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Improving DBS targeting using 3D visualization of intraoperative stimulation tests

Ashesh Shah¹, Fabiola Alonso², Jean-Jacques Lemaire³, Karin Wårdell², Daniela Pison¹, Jerome Coste³, Erik Schkommodau¹, Simone Hemm-Ode^{1,2}

¹Institute for Medical and Analytical Technologies, University of Applied Sciences and Art Northwestern Switzerland, Muttenz, Switzerland

²Department of Biomedical Engineering, Linköping University, Linköping, Sweden

³Centre Hospitalier Universitaire de Clermont-Ferrand, Image-Guided Clinical Neurosciences and Connectomics (EA 7282, IGCNC), Université d'Auvergne, Clermont-Ferrand, France

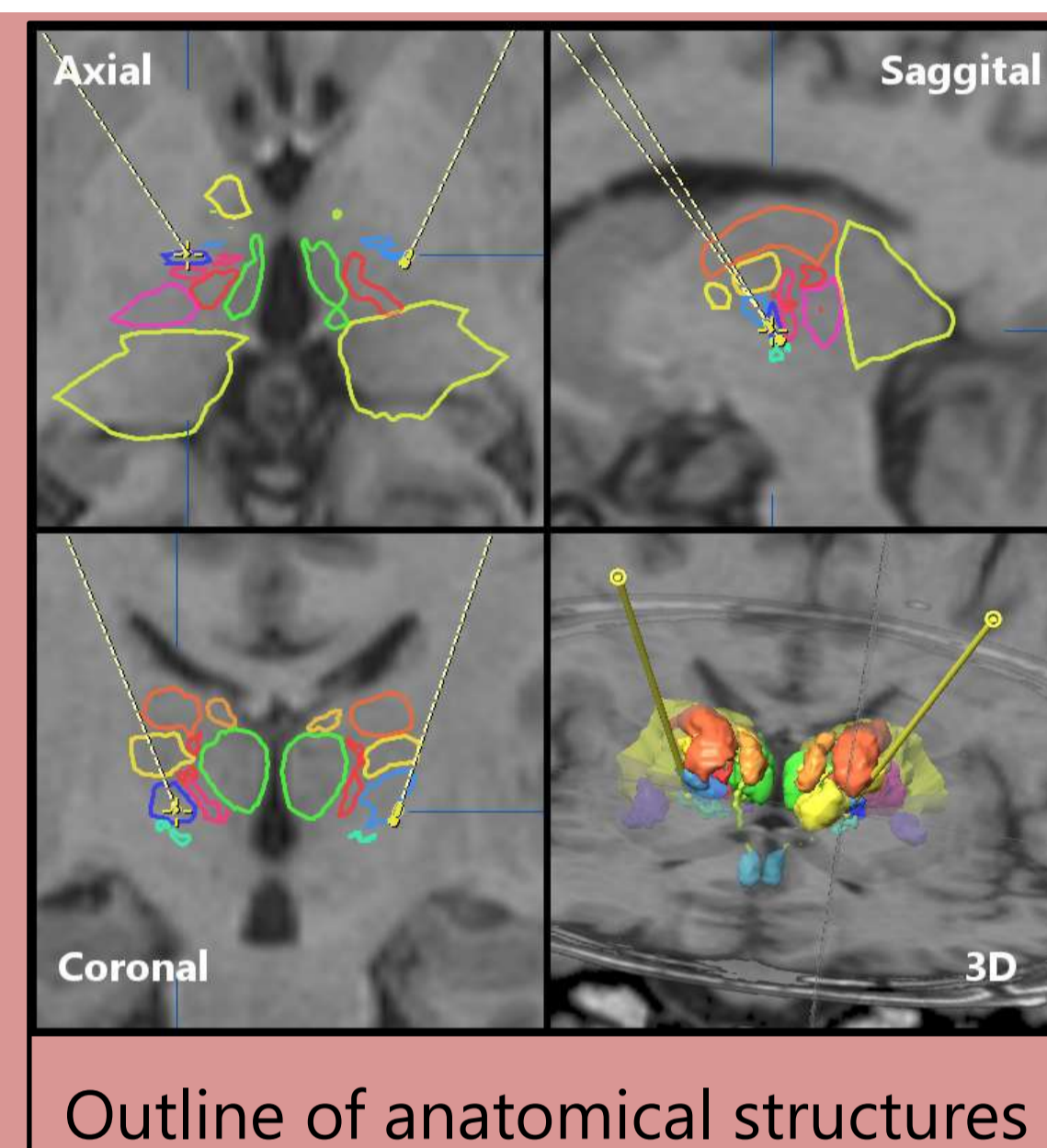
Background

For a typical DBS surgery, a significant amount of patient data is collected. Multiple image data sets (MR and CT) are acquired to be used for planning. Surgical teams identify different anatomical landmarks in these images and use them to plan a trajectory to the target. During surgery, along this planned trajectory, an electrode is inserted and stimulation tests