Automatic lateral ventricle segmentation in infant population with high risk of autism

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Introduction

Autism is a developmental disorder with high degree of variability (Geschwind 2008). There are indications that abnormal subjects brain growth (Piven 1995) may result in different brain development trajectories in the early stages of life. Previous studies showed that significant differences in the shape of lateral ventricles (LV) could be found in primary school-age populations (Vidal 2008). In the current study, we present a new method of automatic segmentation of LV on MRI scans of young infants (6-24 month old), and apply it to a large database of scans of healthy infants and infants with high risk of autism spectrum disorder (ASD). Our method relies on the combination of state-of-the-art: non-local patch-based segmentation technique (Coupe 2011) and non-linear registration (Collins 1995). Our results show high degree of accuracy when compared to the expert segmentations.

Materials & Methods

MRI Data were drawn from an ongoing longitudinal study of brain and behavioral development in ASD (Infant Brain Imaging Study). Participants included 294 high-risk infants (HR) and 117 low-risk (LR) followed to 24 months. Informed consent was given by the parents of all participants. MRI scans included a T1w MP-Rage TE/TR = 3.16/2,400 ms 1x1x1mm resolution and a 3D T2w FSE TE/TR = 499/3,200 ms 1x1x1mm resolution.

All available MRI datasets were grouped by age: 6,12 and 24 months old (V06, V12 and V24) and underwent following steps: (i) inhomogeneity correction (Sled 1998) (ii) intensity normalization (iii) linear (rigid body) registration to stereotaxic space. A subset of the MRI data (V06:136 scans, V12:20,V24:20) were segmented with atlas based initialization (Gouttard 2007) followed by manual post-processing in ITK-SNAP (Yushkevich 2006) by an expert. T2w scans were used to create non-linear anatomical templates for each group (see Fig. 1). Resulting non-linear transformations were applied to the segmentations, forming an anatomical library for non-local patch-based segmentation algorithm (Coupe 2011).

The method: algorithm consists of following steps: (i) image pre-processing (see above) (ii) non-linear registration of the subject's T2w scan to the appropriate template (Collins 1995) , (iii) warping the T2w scan and then applying the patch-based segmentation algorithm using the appropriate library with 5x5x5mm patch size and 5x5x5mm search space, (iv) using inverse transformation to bring segmentation results back into linear space.

Validation: Accuracy of the algorithm was validated independently for each age group, using a leave-one-out experimental design: for each of the 176 manually segmented scans, the rest of the manual

segmentations from corresponding age group were used in the above algorithm and then result was compared with the manually defined labels.

Application: Algorithm was then applied to all 720 datasets and total volume of LV was calculated.

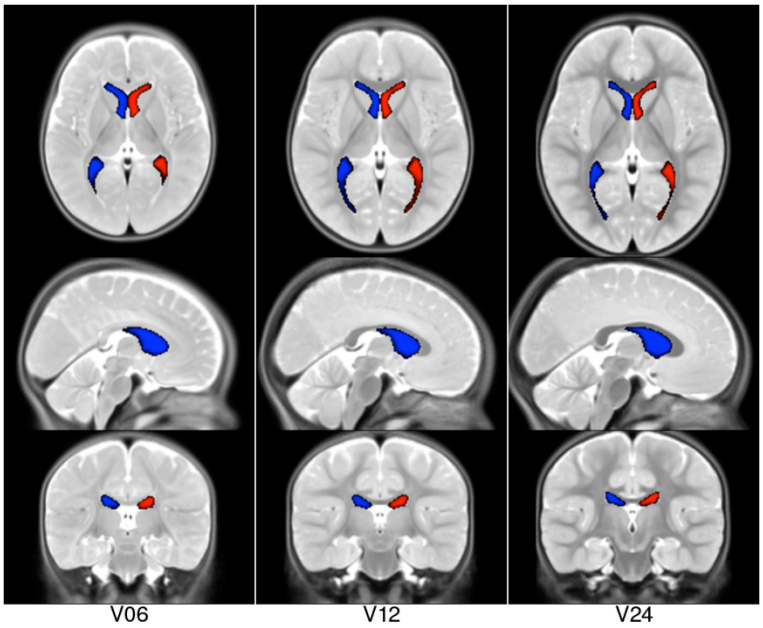
Results

Anatomical templates created using (Fonov 2011) are shown in Fig. 1. Results of cross-validation are shown in Figs 2 & 3; Fig. 3 demonstrates median segmentations. Overall, the method shows higher ICC values then existing state-of-the art segmentation methods for infant population (0.953) (Kempton 2011) and the Bland-Altman plots indicate that the procedure is unbiased. At 0.953-0.967, the Dice kappa values show very high agreement with manual labels.

Total volumes for left and right LV across all datasets are shown in Fig. 4.

