# Registration of the digital Morel atlas to the MNI brain template for the assignment of thalamic lesions

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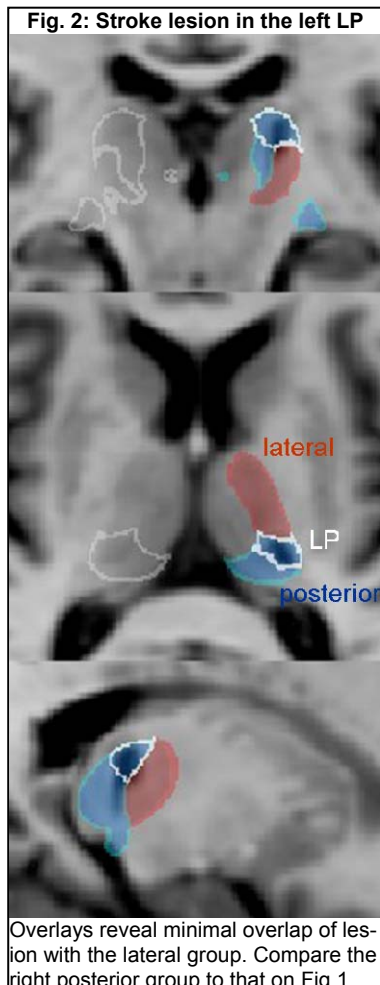
## Introduction

Spatial registration to population-averaged brain templates, e.g., those provided by the Montreal Neurological Institute (MNI), is pivotal to voxel-based statistics and anatomical assignment. Many nuclei of the human thalamus are not visible on structural MRI due to small size and/or poor contrast, but on histology-based stereotactic atlases (1) that have now become available in digital form. The digital "Morel atlas" (2) was registered to the MNI brain template in order to infer nuclear territories from structural MRI after registration to standard space.

## Methods

The vtk surface meshes of the digital Morel atlas (2) correspond to the (radiological) right thalamus, but fall outside the imaging volume. The nodal coordinates of the Thalamus.vtk surface were first shifted into position (with inverted x-coordinates for the left hemisphere) and then transformed into a pixel mask using the "first_utils" tool of FSL 4.1 (www.fmrib.ox.ac.uk/fsl). Manual registration was performed successively by anatomical landmarks on the thalamic surface and on the MNI152_T1_0.5mm brain template provided with FSL (www.fmrib.oxac.uk/fsl) to determine affine transformations. These landmarks included the thalamic adhesion, the mamillothalamic tract (MTT), the lateral geniculate nucleus (LGN), the habenular nucleus, the anterior pole of the anterior ventral nucleus (AV), and the posterior pole of the medial pulvinar. Three iterations were performed since neither landmark was sufficiently well defined in all three coordinates. Finally, each vtk mesh of the atlas was transformed to MNI space and converted into pixel masks for the left and right thalamus. Structural T1-w MRI (MP-RAGE, TI = 0.9 s, α = 9°, TR = 2.25 s, 1mm resolution, 3T Siemens TRIO) was non-linearly registered to MNI space using FSL "fnirt" to correct for individual thalamic shape.