are performed. The changes in patient's symptoms with varying stimulation parameters and position of the electrode are noted and used to decide the optimal position to implant the DBS lead. Currently, the various information collected during the surgery is "mentally" visualized and analyzed for surgical decision making. We present here a method to visualize and analyze this multitude of information for surgical decision making using patient-specific simulations of electric field distribution in combination with intraoperative accelerometry based tremor evaluation and direct-targeting technique of DBS.

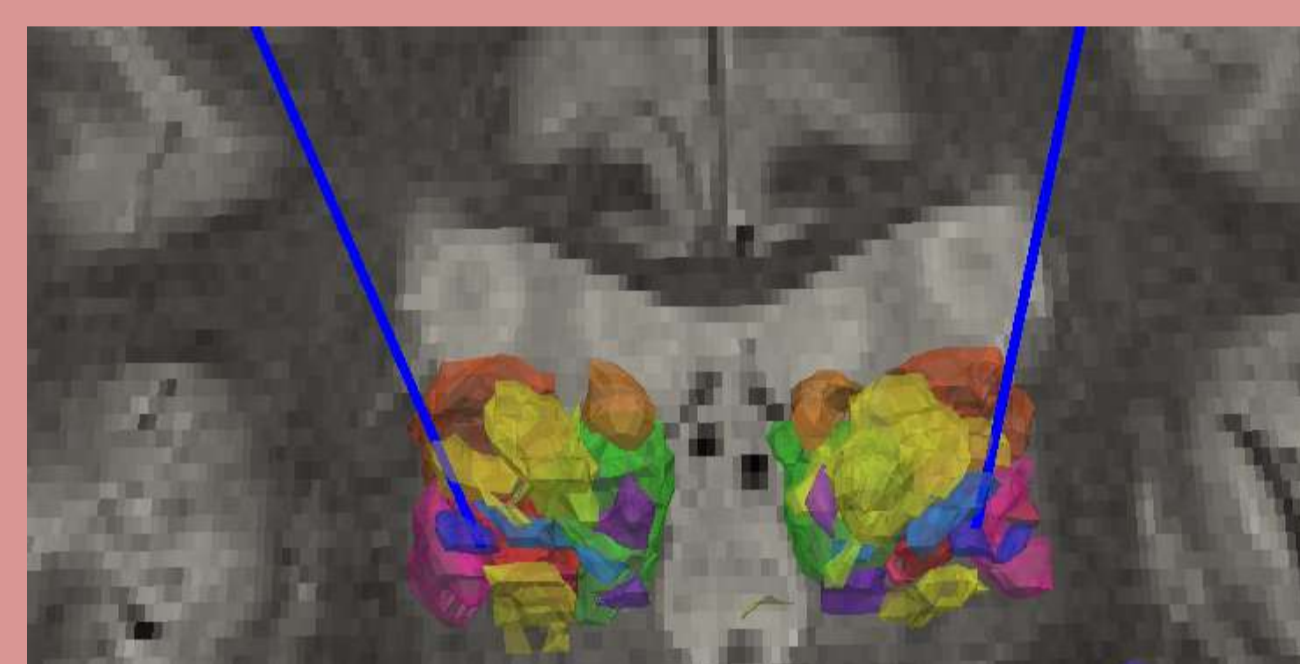
Method

Preoperative information

- Stereotactic CT and MR (x2) data sets were acquired.
- Using iPlan Stereotaxy (Brainlab) software, surgical team outlined different thalamic nuclei, identified the target structure¹ and planned 2 parallel trajectories and 5-10 stimulation test positions per trajectory.
- 3D co-ordinates of the trajectory, anatomical structures and target were exported using an interface based on VVLink and VTK (Kitware).

