Measuring cortical thickness of the human brain using ultra high resolution data

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INTRODUCTION

The analysis of the human cerebral cortex and the measurement of its thickness based on MRI data provide insight into normal brain development and neurodegenerative disorders. Accurate and reproducible results of the cortical thickness measurement are desired. In addition to data processing tools, the quality (i.e. resolution) of the imaging data is evaluated. We thus compare ultra high resolution data acquired at 7T with 3T data for measuring the cortical thickness of the human brain.

MATERIALS AND METHODS

Six healthy male European adults were scanned on 3T (1mm isotropic resolution) and 7T (1mm and 0.5mm isotropic resolution) systems (Siemens, Erlangen, Germany) with corresponding 3D MP-RAGE and 3D gradient echo methods. SPM8 [1], FSL [2], FreeSurfer [3], 3D Slicer [4] and ARCTIC [5] (3D Slicer module) were used to segment the brain and measure its cortical thickness.

SPM8 was used for intensity correction based on the 3D-GE data as introduced by van de Moortele et al. [6]. With FreeSurfer only the 1mm³ data was processed, as it is currently not possible to fully process data with a higher native resolution.

To process the 0.5mm³ data three different fully automatic segmentation tools were used first: ARCTIC, SPM8 and FSL. These segmentations were used within ARCTIC to determine the cortical thickness. FreeSurfer was used to create skull stripped volumes for the segmentation with SPM8 and FSL.

RESULTS

The cortical thickness determined from the 1mm³ data at 3T and 7T is very similar. However, the difference between the 3T or 7T 1mm³ and 7T 0.5mm³ data is very significant (see Tab. 1). The temporal lobes have been excluded due to contrast inhomogeneities in this region at 7T (imperfect adiabatic inversion).

It was also discovered that FSL is more suited for the segmentation of the brain at ultra high resolution than SPM8 or ARCTIC. As seen in Fig. 1 for example the CSF in the sulci is recognized best using FSL. The cortical thickness results based on the different segmentations are shown in Tab. 2.

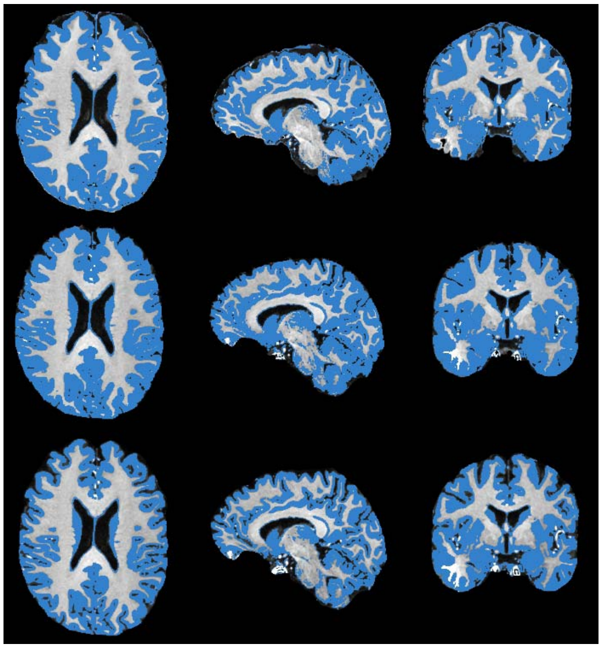

Fig. 1: Different tools used to segment gray matter of 7T data with an isotropic resolution of 0.5 mm. Top to bottom: ARCTIC, SPM8, FSL

	1mm (3T)	1mm (7T)	0.5mm (7T)
Left hemisphere			
Frontal lobe	3.56 ± 1.33	3.62 ± 1.73	2.40 ± 1.46
Parietal lobe	2.94 ± 1.18	2.79 ± 1.15	2.08 ± 1.13
Occipital lobe	2.82 ± 1.58	2.62 ± 1.71	1.72 ± 1.08
Right hemisphere			
Frontal lobe	3.56 ± 1.37	3.64 ± 1.74	2.40 ± 1.44
Parietal lobe	2.97 ± 1.22	2.94 ± 1.27	2.08 ± 1.15
Occipital lobe	2.99 ± 1.78	2.78 ± 1.92	1.73 ± 1.16

Tab. 1: Mean cortical thickness in mm of six healthy male European adults processed completely with ARCTIC using different resolutions and scanners. 3T: MP-RAGE; 7T: intensity corrected volume. The standard deviation is not a criterion for accuracy, but reflects the anatomical variance in these regions.

	ARCTIC	SPM8	FSL
Left hemisphere			
Frontal lobe	2.40 ± 1.46	2.68 ± 1.32	1.86 ± 0.91
Parietal lobe	2.08 ± 1.13	2.70 ± 0.97	1.78 ± 0.75
Occipital lobe	1.72 ± 1.08	2.38 ± 1.04	1.62 ± 0.68
Right hemisphere			
Frontal lobe	2.40 ± 1.44	2.61 ± 1.20	1.83 ± 0.88
Parietal lobe	2.08 ± 1.15	2.65 ± 0.98	1.77 ± 0.76
Occipital lobe	1.73 ± 1.16	2.22 ± 1.04	1.58 ± 0.70

Tab. 2: Mean cortical thickness in mm of six healthy male European adults processed with ARCTIC using 0.5mm isotropic intensity corrected volume and different tools for initial segmentation. The standard deviation is not a criterion for accuracy, but reflects the anatomical variance.

DISCUSSION

The difference between the results of the 1mm³ and 0.5mm³ data is likely to be caused by reduced partial volume effects and therefore more accurate segmentations for higher resolution. This implies a bias of the segmentation to overestimate gray matter for lower resolution. It can be assumed that the ultra high resolution data acquired at 7T leads to more accurate results of the cortical thickness compared to lower resolutions. This is supported by the lower variation between the segmentation methods and that the cortical thickness reduces independently of the segmentation tool at higher resolutions. FSL should be used as the segmentation tool, as better visual results and less anatomical variance in the results of the cortical thickness have been achieved, though the gray matter is sometimes underestimated.

To process ultra high resolution 7T data, it is useful to combine the advantages of various software applications. We propose a processing pipeline for measuring the cortical thickness of the human brain from 7T data by using SPM8 for inhomogeneity correction, FreeSurfer for skull stripping, FSL for segmentation and ARCTIC for the measurement of cortical thickness.

ACKNOWLEDGEMENTS

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