Atlas aided stereotactic deep brain stimulation: aDBS

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Challenge of deep brain stimulation: Positioning of stimulation electrode

The efficacy of stereotactic neurosurgical treatment is directly related to the electrode implantation accuracy.

To improve the target selection during the planning process with anatomical information and to evaluate the final electrode contact position in common space the use of brain atlases fitted to the individual MRI has been proposed [1].

We developed a novel nonlinear multigrid atlas co-registration method that transforms anatomical atlas information [2, 3] onto the individual patient MRI.

Where are electrode contacts located? **Atlas aided DBS**

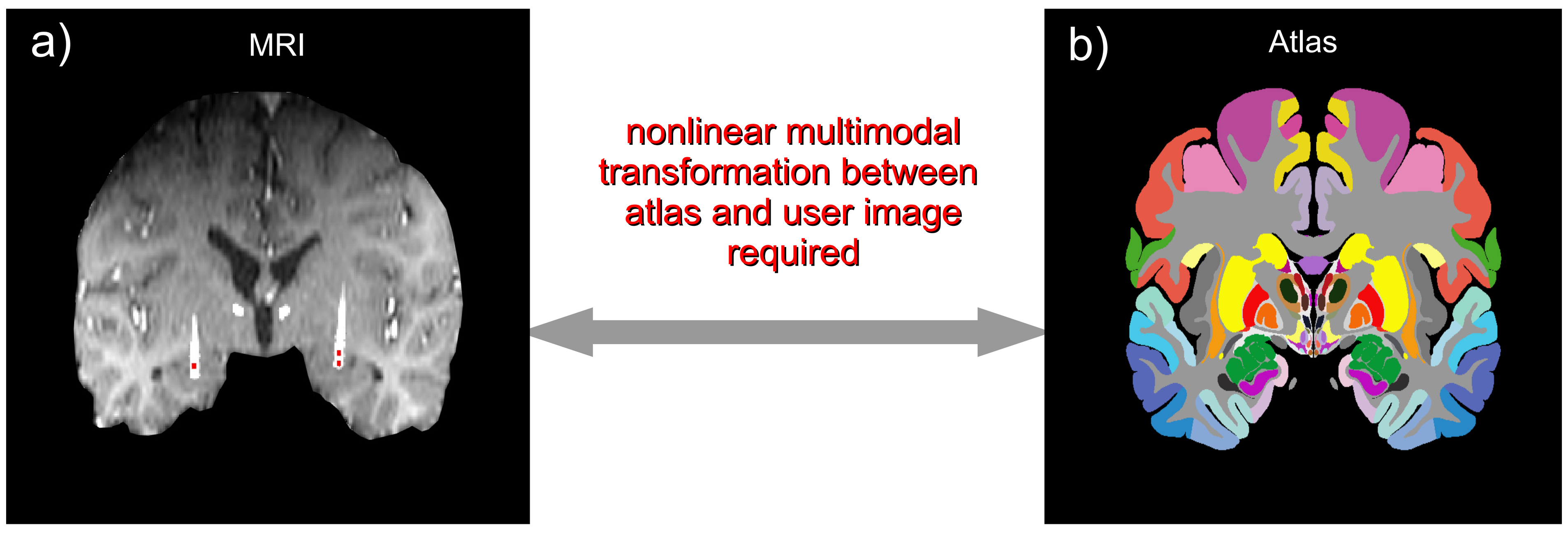

Figure 1. The interpretation of the position of electrode contacts can be aided with the Atlas of the Human Brain [2,3]. **(a)** Patient MRI fused with the CT the of the electrodes (white). Contacts are marked red. **(b)** Color plate from the Atlas of the Human Brain corresponding to the patient MRI

Novel multigrid multimodal nonlinear registration method

Our method uses a novel distance measure, which estimates the displacement between atlas and MRI by nonparallellity of gradients and ensures good distance estimation also in regions of low intensity changes [4].