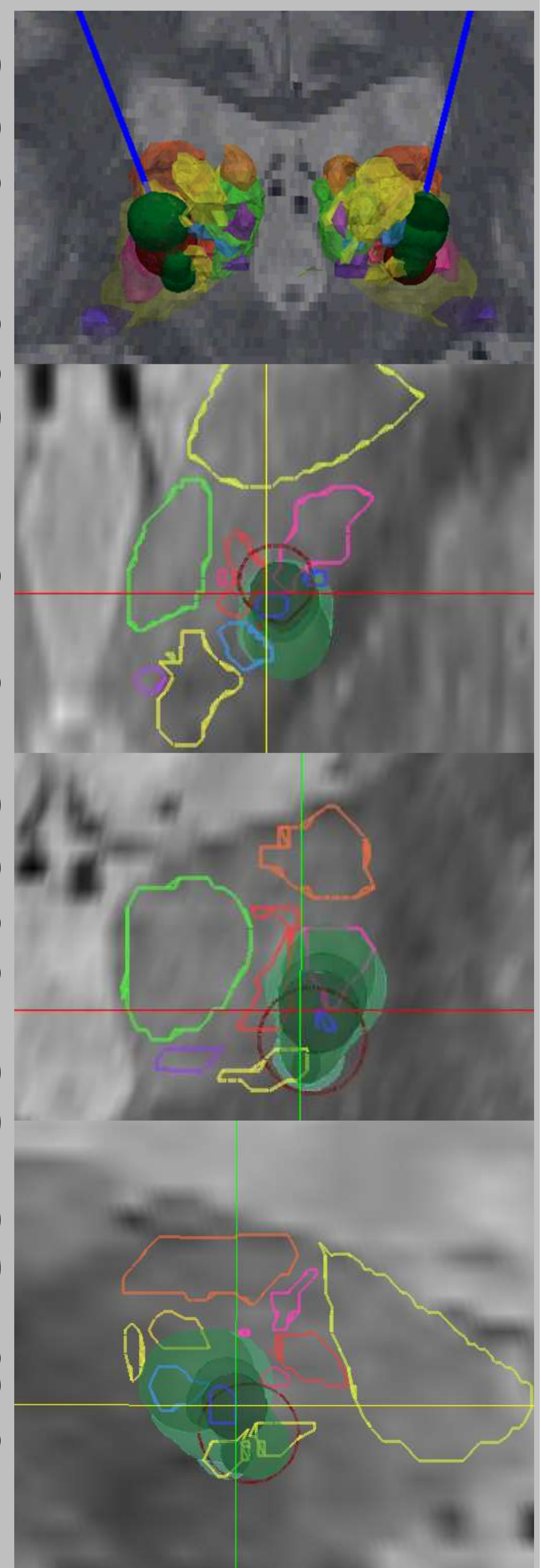


Object	Coordinates (Image)		
	X	Y	Z
Entry	175.78	121.28	98.87
Target	163.47	150.58	48.81



