

# High-resolution diffusion tensor imaging of the hippocampus: a comparative study of multi-shot vs. single-shot acquisitions

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**Introduction:** The hippocampus is known to be susceptible to a wide variety of neurologic diseases including Alzheimer's disease (AD) [1] or temporal lobe epilepsy (TLE) [2]. Early pathological changes may be presented as slight signal difference, but they are not always easy to detect. DTI is a promising method to identify pathologic changes of hippocampus and its surroundings in the brain, and quantitative analysis of DTI indices allows us to make early diagnosis of AD or to provide lateralizing information in unilateral TLE. As the hippocampus has a complicated structure and surrounded by cerebrospinal fluid (CSF), high resolution DTI may give us accurate localization with less partial volume artifacts of CSF, but it is susceptible to low SNR. Therefore, we investigated reproducibility of high-resolution DTI measurements of ADC and FA by using two latest high-resolution DTI sequences: multi-shot Readout-Segmented EPI with 2D navigator-based reacquisition DTI (RS-DTI) [3,4], and single-shot advanced DTI (Adv-DTI), which enable to shorten TE with less distortion by using single refocusing pulse sequence with image based non-affine registration for reducing residual eddy-current induced distortion. Both were provided by Siemens as WIP. Distortion was also compared between them.

**Methods:** RS-DTI and Adv-DTI of the hippocampus were acquired in axial images, parallel to the long axis of the hippocampus in 10 healthy subjects (7 males, 3 female, age range: 27-44 years, average 32.2 years old) after obtaining written informed consent. All subjects were scanned by a 3T MR scanner (MAGNETOM Trio, A Tim System, Siemens AG, Erlangen, Germany) with a 32-channel head coil. RS-DTI was scanned in 5min 17sec with TR 7000ms, TE 70ms and readout segments 5. Adv-DTI was acquired in 5min 43sec with TR 7000ms, TE 75ms, parallel imaging factor 2 and 6 averages. Both scans had the same parameters of FOV 210mm, matrix 192x192, in-plane resolution 1.1x1.1mm, slice thickness 2.2mm, number of slices 40. MPGs were applied in 6 directions with  $b=1000s/mm^2$  and  $b=0s/mm^2$ . As an anatomical reference, T2-weighted images (T2WI) and 3D T1-weighted images (MPRAGE) were also acquired. These measurements were repeated twice for each subject about 1 month interval. Both RS-DTI and Adv-DTI were coregistered to the T2WI image by affine transformation. To measure ADC and FA values, ROIs were manually placed at 3 areas of the hippocampus (head, body and tail), white matter of temporal lobe and lateral ventricles (placed at inferior and posterior horns, averaged) on B0 image, which were applied to ADC and FA images. Percentage differences between the first and second scans were calculated and statistically compared by using paired t-test. A  $P$  value  $< 0.05$  was considered significant. Displacement at ambient gyrus, hippocampal head and tail in phase encoding direction between T2WI and B0 images was measured and considered as a geometric distortion. To illustrate areas with high percentage difference in this subject group, T2WI, ADC and FA images were coregistered to a MPRAGE and anatomically normalized, and corresponding areas were summed and rendered on a high-resolution template [5,6].

**Results:** ADC and FA values at hippocampal head, body, tail, white matter and CSF are summarized on Table.1. ADC values at hippocampal head and WM was slightly higher than others on RS-DTI. FA values on Adv-DTI were comparable to previously reported values, but they were much higher on RS-DTI. Percentage difference of test-retest ADC measurements of two methods are presented on Figure 1. Averages of percent difference were higher on RS-DTI, but significant difference was observed only at the body of the hippocampus. The differences were more than 10% at the CSF, which was much higher than other areas. Voxels with higher percentage difference than 10% was selected in each subject, and number of subjects over this threshold was presented by overlaying them on a standard brain image (Figure 2). Results of distortion analysis are presented on Figure 3. RS-DTI had much less distortion than Adv-DTI.

**Discussion and Conclusion:** In a clinically acceptable scan time around 5 minutes, both DTI scans showed high reproducibility of ADC measurements. FA values were much higher in RS-DTI, which may be attributable to lower SNR caused by multi-shot acquisition. However, RS-DTI had much less distortion and more accurate population-based analysis would be capable for an ADC evaluation. On the other hand, Adv-DTI had higher reproducibility of ADC and reliable measurements of FA values within a reasonable scan time. If a scan is focused on ADC, RS-DTI would be a better choice, but Adv-DTI should be selected if FA is also required despite somewhat higher distortion. In either case, CSF had much higher variance and it had better be excluded from further analysis. A high resolution B0 image can be used for segmentation, and effect of CSF would be excluded from ADC and FA analysis as in the voxel-based morphometry.

**References:** [1] Mielke MM et al., NeuroImage 2009;46:47-55, [2] Yoo et al., AJNR 2003;23:809-812, [3] Porter et al. MRM 2009;62:468-475, [4] Holdsworth et al. MRM 2009;62:1629-1640, [5] Vladimir Fonov et al., NeuroImage 2011;54:313-327, [6] Vladimir Fonov et al., NeuroImage 2009;Vol.47,Suppl.1:S39-S41

	hippo_head	hippo_body	hippo_tail	WM	CSF
Adv-DTI	ADC 0.730±0.045	0.729±0.038	0.731±0.039	0.638±0.060	2.052±0.539
	FA 0.184±0.021	0.198±0.034	0.189±0.023	0.348±0.050	0.093±0.039
RS-DTI	ADC 0.766±0.058	0.730±0.053	0.731±0.048	0.710±0.052	2.079±0.374
	FA 0.312±0.031	0.317±0.043	0.317±0.032	0.439±0.055	0.166±0.051

Table 1: Each value represents mean ± standard deviation. ADC values are expressed as  $1 \times 10^{-3} \text{ mm}^2/\text{s}$

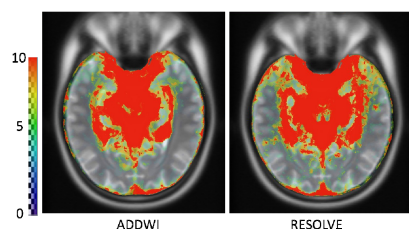


Figure 2: Voxels with higher percentage difference than 10 %

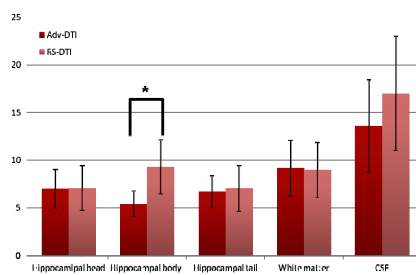


Figure 1: Percentage difference of test-retest ADC \*:  $P < 0.05$

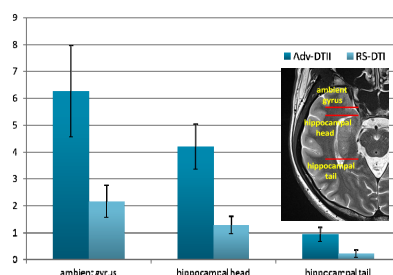


Figure 3: Geometric distortion (mm)