Population-based human brain MRI atlas with sharp contrast and its application in image registration

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Introduction: MRI has been widely used in non-invasive study of morphological changes in the human brain neurodegenerative diseases. The image registration of MR images becomes an important step in statistical analysis by incorporating information into an atlas space. Highly elastic image transformation tools require a template with sharp anatomical definition and, thus single-subject (SS) templates are often used. However, a SS template may introduce bias in anatomical quantification. By using the newly developed template estimation technique [1] for image mapping, we aim to generate group-based atlases for normal aged and age-matched AD subjects, with unbiased structures and sharp tissue contrasts. The new atlases were compared with a conventional SS [2] and group-based atlases for the normal aged dataset to demonstrate their advantages. Improvement in registration accuracy was also observed.

Methods: T1-weighted MRI data from 12 normal aged subjects (age 75 ± 5.9 years old) and 12 age-matched Alzheimer's disease patients (age 75 ± 4.2 years old) were included in this study. MR images were skull-stripped, affine transformed to the ICBM152 coordinate, and re-sampled to 181x217x181 with 1 mm isotropic resolution. For normal aged dataset, we selected one subject's image as an initial template, and the weighted-LDDMM image matching algorithm[1] was applied to estimate the template based on the observed population (the process called VTE, Volume image based Template Estimation). The AGA and NGA images were generated by averaging after affine and nonlinear mapping of the 12 normal aged images to an SS atlas [3] (also in ICBM152 coordinate), respectively. Volumes of 24 subcortical brain structures were measured in the VTE atlas, SS atlas and subject images via manual segmentation, and were normalized by each mean value of the structure from the dataset. For the age-matched AD dataset, VTE-AD atlas was generated, and the image registration accuracy of nonlinear mapping by using 1) a general SS atlas, 2) a single subject within the group as atlas, and 3) VTE atlas was examined by kappa analysis on the 24 manually delinated subcortical structures.

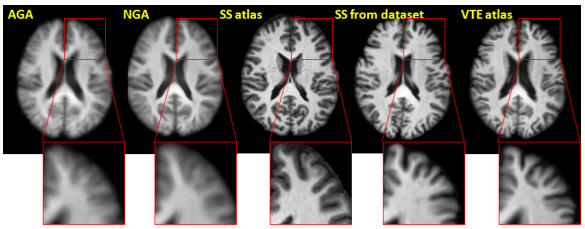

Fig.1. Comparison of brain atlases for normal aged subjects. VTE atlas has similar structural geometry as group-based AGA and NGA; and has preserved image sharpness as the SS from dataset.

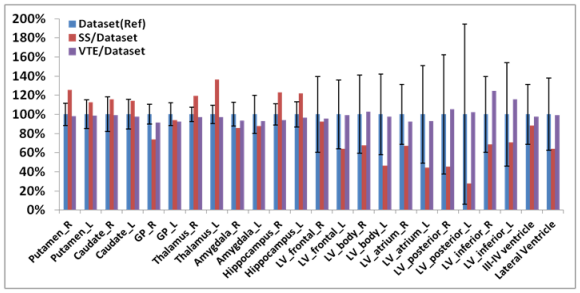

Fig.2. The normalized volume measurement for 24 subcortical brain structures for normal aged dataset, SS atlas and VTE atlas images. The volumes in VTE atlas (purple) approximated the mean volumes of dataset (blue) within 10% range, while the SS atlas (red) has severely biased structural volumes from the data means.

Results and Discussion: In Fig.1, the VTE atlas has sharper structural contrast than the AGA and NGA atlases. In terms of anatomical bias, the subcortical structure volumes in the VTE atlas approximate the mean volumes of the 12 subjects within 10% range of the group average volumes, while the volumes of several structures in the SS atlas were significantly biased (see Fig.2). Fig.3 shows the VTE atlases for normal aged and AD populations. Each atlas presents its population averaged morphological features with clear anatomical definition, including the severely enlarged ventricles due to tissue atrophy. The comparison of registration accuracy for the AD population (Fig.4) shows that by using VTE-AD atlas, more accurate and stable (less dependency on deformation elasticity) registration accuracy can be achieved compared with SS atlas, especially for the ventricles and neighboring structures. The results suggested that the group-specific VTE atlas, which minimizes the amount of deformation between template and subject images, can improve the image mapping performance and provide us more reliable results for morphological analysis based on segmentation or voxel based analysis.

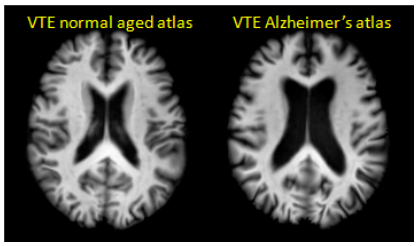

Fig.3. The VTE atlases for the AD patients (right) and age-matched controls (left).

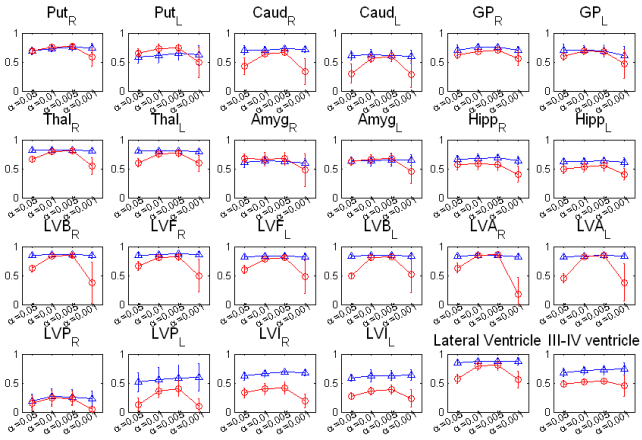

Fig.4. The kappa values of AD dataset for 24 subcortical structures by using SS (red) and VTE atlas (blue) for image registration. Four parameter values of registration were examined. VTE atlas achieved more stable and higher kappa values than the SS atlas, especially for the ventricles and neighboring structures.

References: [1] J. Ma, *et al.*, Neuroimage. 2008, 42(1): 252-261. [2] K. Oishi, *et al.*, Neuroimage. 2009, 46(2): 486-499.

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