Construction and segmentation of pediatric head tissue atlases for electrical head modeling

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Introduction:

Accurate population models of head tissue geometry and conductivity are essential for accurate source localization in electroencephalography (EEG) and precise targeting in transcranial electrical stimulation (TES). The work described here is part of a larger effort to build a comprehensive set of age-specific pediatric head models, based on merging multiple imaging modalities (structural MRI, CT, diffusion-weighted MRI, Electrical Impedance Tomography (EIT)) to enable creation of atlases of soft tissues, skull mineralization density, and anisotropic electrical conductivity of white matter (supported by NIH grant R44 MH106421).

Here we describe our construction of average T1 MRI atlas images, and compare two approaches for segmentation. Using images obtained from the NIH Pediatric MR Database (Evans 2006, Almli et al 2007), we calculated a series of atlases in 4 month age increments from 0 to 1 year, from 1 to 2 years, then in 2 year age increments (2-4 years, 4-6 years, etc.), from ages 2 to 18.

Our ultimate goal being the production of head conductivity models, we are especially interested in accurate segmentation of these atlases; electrical head models (i.e. lead field matrices) can then be computed based on assigning electrical conductivities for different tissue types consistent with known values from the literature (e.g. Salman 2005). We use BrainK (Li et al, 2016), which computes a segmentation based on a single MRI image, using internal skull templates for skull segmentation. For an atlas computed from a collection of individual images, such a tool can be used in two distinct ways: a) directly segmenting the average atlas ("direct atlas segmentation"), or b) segmenting each individual MRI image, and then aggregating the individual segmentations ("aggregate atlas segmentation").

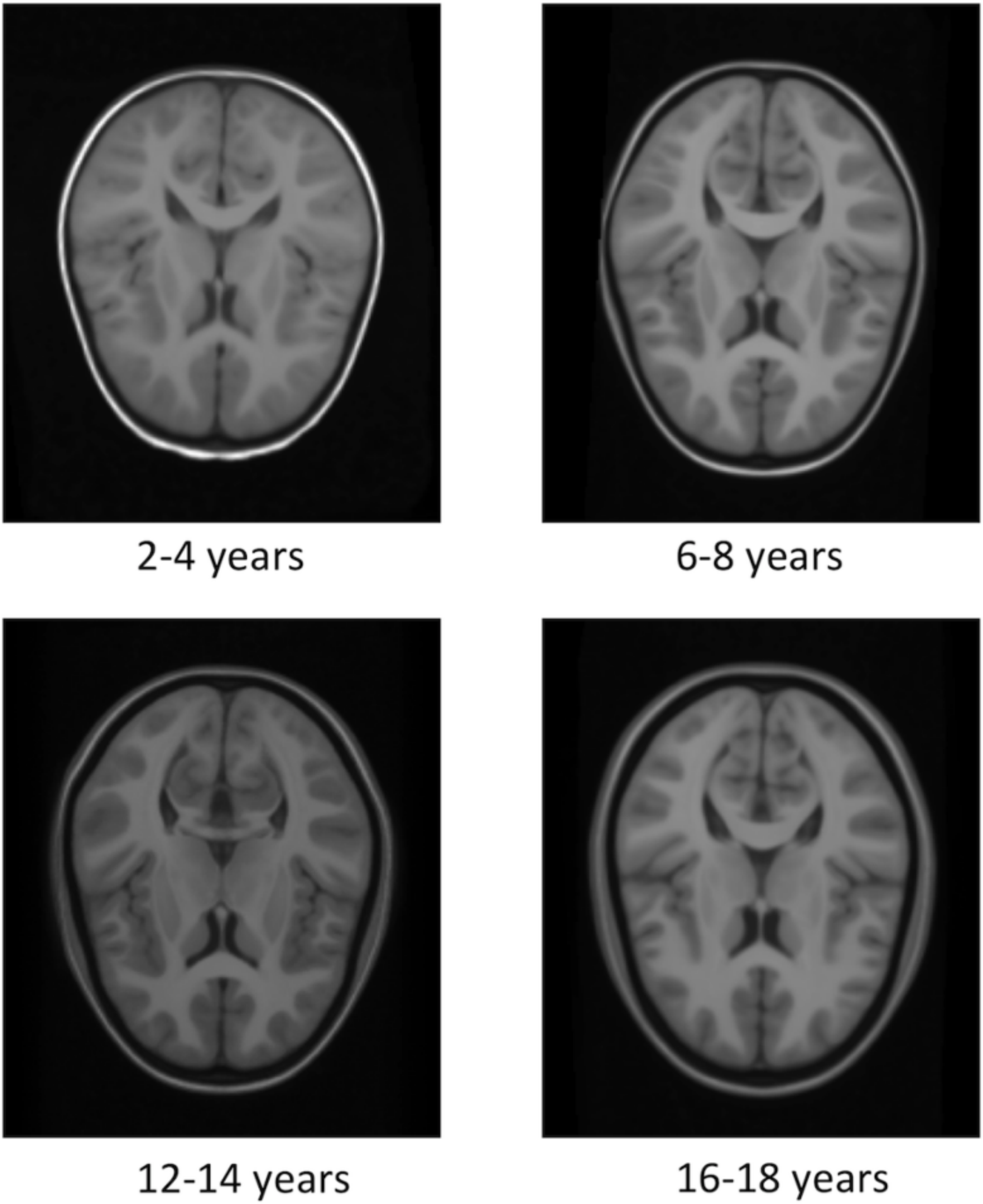
Methods:

