High Resolution Imaging of the deep cerebellar nuclei at 7Tesla

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INTRODUCTION

Cerebellar function and underlying anatomy has been investigated during recent years with growing interest and effort, however, a unified theory of its contribution to brain function remains elusive[1]. The deep cerebellar nuclei (dentate, fastigial, globose, emboliforme) are of significant functional importance but difficult to investigate in detail non-invasively because of their small size and tight arrangement. Recent advancement in magnetic resonance imaging (MRI) led to better visualization of these cerebellar substructures. In particular magnetization transfer[2] and high-resolution proton-density imaging techniques[3], as well as susceptibility weighted imaging (SWI) at 7 T have been employed[4]. The aim of this work is to further improve the depiction of the deep cerebellar nuclei with the different strategy of gray matter nulling in an inversion recovery approach. To this end, the inversion time of a 3D-MPRAGE was optimized for gray matter attenuation at 7T and performed with very high spatial resolution (voxel size = 0.275mm^3). The resulting sequence is applied to study the contentious issue of the size and hemispheric asymmetry of the dentate nuclei (DN) in relation to handedness.

MATERIAL & METHODS

26 healthy volunteers (12 female; median age 28, 13 right-handed) were investigated on a 7T MR system (Philips Healthcare, Cleveland, USA) using a quadrature transmit head coil together with a 32-channel receive array (NOVA Medical, Wilmington, USA). A modified 3D-MPRAGE sequence in the sagittal and transverse planes was performed with the following parameters: FOV 200x180 mm^2, TR for Inversion: 3 s, TR: 12 ms, TE: 5.8 ms, readout flip angle α: 7°, acquired voxel size: 0.65 x 0.65 x 0.65 mm^3, 90 slices, NSA =1, acquisition time: 15:34 minutes. To compensate for B_1 inhomogeneity, a highly adiabatic inversion prepulse (hypersecant, duration 22 ms, amplitude 15 μT) was implemented. The acquisition delay (TI) after the inversion prepulse was experimentally optimized and set to 850 ms for gray matter nulling. Nuclei were segmented by three independent examiners using the AMIRA software package (Version 5.4.3, Visualization Sciences Group, Burlington USA). The derived volumes were then analyzed using SPSS 20 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). Cronbach's alpha was calculated to test inter-rater reliability. The relations between mean dentate volumes for each hemisphere (mean over the three raters), sex (between-subjects-factor), handedness, and age (within-subjects factors) were assessed by a repeated measure ANOVA (rmA).

RESULTS

Figure 1 a-d show typical resulting images, reflecting exceptionally high quality towards the delineation of the complex layer structure of the DN (Fig 1 a-d). Cronbach's Alpha (inter-rater reliability) was high with 0.911 (left DN) and 0.934 (right DN). Over all volunteers, mean DN volumes differed significantly ($F = 13.73$, $p = 0.001$) with 995 mm^3 (left DN) and 944 mm^3 (right DN). DN volumes also differed significantly in both hemispheres between male and female (right DN volume male/female; 987 mm^3 / 890 mm^3; $F = 4.77$, $p = 0.039$ and left DN volume male/female; 1042 mm^3 / 940 mm^3; $F = 5.81$, $p = 0.024$).

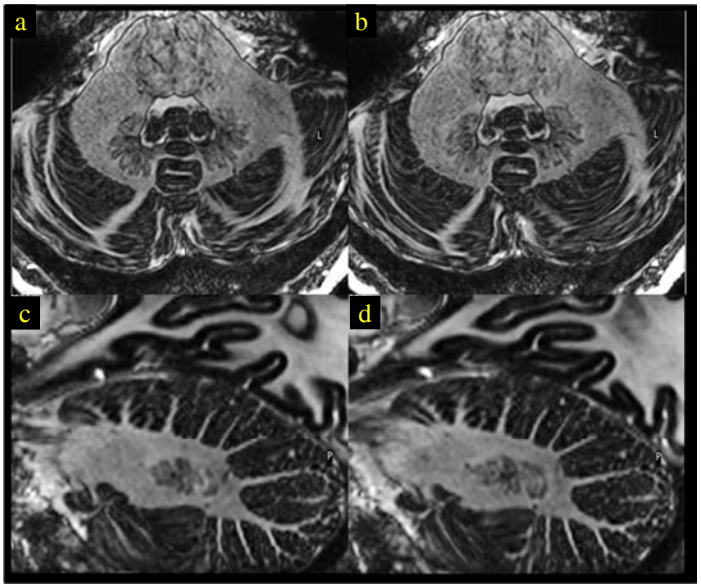

Figure 1: Representative axial images (a,b) and sagittal, multi-planar reconstructions (c,d) illustrating the complex morphology of right and left lateralized dentate nuclei.

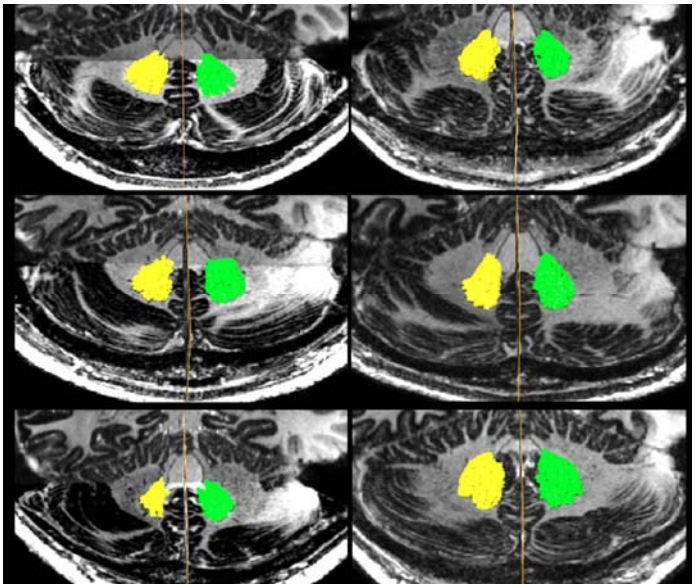

Figure 2: Illustration of the size relation and variability in six subjects for left (yellow) and right (green) DN after segmentation and volume rendering

DISCUSSION

Based on the aim to better visualize and delineate cerebellar substructures (distinctly focusing on the DN), we have explored the use of a modified MPRAGE sequence optimized for gray matter attenuation. The reported results indicate that this strategy is highly effective at generating suitable contrast within the cerebellum. The resulting differentiation of its substructures was readily sufficient for segmentation of the complex DN morphology. From a functional perspective, no relation could be observed between DN volumes and handedness; however, we observed a left > right asymmetry in volume sizes. To date, there is no clear explanation for this finding. Finally we found smaller DN volumes (bilateral) in females, which may be related to the general slight gender difference in brain size.

CONCLUSION

The use of an optimized high resolution 3D-MPRAGE sequence in the gray matter nulling regime at 7 T provides clearly enhanced image contrast ideal to delineate the DN from surrounding tissue. This imaging regime may also provide improved measurement options of adjacent deep cerebellar nuclei like Ncl globose fastigial and emboliforme allowing the investigation of these small cerebellar nuclei with sufficient quality.

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