Automatic segmentation of deep grey matter structures for the assessment of DTI images

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Introduction
Diffusion Tensor Imaging (DTI) can detect pathological changes in the microscopic tissue environment of the central nervous system [1,2]. One current limit to the use of this modality in the diagnosis of neurodegenerative diseases is the need to manually define brain structures of interest for quantification. This procedure is time-consuming, requires experienced operators and results are sensitive to inter/intra-rater variability [3]. Automatic segmentation would overcome these problems, but is hindered by the low tissue contrast inherent in DTI acquisition, and typically by its low spatial resolution, which lead to partial volume effects [4]. We evaluated the replacement of manual segmentations by the automatic segmentation of structures of interest on DTI maps using high resolution T1-weighted images.

Methods

Control subjects. Ten healthy subjects (age 40±11 [mean±sd]; 7 male) were studied using a 1.5 T GE Signa Horizon LX. A T1-weighted axial volumetric image was acquired using the FSPGR sequence; TE=600 ms; TR=5.1 ms; TR=12.5 ms; 25.6 cm square FOV, 1 mm slice thickness; in-plane resolution=192x192; NEX=2. DTI parameter maps of mean diffusivity (MD) were generated using DTIFIT (FSL) [5]. Automatic segmentation of the volumetric image was performed using FIRST (FSL) [5] to bilaterally define four grey matter structures of interest – caudate, putamen, thalamus, pallidus. These structures were registered onto the DTI maps by affine, followed by non-linear, registration (AREG/NREG; FSL) [5]. The same structures were delineated manually by 5 experienced raters directly on the DTI maps. A consensus segmentation was defined using the STAPLe algorithm [6]. MD values were compared for each structure using automatic and manual segmentations. To avoid partial volume effects, we automatically defined masks to exclude CSF and white matter (WM) from segmented structures.

Patients. The above protocol was applied in 3 patients, with established diagnoses: Patient 1 (35 y.o./M) Creutzfeld-Jakob disease; Patient 2 (51 y.o./F) spastic dystonia syndrome homoplasmic for LHHN mDNA mutation G14459A/ND6. Patient 3 (64 y.o./M) progressive supranuclear palsy ( PSP). These cases were expected to result in altered MD in deep grey matter compared to control values.

Results

Control subjects. For each subject left and right structures were compared, and no significant differences were found, either for manual or automatic segmentation. Masking the automatically-defined structures (to exclude CSF and WM) reduced the number of pixels selected by a mean of 7%, 15%, 2% and 7% respectively for caudate, pallidus, putamen and thalamus. The result was a significant reduction in mean MD for caudate, putamen and thalamus. Comparisons of MD quantification using masked manual and automatic segmentation are shown in Fig. 1. Paired t-testing revealed that manual and automatic segmentation gave a different result in the caudate, but not in the pallidus, putamen or thalamus. However the automatic segmentation appreciably reduced the SD in caudate (from 0.022 to 0.016 ×10^-3 mm^2.s^-1).

Patients. Comparisons of MD for automatically segmented deep grey matter structures are shown in Figure 2. Patient 1 shows a decrease of MD in caudate and putamen. The alteration of MD is more evident in both structures on the left side. Conversely patient 2 shows an increase of MD in caudate, pallidus and putamen. Similarly, in patient 3, MD was increased in all deep grey structures.

Discussion

Visually, structures derived from segmentation of volumetric imaging register reasonably well onto the DTI images, but some additional processing is needed to reduce the influence of partial volume effects. The automatic segmentation procedure was able to reproduce MD values similar to those derived from manual segmentation in 3 out of 4 structures considered. In the caudate, MD values were lower, possibly due to the fact that manual segmentation selected only the head of the caudate while the whole structure was selected by the automatic procedure. In automatically-selected anterior caudate MD values were slightly increased (0.783 vs 0.775 ×10^-3 mm^2.s^-1) for the whole structure). In addition, manual segmentation may include pixels of ventricle partial volume which the CSF mask is unable to exclude. The results from the patients were in line with expectations.

Registration was successful even in the case of patient 2, where the dimensions of deep grey matter structures were reduced due to necrosis (Fig. 3). In some cases, where the MD was visibly altered by pathology, some pixels were erroneously masked out of the structure. In such cases there will have been a reduction in apparent MD, even though the results at least for the test case, were decisively abnormal.

References