Highlights: Clinical MR protocols do not capture the complexities of the internal brainstem structure. The segmentation approach presented here uses linear re-scaling and k-mean clustering to identify 6 different gray and white matter subtypes corresponding to different brainstem structures on 3 and 7T MP2RAGE derived T1 weighted and T1 relaxation images.

Abstract

Objective: The brainstem is a complex structure consisting of densely packed and often not well delineated fiber tracts and small nuclei that play a crucial role in a variety of functions including locomotion, sensory processing, autonomic control, consciousness and even cognition. Disturbances of brainstem functions are thought to be an early symptom of several neurodegenerative diseases, e.g., progressive supranuclear palsy, Alzheimer's and Parkinson's disease, and are also known to contribute to other disabling chronic conditions, e.g., chronic pain, stress, sleep disorders and epilepsy. Except for the red nucleus and substantia nigra its internal structures are not well delineated in clinical MR images which complicates early detection and monitoring of brainstem pathology with imaging. The overall goal of this project was 1. To develop a method to segment internal brainstem structures from the images derived from the MP2RAGE sequence. 2. To compare the segmentation performance at 3T and 7T.

Methods: T1 weighted images (UNI) and T1 relaxation maps (T1map) derived from MP2RAGE acquisitions were obtained from two publicly available data sets. 1. 50 healthy subjects who had been studied on a 3T MR for the Leipzig Study for Mind-Body-Emotion Interactions (LEMON) project: 2. 46 healthy subjects who had been studied on a 7T for the Atlasing of the basal ganglia (ATAG) project. 46 7T. The UNI and T1map images were re-scaled using a linear scaling procedure to enhance the gray/white matter contrast and a ratio (RATIO) image from these re-scaled images calculated. The brainstem was extracted and k-mean clustering used to identify 6 different intensity clusters from these 3 images at 3T and 7T. Non-linear diffeomorphic mapping was used to warp the 6 intensity clusters in subject image space into a common space to generate probabilistic group averages/priors that were used to inform the final probabilistic tissue segmentations at the single subject level for each field strength.

Results: The 6 intensity clusters corresponded to 6 brainstem tissue types (3 gray matter clusters and 2 white matter clusters and 1 csf/tissue boundary cluster). Despite being very similar on visual inspection, the quantitative comparison of the 3T and 7T probabilistic averages showed subtle differences which resulted in slightly different results when investigating age-associated brainstem volume losses (see Figure). Further studies are necessary to investigate how resolution and field strength contribute to these differences.

Conclusion: The segmentation approach presented here identified similar brainstem gray and white matter structures at both field strengths. The MP2RAGE sequence is available on Siemens and Philip magnets and acquisition times between 8-12 min make it suitable for clinical imaging protocols. This could have important implications for the early detection of neurodegenerative diseases starting in the brainstem.

Figure