Establishing Probabilistic Chinese Human Brain Templates using HAMMER Elastic Registration Algorithm

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INTRODUCTION Neurological diseases cause significant health problems, which affect human life quality severely. MRI has been a powerful imaging tool to diagnose normal and abnormal brain anatomical structures and functions non-invasively. Up to date, the most widely-used human brain templates for neuroscience studies are the Talairach brain coordinate system and the standard MNI (Montreal Neuroscience Institute) brain templates, which were generated from a series of MRI scans based on people of the western society [1]. However, fundamental genetic and environmental disparities between Chinese and Western human subjects result in the overall and regional difference of brain shape and volumes between the two groups. Such difference may cause mis-localization of activated brain regions during functional MRI and other cognitive science studies. It may also cause positional mismatches during the image-guided stereotactic neurosurgery for Chinese patients when using the MNI templates. Therefore, there is a necessity and vital importance to develop the Chinese digitized standard brain (DSB) templates as the basis of Chinese human brain projects for brain research [2]. Here we present a preliminary study to construct Chinese human brain templates using the automatic deformable HAMMER (Hierarchical Attribute Matching Mechanism for Elastic Registration) registration software. HAMMER was proved to be a robust registration algorithm which yields high resolution and sharp average brain templates with high accuracy [3].

METHODS 14 female and 12 male healthy volunteers were involved in this study. They were aged between 20 to 30 years old with no obvious brain abnormalities. The average age was 24.3+/-0.6 yrs for the female group and 26.1+/-0.4 yrs for the male group. The traditional T_1-weighted images were acquired using the 3D T_1-weighted MP-RAGE sequence on a Siemens 1.5T Sonata scanner in Beijing Xuan Wu Hospital. Image parameters were set as follows: flip angle=15°, TR/TE/TI=2000/4 ~ 4.5/1100ms with 192 slices, slice thickness (ST)=1mm, image field of view (FOV)=256x256mm^2, in-plane image resolution=256x256, resulting in an isotropic voxel size of 1x1x1mm^3. Total imaging time was 13min per 3D data set. The MR images were preprocessed before running the HAMMER registration algorithm. These preprocesses included format conversion (MRIConvert), reorientation to AC-PC position, alignment to the same brain position by MIPAV, skull stripping by BET2 and tissue segmentation to gray matter (GM), white matter (WM), and ventricles (VN) via FSL (FMRIB Analysis Group, Oxford, UK). Cerebellum was retained to keep the brain intact during the HAMMER normalization procedure. We have employed the following strategy in generating brain templates for each group. First, by examining the aligned preprocessed individual images, a middle-sized brain for each group with intact brain structures and brain symmetry was picked up by an experienced radiologist, and served as the initial brain template when running the HAMMER program. All other aligned brain samples (N-1) within each group were aligned with their respective template, and deformation fields were recorded during each registration. The (N-1) deformation fields were then averaged to generate an average deformation field, used to transform the current template to the new place and then a nearby brain sample was picked up as a new template. With the new template, the whole registration procedure would be repeated until the whole process converged. Finally, all brains in each group were normalized to the same space and the results were averaged to generate an average brain image. With increase of brain samples, the average brain image can be served as the Chinese human brain template for different age and gender, to be used for volumetric and regional group analysis in the future studies.

RESULTS Fig.1 demonstrates the axial views of images during automatic normalization by HAMMER. (a), (d) display the individual brains finally selected as male and female templates by the registration procedure described above; (b), (e) are the original subject images, and (c), (f) represent the warped images. The major brain morphological structures of the original images were deformed hierarchically to the templates. The shapes of gross and regional structures of the warped images matched the templates quite well. The template of the female group was smaller than the male group in our study. Fig. 2 shows the average brain images for the male and female groups in three orthogonal views with HAMMER registration. The edge sharpness of the average warped brain images was shown as a visual proof of the accuracy of the HAMMER normalization algorithm. Table 1 lists the Chinese brain characteristics measured quantitatively from the male and female average brain images compared with the MNI data set (average age=23.4+/-4.1yrs). The Chinese brain templates were generally smaller in length and height than the MNI templates of the western society. Instead, the width/length ratio for the average Chinese brain was larger than the MNI brain template, i.e., the Chinese human brain was more spherical, which was consistent with a previous report from Taiwan [4]. The parameters of brain dimensions of the female group were smaller than the male groups, as mentioned above. This observation may not be the same when we conduct the study on a larger data set of Chinese people in the future.

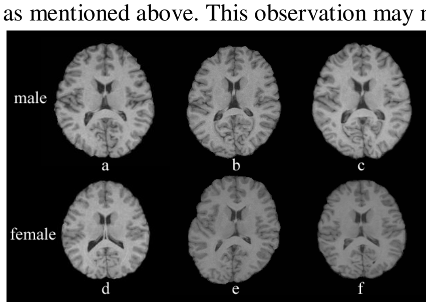

Fig.1.Demonstration of the normalization process by HAMMER.

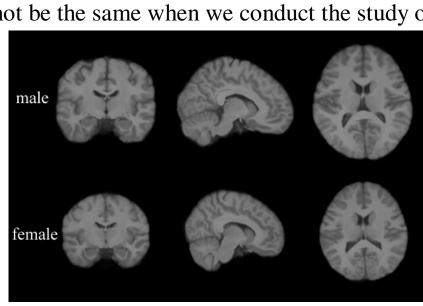

Fig.2. The average normalized brain images for the male and female groups.

DISCUSSION The accuracy of volume analysis relies heavily on perfect registration between the templates and individual images. Our original brain images have a wide variability of brain shape and size, including ventricular size and shape and other major brain structures. Notably, using HAMMER registration, the average brain images have sharp boundaries of cortices, ventricles, WM and GM regions, compared to other registration results [1,4]. This advantage renders HAMMER a powerful registration algorithm for statistical analysis during group studies. In the future, we plan to further apply the HAMMER registration algorithm to a large database of the Chinese human brain project, and generate the templates which will fit better to Chinese human groups with different age and gender.

Table 1. Brain characteristics measured from the male and female Chinese brain templates vs. the MNI data set.

	Chinese Male	Chinese Female	MNI
Length(L)	16.1± 0.3cm	15.3± 0.2cm	17.6±0.2cm
Width(W)	14.6± 0.1cm	13.6± 0.1cm	14.0±0.2cm
Height(H)	10.3± 0.1cm	9.6± 0.1cm	12.0±0.2cm
W/L Ratio	90.68%	88.89%	79.55%
H/W Ratio	70.55%	70.58%	85.71%
H/L Ratio	63.98%	62.75%	68.18%

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