## Results

The MNI brain is larger and angulated by about 7° against the intercommisural orientation of the Morel atlas. The thalamic hemispheres are slightly asymmetric and form an angle of about 3° against each other. The scalings in x- and z-direction depend mainly on the position of the LGN. The lateral pulvinar (PuL) of the template lacked contrast against the internal capsule (IC) because of its high iron content (3,4). The Morel atlas excellently outlined the WM tracts within the thalamus; the hyperintense margin of IC (disguised by windowing in Fig. 1) fell outside the Morel regions and thus assigned to external medullary lamina, medial of the reticulate nucleus. The geniculate nuclei and the AV and LD were contrasted against embedding WM.
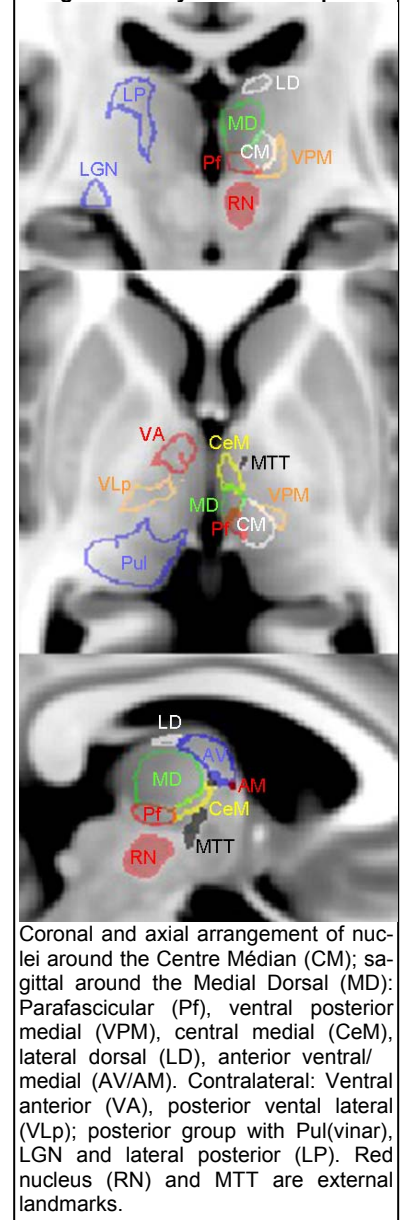
Small residual deviations after affine registration were found around the anterior and posterior poles, where the outlines did not extent to the thalamic borders. Still, underlying nuclear territories can be assigned to thalamic lesions, as demonstrated on a stroke of the posterior lateral choroid artery in the Lateral Posterior (LP) (Fig. 2). Although the thalamus is structurally quite conservative, affine registration alone was not sufficient to correct for individual differences in thalamic shape.

## Discussion

The co-registered Morel atlas allows the assignment of thalamic nuclei in MNI space without prior knowledge of their complicated spatial arrangement. Verification was of the affine registration was mainly based on he detailed contrast features of the population-averaged MNI template (intrathalamic tracts, protruding inferior and super-ior nuclei). The hypointense area of the centre médian nucleus (CM) provides an important landmark (Fig. 1).

Contrary to the digital surface atlas, the FSL-derived masks overlap at their marginal pixels (see Fig.1). A res-olution of 0.5mm still renders small features and nuclei. The Morel atlas is based on histology and thus unlike structural MRI contrast, which is sensitive to myelinated axons. Therefore, we excluded the surrounding axonal tracts during registration.

The affine transformations were bases on surface landmarks. Within the thalamus, nuclei often lacked distinct borders and/or exhibited intensity gradients. This poses considerably difficulties when the spatial congruence is to be improved by a non-linear spatial transformation. Moreover, morphologic deformations by atrophy and pathologically altered contrast may impose additional sources of error to the assignment of nuclei. Ideally these should be cross-checked for consistency with additional information on vascular territories and/or neuropsychological symptoms. The individual co-registration is expected to benefit from parameter maps of T1, T2, (5) or magnetization transfer (6) since these feature a high contrast without spatial bias.



Fig. 1: Overlays on MNI template

Coronal and axial arrangement of nuc-lei around the Centre Médian (CM); sa-gittal around the Medial Dorsal (MD): Parafascicular (Pf), ventral posterior medial (VPM), central medial (CeM), lateral dorsal (LD), anterior ventral/medial (AV/AM). Contralateral: Ventral anterior (VA), posterior vental lateral (VLp); posterior group with Pul(vinar), LGN and lateral posterior (LP). Red nucleus (RN) and MTT are external landmarks.



Fig. 2: Stroke lesion in the left LP

Overlays reveal minimal overlap of les-ion with the lateral group. Compare the right posterior group to that on Fig.1.

## References

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