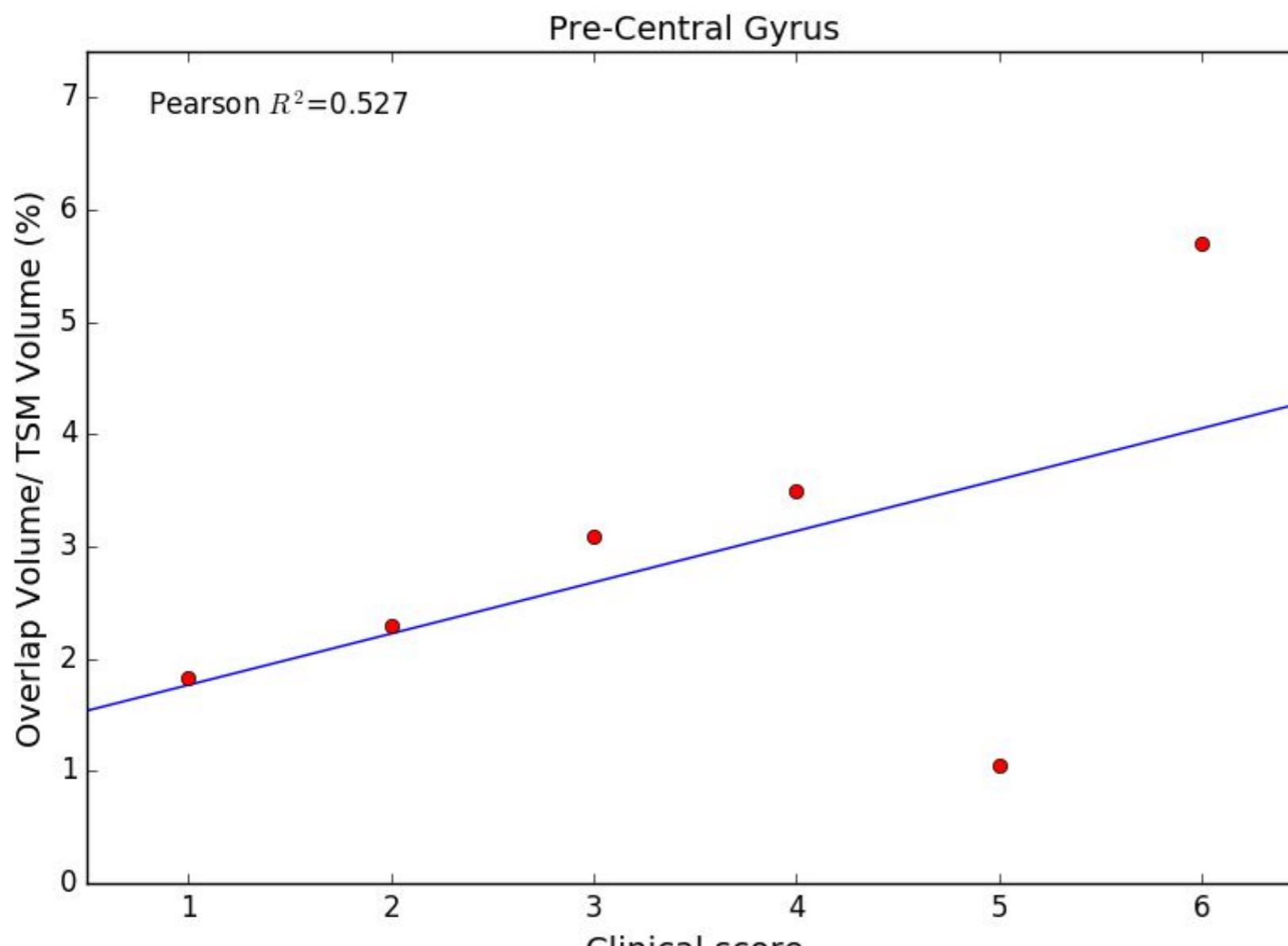
In a retrospective way (on 16 patients) the degree of overlap between the lesion volume and that of the target obtained through thalamic parcellation was correlated with an index that measures the clinical outcome after at least 3 months.

Clinical Score Scale





PRELIMINARY RESULTS OF THE QUANTITATIVE COMPARISON



The more the lesion overlaps the thalamus region identified by the thalamic parcellation, the better the outcome of treatment will be.



Conclusions and Perspectives

- In all cases it was possible to represent the major groups of thalamic nuclei that are connected to the cortex.
- It was possible to evaluate the overlap between the thalamic parcellation maps obtained (with particular attention to the VIM nucleus) and the lesions induced by tcMRgFUS

What's next?