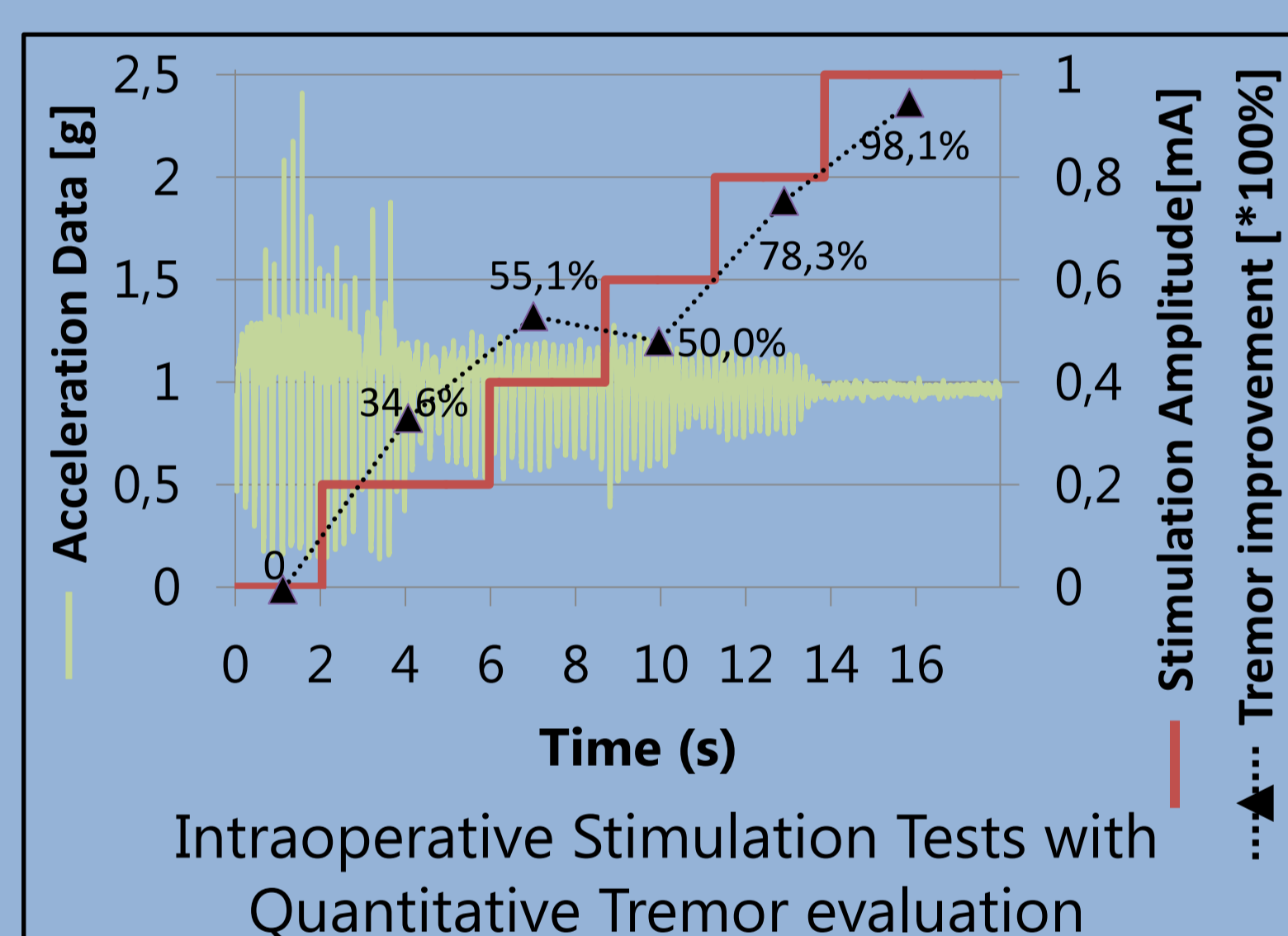
Improvement Maps

Data Consolidation and Visualization



Intraoperative information

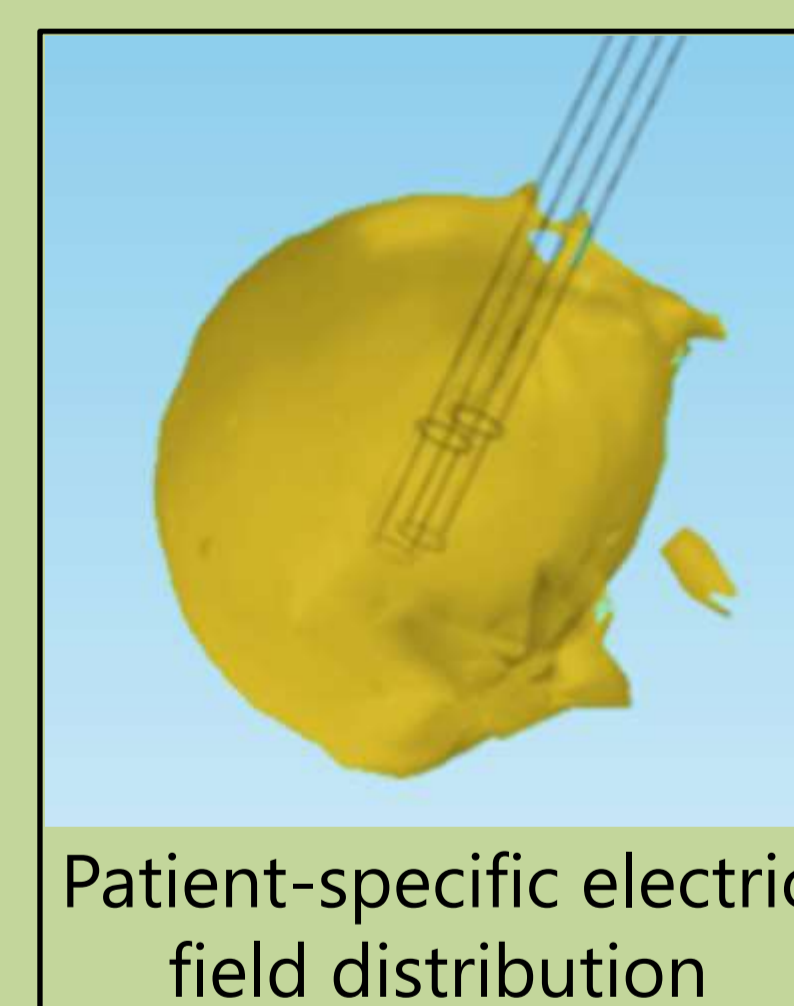
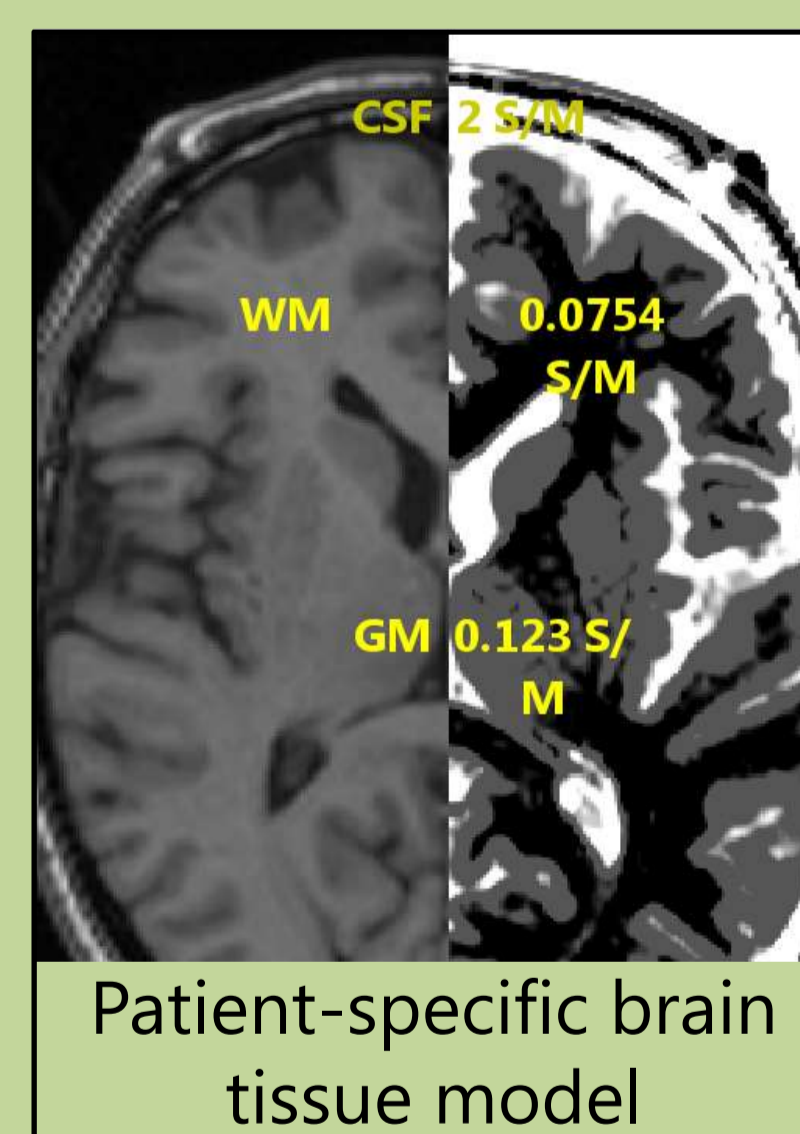
