Image coregistration of diffusion tensor imaging and structural MRI data of the MIDA model
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Introduction: Computational modeling is used to calculate the electric field distribution due to low frequency stimulation devices, including deep brain stimulators (DBS). Such modeling requires a detailed structural model and anisotropy information [1]. The Multimodal Imaging-Based Detailed Anatomical (MIDA) model [2], generated from the structural Magnetic Resonance Imaging (MRI) data, provides 153 anatomical structures of the human head and neck. Inclusion of tractography through Diffusion Tensor Imaging (DTI) provides anisotropy information. The original MIDA work included DTI; however, the result can be improved by fine-tuning image coregistration of DTI and structural MRI. In this study, we focused on optimizing image coregistration methods and compared the outcome with the original DTI values.

Materials and Methods: The following MIDA MRI data were used: 1.4x1.4x2.5mm3 Diffusion Weighted Imaging (DWI) data acquired with 32 gradient directions and 0.5mm-isotropic structural data acquired with T1 and T2 contrast. The T1 data was first processed with Freesurfer [3,4], which was required for the subsequent diffusion pipeline. The tensor information was calculated from DWI using FreeSurfer’s dt_recon pipeline. The DTI results were overlaid onto the T2-weighted dataset with five different coregistration methods including three rigid and affine algorithms (boundary-based registration [5], Image Registration Toolkit (IRTK) [6], and Advanced Normalization Tools (ANTSs) [7]), as well as two non-rigid algorithms (IRTK [8,9] and the SyN algorithm in ANTs). For coregistration with the SyN algorithm, a number of parameters were optimized: image similarity metric, bias correction, initial moving transform, and interpolation. The fractional anisotropy (FA) and apparent diffusion coefficient (ADC) values were calculated in seven white matter (WM) regions relevant to DBS modeling: Amygdala, Caudate Nucleus, Hippocampus, Globus Pallidus (GP), Nucleus Accumbens, Thalamus, Putamen. The average FA and ADC values in each region were compared to the ones from the original DTI results without any coregistration applied.

Results and Discussion: Some misalignment was found in rigid coregistration with FreeSurfer and IRTK (Fig. 1A), such as the edges of the cortex and the corpus callosum. The misalignment in non-rigid IRTK was minor (Fig. 1B); however, the coregistered image was not compatible with tensor and vector reorientation thus resulted in a loss of the directionality. The ANTs SyN algorithm (Fig. 1C) was able to align the images and reorient tensor information. The SyN algorithm was sensitive to interpolation method; small differences in mean ADC were found in the GP. The mean ADC value calculated with BSpline were 10 times larger than the original mean value. The mean ADC value calculated with nearest neighbor were within one standard deviation compared to the original mean value. The GP in the T2 data showed a distinct intensity difference compared to surrounding tissues. This may account for the increased sensitivity in coregistration which resulted in differences in mean ADC.

Translational Impact: DTI data was successfully coregistered on submillimeter T2 data using ANTs SyN non-rigid coregistration with nearest neighborhood method. Our results are in agreement with the 1x1x1 mm3 results reported by Klein et al. [10]. Future studies include incorporating the calculated tractography (Figure 2) in the computational modeling platform. These fiber tracts can help determine the anisotropic electric conductivity of WM tissues.

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