- These analyses will be performed on a larger number of patients
- These analyses will be applied **in a predictive way** during the planning of the TcMRgFUS treatments and could allow the temporal optimization for the patients with thalamic anatomy different from neurological atlases.



FUNDING

Project GR-2016-02364526 (Ricerca Finalizzata 2016
- Giovani Ricercatori): “Trans-cranial MRgFUS for the
treatment of medication refractory essential tremor:
Italian and world-first trial using a 1.5T MR unit.”



Ministero della Salute



UNIVERSITÀ
DEGLI STUDI
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THANK YOU FOR YOUR KIND ATTENTION!

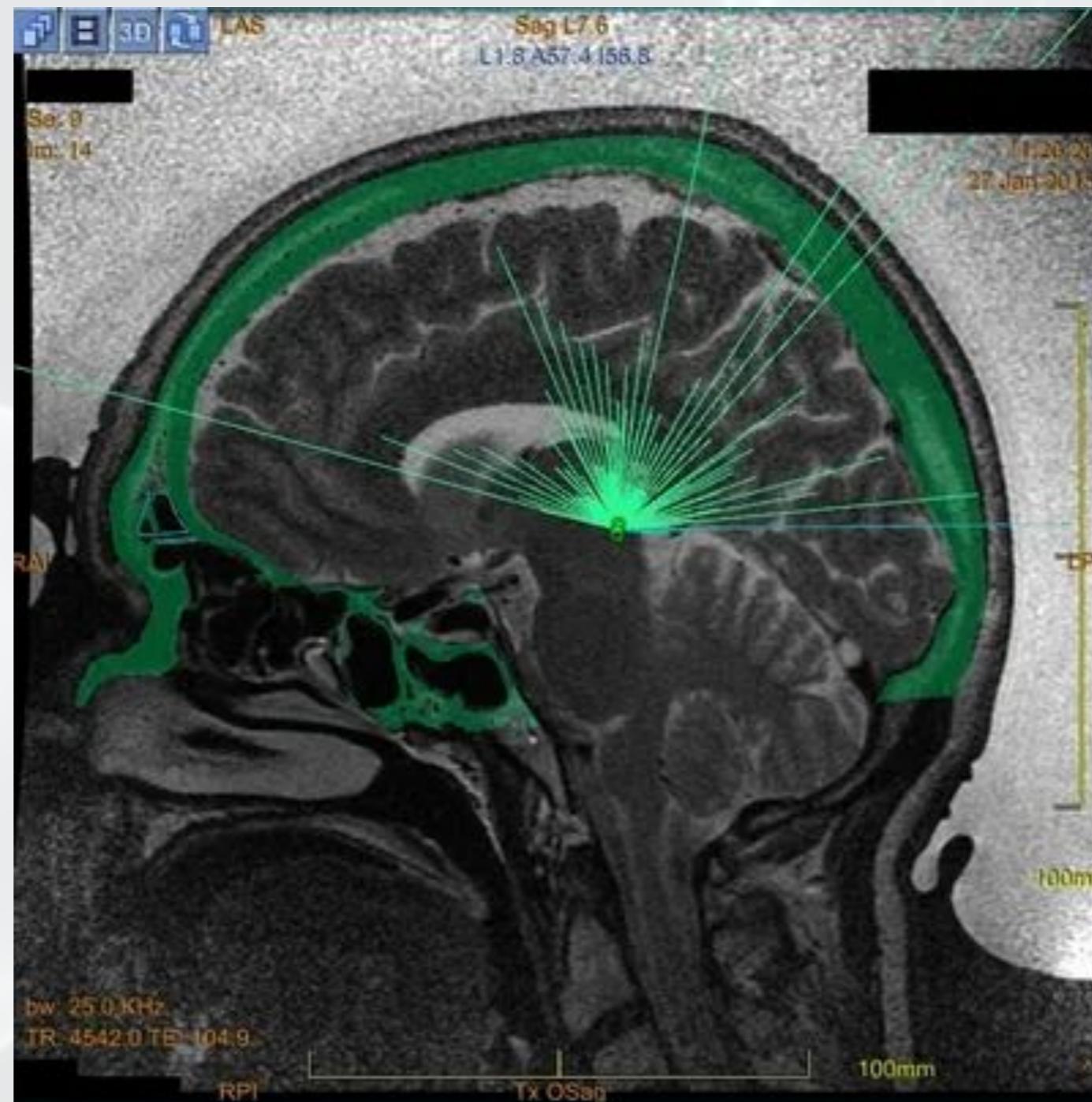


Immagine tratta dal primo trattamento tcMRgFUS
eseguito in Italia, nel gennaio del 2015 a Palermo.