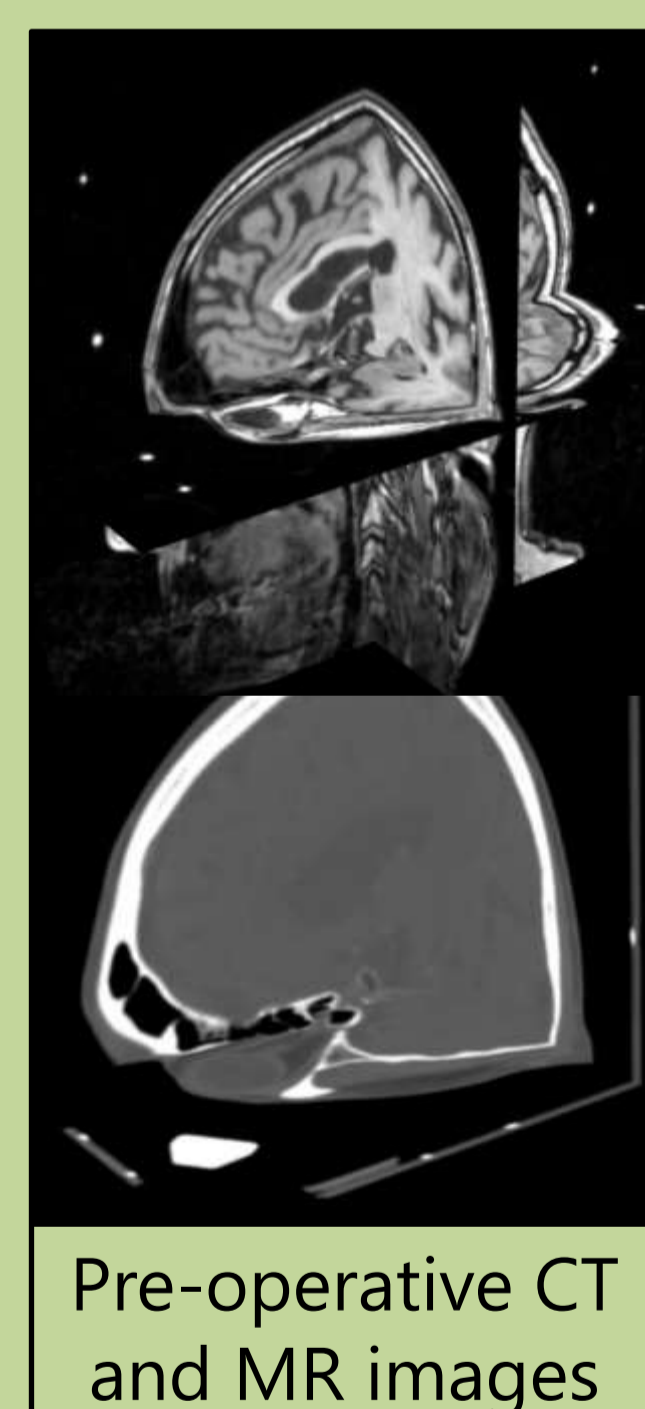
- Stimulation tests were performed at the pre-determined positions using an exploration electrode-Neuroprobe (Alpha Omega Engineering)
- Improvement in tremor was evaluated using a 3-axes accelerometer attached to the patient's wrist and recording data in synchronization with stimulation current amplitude²
- Effective stimulation current amplitudes were identified using post-operative data analysis.



