Mapping Human Subcortical Areas in-vivo Based on T_2^*-Weighted, R_2^* and Phase Images at 7 T

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Introduction

Subcortical brain regions such as the basal ganglia and thalamus have important roles in brain function that may be compromised by a number of diseases. Their accurate localization is often challenging with clinical MRI contrast such as T_1 and T_2 that are optimized to distinguish the main tissue compartments of CSF, cortical grey matter and white matter. Previous work has shown that magnetic susceptibility images (T_2^* weighted magnitude, R_2^*, and phase maps) may provide additional contrast in sub-cortical regions[1]. Here, we generate a brain atlas with the aim to distinguish the sub-regions in the subcortical areas that are not clearly visible in T_1-weighted data[2].

Methods

MR acquisition

- 10 subjects (male / female = 5 / 5, age = 46 ± 12, 22 - 66 yrs)
- GE 7 T whole body scanner, 32-channel phased array head coil
- 2D Multi-Echo GRE

  0.3×0.3 mm^2, thk/space = 0.8/0.2 mm, TE = 15.5/30.0/44.5 ms, flip angle = 75°, bandwidth = 62.5 kHz, SENSE rate = 2
- 3D MPRAGE with 1 mm isotropic resolution

Data processing

- R_2^* was calculated from a mono-exponential fit to the TE-dependent signal intensity
- The phase (TE = 15.5 ms) was unwrapped using FSL and the background phase was derived by convolving a Gaussian kernel (FWHM = 5 mm). Continuous phase maps were then generated by subtracting the background phase from the unwrapped data

Image registration

- The T_1-W image obtained from MPRAGE was registered to MNI brain template using nonlinear registration (FNIRT), and the registration matrix was reserved
- The GRE magnitude image was first registered to the T_1-W image using linear registration (FLIRT) , then aligned to MNI brain template using the registration matrix obtained above
- The same linear and non-linear registration procedures were applied to the phase and R_2^* maps, obtaining the registered phase and R_2^* maps, respectively

Comparison to thalamic atlas

- The Morel human thalamus atlas[3], which is based on a comprehensive histological study, was used for comparison
- 59 subgroups of nuclei on 26 slices in Morel atlas were identified and registered to MNI brain template by aligning their intercommissural planes and corresponding locations for the anterior and posterior commissure
- Registered color-coded subgroups were overlaid on phase data

Results

1

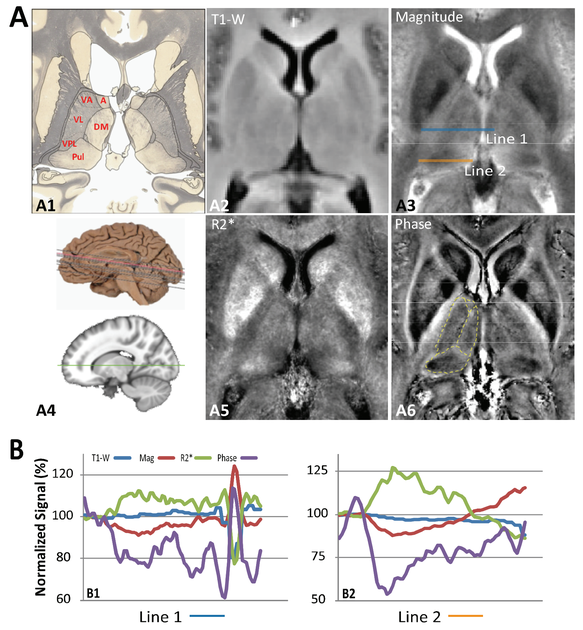

Fig 1. ***A)*** *Axial slice showing subcortical contrast from group averaged T1-W, GRE-magnitude, R_2^* and phase maps, in comparison with myelin stain at similar location (slice directions are slightly different between MRI and stain image, as shown in A4). A: anterior; DM: dorsomedial; Pul: pulvinar; VA: ventral anterior; VL: ventral lateral; VPL: ventral posterolateral;* ***B)*** *Line profiles in the areas marked on A3.*

2

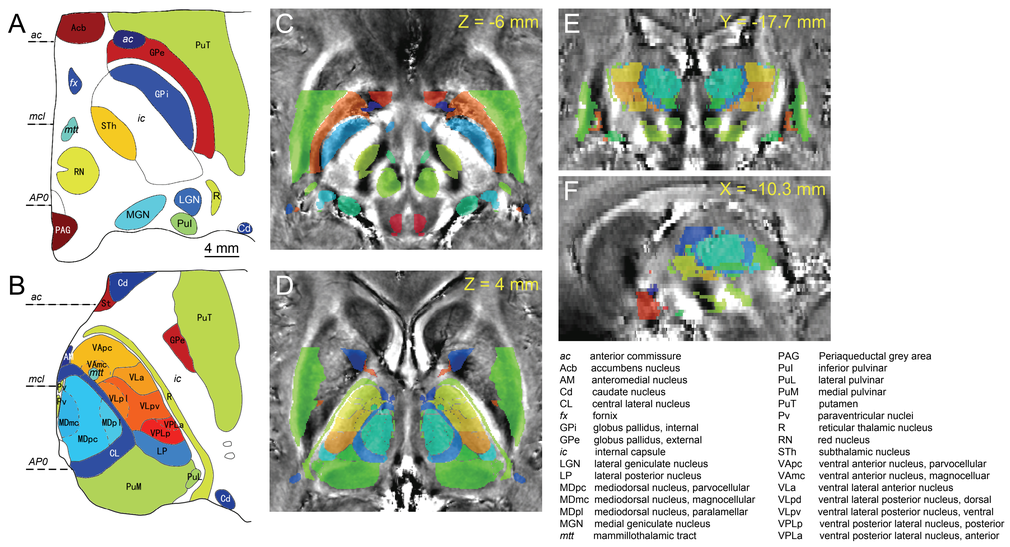

Fig 2. ***A,B)*** *Two slices from Morel atlas. 59 sub-regions are indicated in colors;* ***C,D)*** *Phase maps at corresponding slices overlaid with Morel atlas showing subcortical regions. These sub-regions match the contrast in phase maps;* ***E,F)*** *Coronal and sagittal views of data shown in C) and D).*

Discussion and Conclusions

In subcortical brain regions, brain atlases generated from susceptibility weighted images, and phase images in particular, show a much stronger contrast than T_1-W data. This contrast is attributed to susceptibility induced magnetic field shifts generated by the increased iron content in the GM of this area[4]. Regions in WM such as the internal capsule and optical radiation have abundant myelin, which results in an overall diamagnetic field shift, accentuating the paramagnetic shift in the iron rich basal ganglia and thalamus[5]. Since all sensory pathways relay through distinct region-specific thalamic nuclei, this work in parcellation of thalamic sub-regions based on susceptibility contrast images may provide anatomic guidelines to neuroimaging studies investigating thalamic function and thalamo-cortical pathways.

References

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