Our nonparallelity distance measure reads:

$$d(R,T,\phi,\vec{x}) := \sqrt[2]{\frac{\|\nabla R(\vec{x})\|_2^2 + \|\nabla (T\circ\phi)(\vec{x})\|_2^2}{2} - (\nabla R(\vec{x})\cdot\nabla(T\circ\phi)(\vec{x}))^2},$$

with T denoting a template image that will be registered onto a reference image R. ϕ denotes displacement field and x coordinates of image pixel.

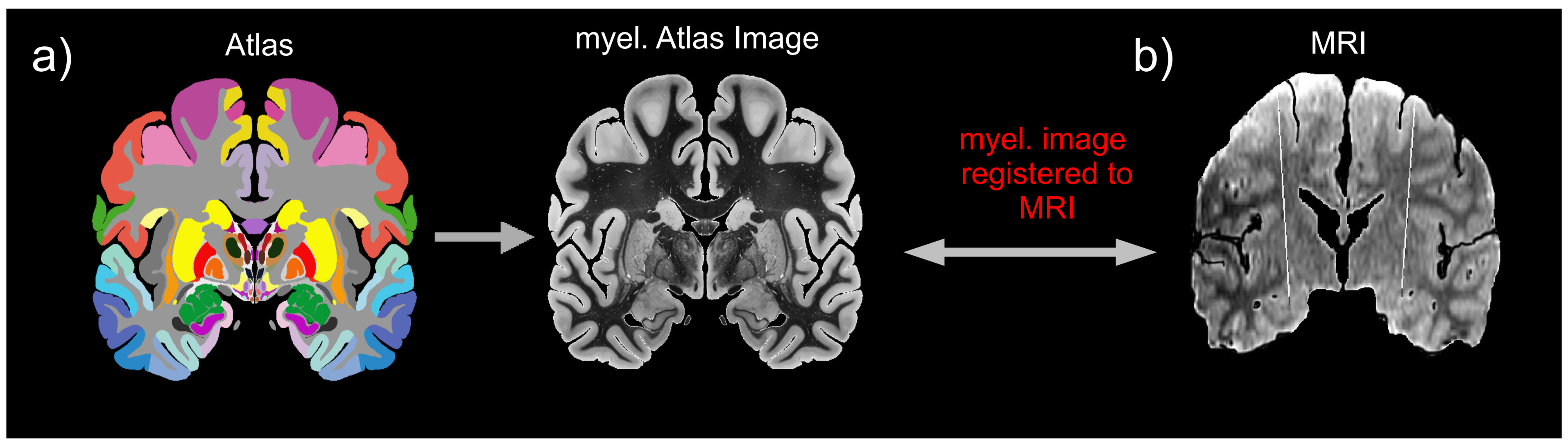

Figure 2: Schema of the registration process. **(a)** Template image. The colored atlas plate is replaced by corresponding brain slice stained for myelin. **(b)** Reference image. The MRI was segmented and contrast enhanced.

Registration results of the novel multimodal method

This method allows for direct (image-to-atlas, I2A) transformation of the electrode contact positions into the reference atlas space (Fig. 3e).

The topographic correct relation of the target points to the transformed atlas provides the possibility to use the transformation matrix to link the corresponding points to the untransformed atlas which thus serves as universal atlas model.