Stimulation current Amplitude [mA]	Improvement in tremor relative to baseline
0.2	12%
0.4	55%
0.6	70%
0.8	85%
1	98%

Patient-specific EF simulations

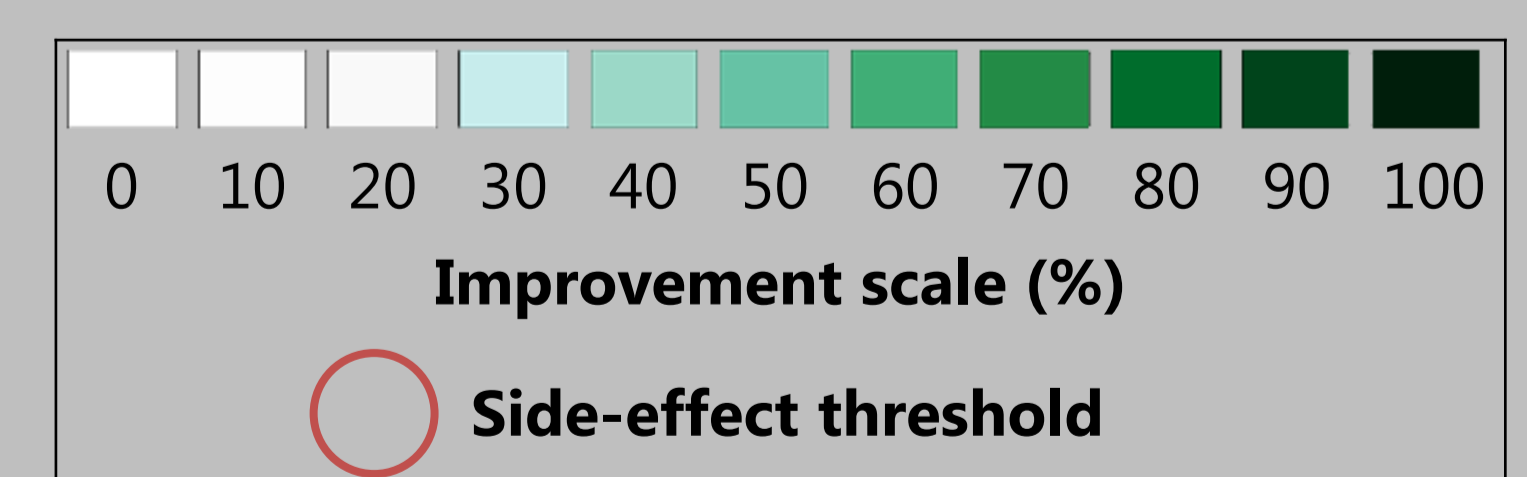
- Preoperative MR T1 was segmented into gray matter, white matter and cerebro-spinal fluid
- Brain tissue model is developed by assigning different conductivity values to the segmented areas.
- A model of the exploration electrode was placed at the different stimulation test locations using the co-ordinates from the planning data.
- The distribution of the electric field was simulated³ for different effective stimulation current identified using accelerometric tremor



Improvement Maps

- Each EF simulation is assigned the corresponding improvement in tremor based on the stimulation current amplitude used as input.
- The large number of EF simulations per hemisphere (on average 17) made visual analysis difficult. Therefore, using voxel-based processing, each voxel in the tested region was assigned the maximum value of improvement.

- This voxel-based processing divided the tested region into smaller parts based on the observed improvement in tremor.
- Visual analysis of such data revealed "hotspots" where DBS lead could be implanted.
- EF simulations of side-effect inducing amplitudes are also visualized (in red). This allows the identification of no-go zones.



References

- 1) Zerroug A, et al.: Personalized mapping of the deep brain with a white matter attenuated inversion recovery (WAIR) sequence at 1.5-tesla: Experience based on a series of 156 patients. **Neurochirurgie** 5014: 183–231, 2016. DOI: 10.1016/j.neuchi.2016.01.009.
- 2) Shah A, et al.: Intraoperative acceleration measurements to quantify improvement in tremor during deep brain stimulation surgery. **Med Biol Eng Comput**, 2016. DOI: 10.1007/s11517-016-1559-9.
- 3) Aström M, et al.: Method for patient-specific finite element modeling and simulation of deep brain stimulation. **Medical & biological engineering & computing** 47: 21–28, 2009. DOI: 10.1007/s11517-008-0411-2.

Prof. Simone Hemm-Ode
T +41 61 4674-796
F +41 61 4674-701
simone.hemm@fhnw.ch

Ashesh Shah
T +41 61 4674-413
ashesh.shah@fhnw.ch



Institute for Medical and Analytical Technologies
University of Applied Sciences and Arts Northwestern Switzerland
Head: Prof. Dr-Ing. Erik Schkommodau.
Gruendenstrasse 40, 4132 Muttenz, Switzerland. www.fhnw.ch/ima