Our average MRI atlases were based on a set of 736 T1-weighted MRI images obtained from the Pediatric MRI Data Repository, created as part of the NIH MRI Study of Normal Brain Development (https://pediatricmri.nih.gov/nihpd/info/index.html). For each age group, we computed atlas images by iterating the following : 1) Given a current template, compute transformations (from a set of transformations allowed at this iteration) registering each individual image onto the the template; 2) Average these transformed images to give the template for the next iteration. We organized our calculations in stages, the first allowing only rigid rotations, the second only affine transformations, and the third allowing nonlinear transformations. All transformations were computed using the ANTs software (Tustison et al, 2014), using symmetric normalization (SyN) based on the neighborhood cross correlation (CC) metric.

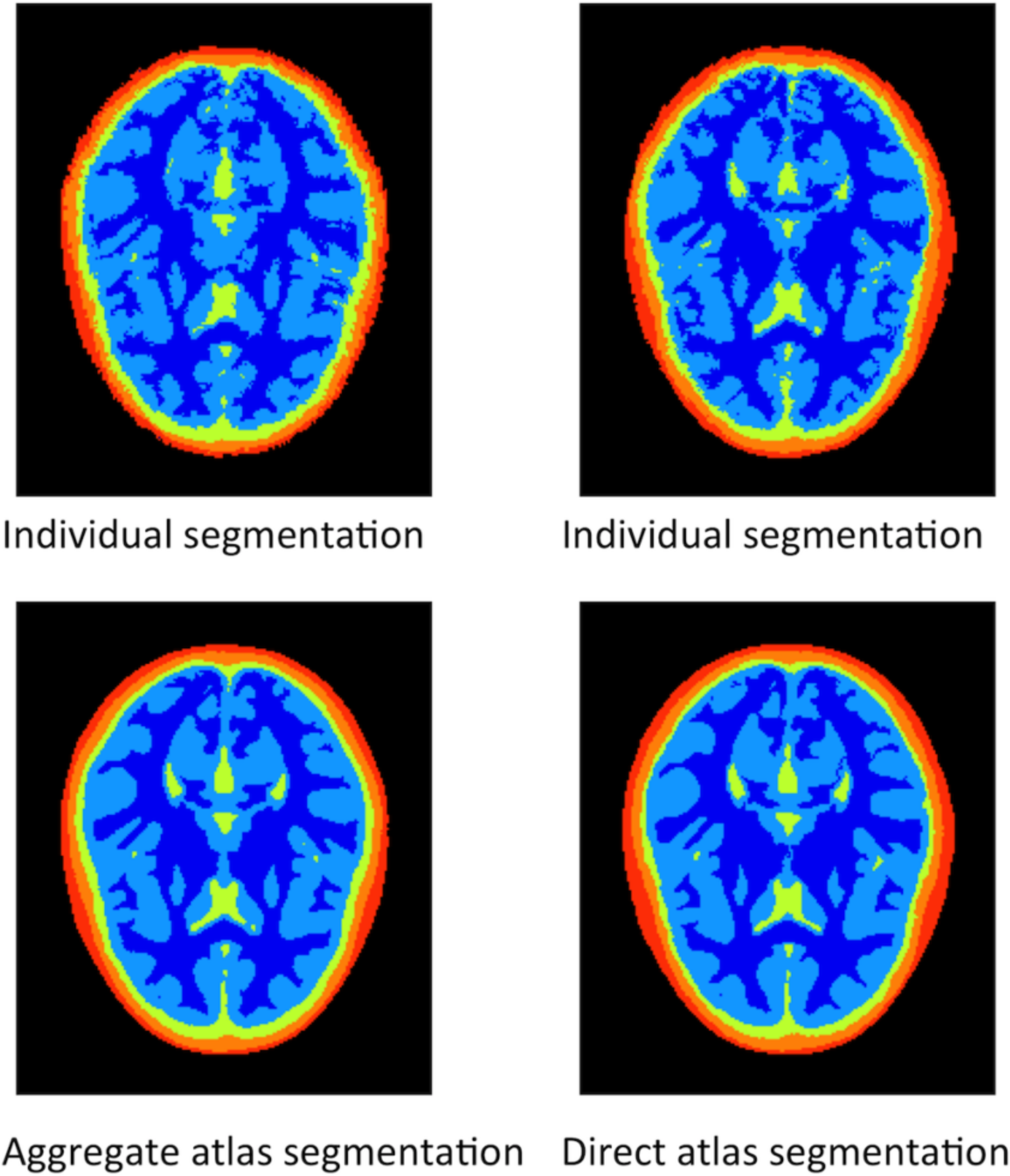
As an example, for the 12-14 age group (63 original images) we computed the aggregate segmentation by segmenting the original images, transforming these segmentations into the atlas space using the same nonlinear transformations computed during the atlas construction, then aggregating them into a single "maximum probability" aggregate segmentation by "voting": i.e. by choosing at each voxel the tissue type that was present most often amongst the individual transformed segmentations.

Results:

