Three-dimensional Segmentation of the Internal Structures of the Human Hippocampus at 7 Tesla

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Introduction

The hippocampal formation is divided into several subfields including the dentate gyrus, the 4 sectors of the Ammon's horn (CA1–CA4), adjacent to the subiculum. These subfields have distinctive histological characteristics and are functionally interconnected. The hippocampal region also contains white matter fibre pathways. The alveus and the fimbria, the main output fiber pathway of the hippocampus, cover CA. In brain diseases involving the medial temporal lobe, these structures can be differentially affected, e.g. neurofibrillary tangles and neuronal loss predominate in the CA1 subfield in Alzheimer's disease, and hippocampal sclerosis predominates in CA1 and CA4 with less damage in CA2 and CA3 regions in temporal lobe epilepsy. Although these structures can not be depicted at 1.5T, previous studies have suggested they can be measured at higher field (4T) [1]. Here, we used whole body 7T to segment in three dimensions the internal structure of the normal human hippocampus.

Material and methods.

Three young healthy volunteers were scanned on a SIEMENS 7T scanner (TrioTim), with a 16 channel head coil. Only the T_2-weighted Turbo Spin Echo sequences were used here, with the following parameters: TR = 4000ms, TE = 77ms, Nex = 1, flip angle: 60°, acquisition matrix 512x512. For the first two subjects, S1 and S2, in plane resolution was 0.375mm², interpolated to 0.1875mm², with slices of 1.2mm and 1.1mm thickness, and a gap of 0.2mm and 0.3mm. For the third subject S3, in plane resolution was reduced to 0.25mm², with no interpolation, on 1.3mm thick contiguous slices; for this last subject, the sequence was repeated three times, the three volumes were co-registered with SPM5, and averaged. The acquisition time was about 8 minutes per acquisition.

The manual segmentation was performed with the ROI module of the Anatomist software (http://www.brainvisa.info/index.html), according to the anatomy of the hippocampus as described in Duvernoy [2].

Results.

We were able to clearly differentiate six subparts of the hippocampus. The hypointense signal corresponding to the stratum moleculare of the cornu ammonis (CA) drives the segmentation of the inner structure [3]; it is considered as a "white matter layer between CA1-3 and the dentate gyrus". The alveus and the fimbria were also hypointense and easily delineated. In the body and tail, the end of the alveus corresponded to the end of the grey matter ribbon of CA. The grey matter was divided into the first 3 segments of CA (CA1-3), the hilum of the dentate (corresponding to the dentate proper and CA4), and the subiculum, according to geometrical limits. Segmentation results are shown in Figure 1. The most anterior part of the hippocampus was not covered for subject S2.

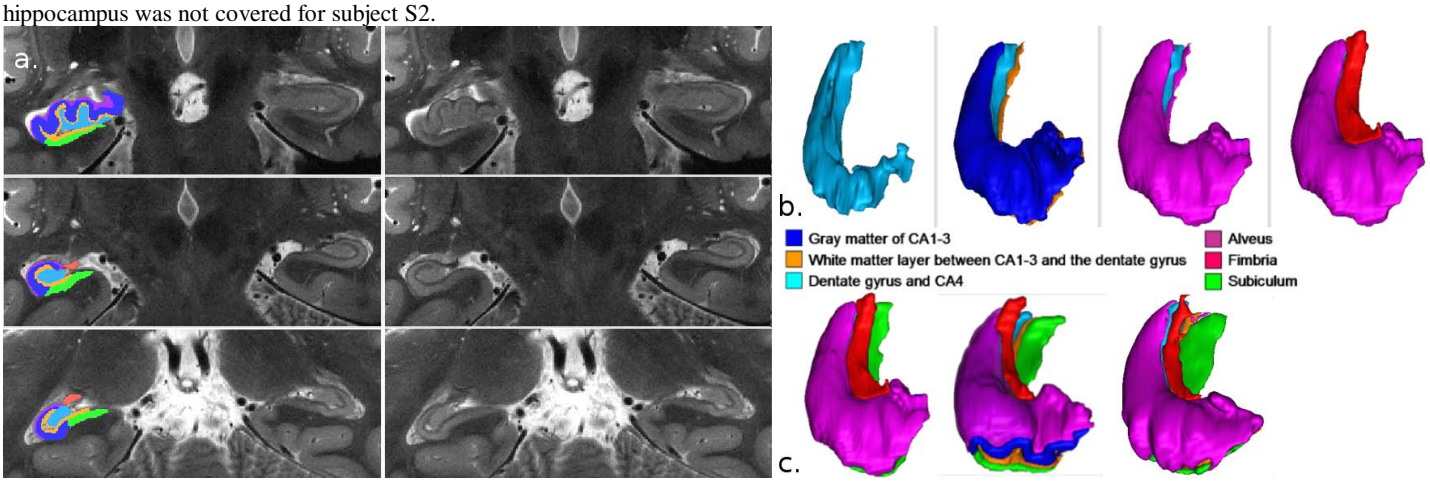

Figure 1. Manual segmentation results: a. 3 coronal slices (top: head, middle: body, bottom: tail) for subject S3. b. 3D surface rendering of the segmented subparts for subject S1. c. 3D surface renderings for all the segmented subparts for the three subjects

Conclusion.

T_2-weighted images at very high field provide improved anatomical contrast. It was possible at 7T to precisely segment the hippocampal subparts in images acquired in vivo. Further studies will be necessary to evaluate the contribution of other sequences, such as gradient echo and susceptibility-weighted images, as well as intra-rater and inter-rater reliability of this manual segmentation protocol on a larger group of subjects. The use of three co-registered acquisitions allows reducing voxel size, but so far does not allow the discrimination of the stratus granulosum of the dentate gyrus.

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