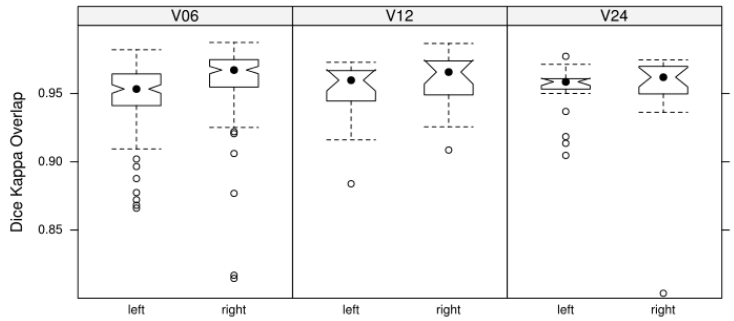
Conclusion

We have developed an algorithm for automatic segmentation of LV in high resolution MRI scans of young infants (6-24 m. o.). The algorithm shows high degree of accuracy verified by leave-one-out experiment, exceeding performance of the recently published state-of-the art technique for the given population. The output of the algorithm will enable localized analysis of the shape of ventricles in a fashion similar to that published in (Vidal 2008) and will allow to study early stages of brain development in the population with high risk of developing autism.



Non-linear average anatomical templates, T2w image modality with LV.

Figure 1



Spatial overlap of automatic segmentation vs. manual segmentation (Dice Kappa)

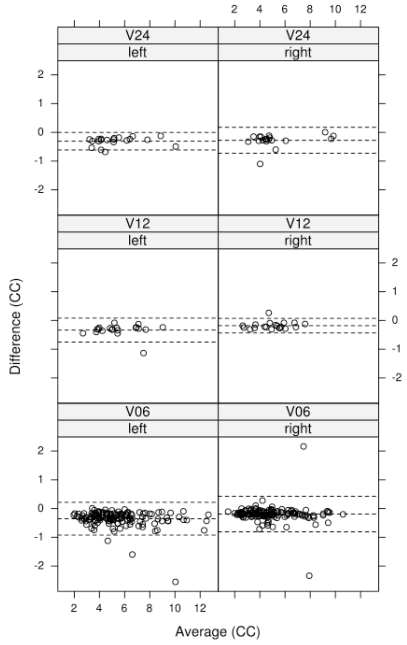
	V06	V12	V24
Left	0.953	0.960	0.959
Right	0.967	0.966	0.962

Median of dice kappa

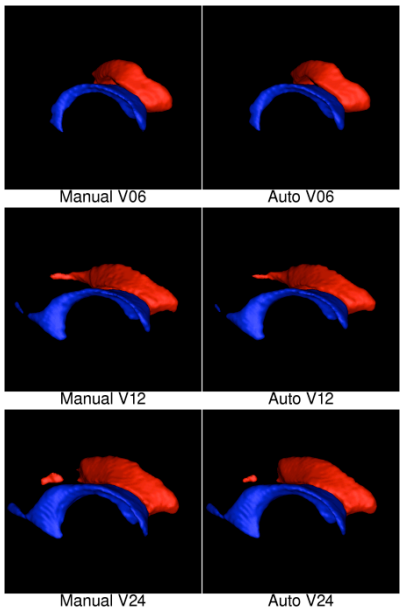
	V06	V12	V24
Left	0.992	0.992	0.997
Right	0.988	0.996	0.994

Inter-class correlation

Figure 2

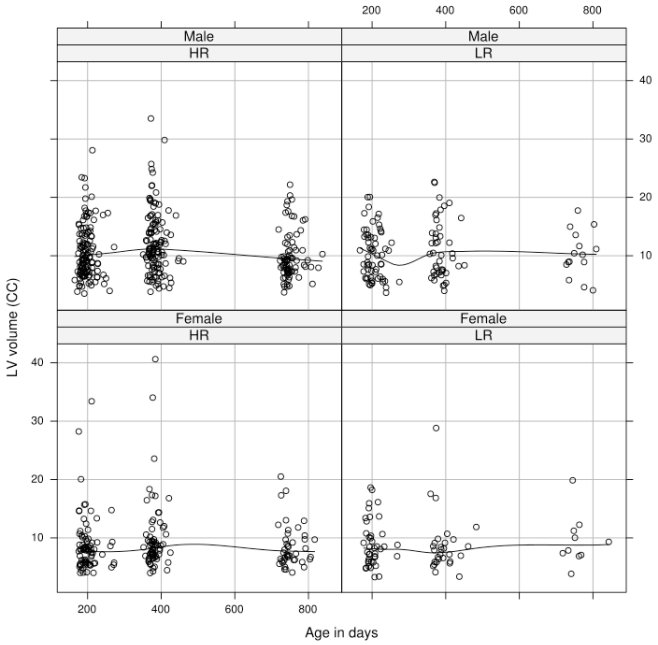


Bland-Altman plot



Typical segmentations

Figure 3



Total volume of LV (cc) vs age

Figure 4

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