Axial slices of selected atlases are shown in Fig 1. Fig 2 shows axial slices of the aggregate atlas segmentation and of the direct atlas segmentation, and two representative individual segmentations (out of 63 total) mapped onto the atlas space.



·Figure 1, Selected average atlas images



·Figure 2, Selected individual segmentation images, and atlas segmentation images (aggregate and direct)

Conclusions:

The direct atlas segmentation and the aggregate atlas segmentation are much smoother than the individual segmentations. Both are quite similar, and give reasonable segmented images. For the ultimate purpose of computing electrical head models, the probability maps (i.e. images with probabilities of each tissue type) can be used to interpolate tissue conductivities in a manner consistent with the inferred uncertainty in the tissue segmentation, an advantage not available from the direct segmentation method.

Imaging Methods:

Anatomical MRI

Informatics:

Brain Atlases [1]

Modeling and Analysis Methods:

Image Registration and Computational Anatomy
Segmentation and Parcellation [2]

Poster Session:

Poster Session - Monday

Keywords:

Atlasing
MRI
Segmentation
STRUCTURAL MRI

[1|2]Indicates the priority used for review

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Not applicable

Please indicate which methods were used in your research:

Structural MRI

For human MRI, what field strength scanner do you use?

1.5T

Which processing packages did you use for your study?

Other, Please list - ANTs, BrainK

Provide references in author date format

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