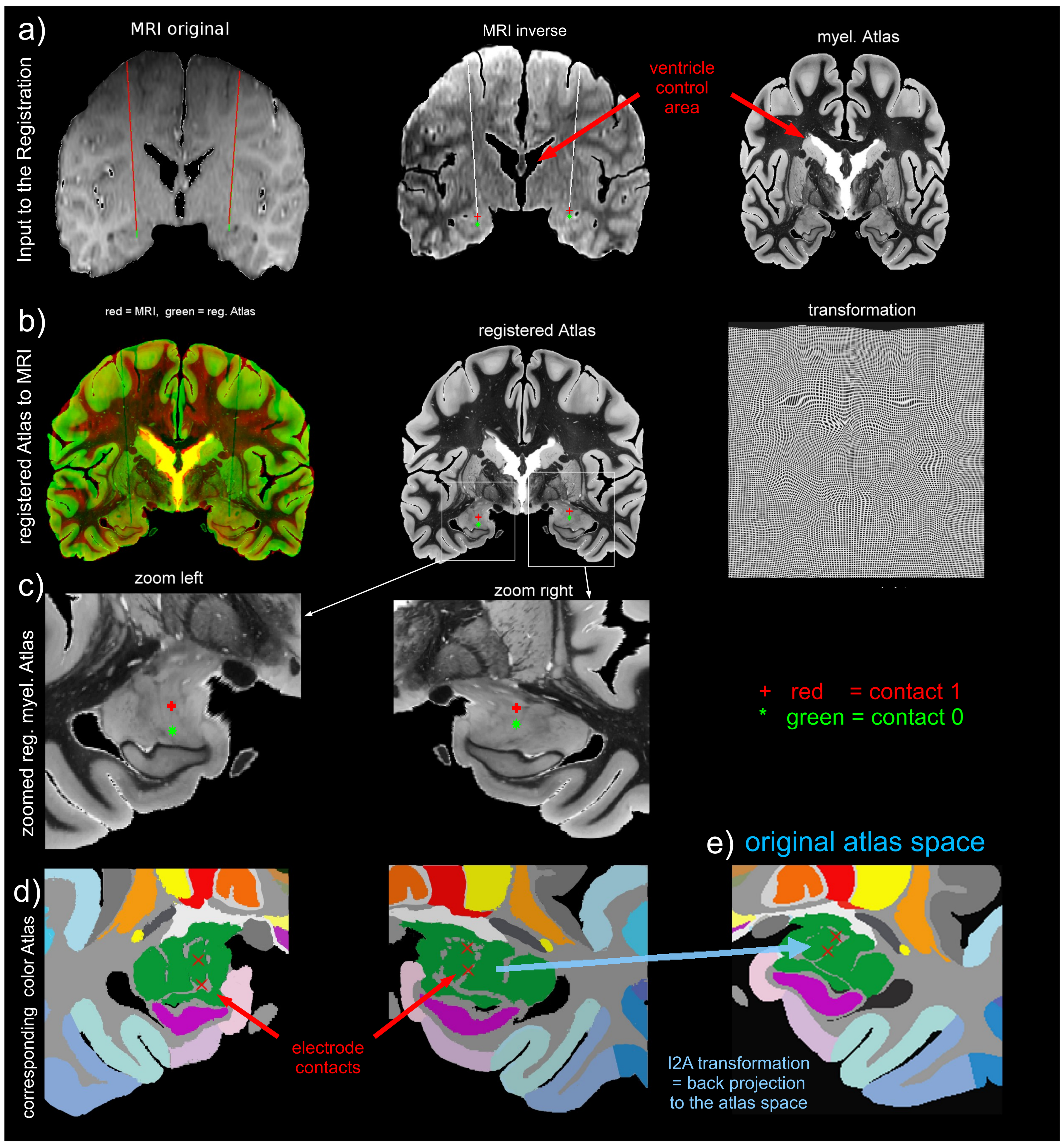

Figure 3: (a) Input to the registration algorithm. The original MRI with the electrode marked red and green (left). The preprocessed MRI (middle); the preprocessing of the MRI contained segmentation, gray value inversion, adaptive histogram equalization and contrast enhancement. (right) The myelin atlas image with ventricle area matched to the MRI. **(b)** Registered myelin atlas image overlaid on the patient MRI (left) and registered myelin atlas image only (middle). Transformation matrix applied to a regular grid (right). **(c)** Zoomed view of the registered myelin atlas image from (b) around the left electrode (left) and the right electrode (middle). **(d)** Color plates corresponding to the zoomed views from (c) with electrode contact positions marked red. **(e)** The positions of the right electrode contacts transformed back to the atlas space by I2A transformation.

Conclusion

Our novel multimodal nonlinear technique provides very good fitting of the atlas to the individual brain and may aid the surgical decision-making process by providing highly detailed atlas information and hence improved target localization prediction.

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