Development of Fetus Brain Atlas from Multi-Axial MR Acquisitions

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Introduction

Innovative applications of advanced MRI techniques to the high-risk fetus are increasingly providing a powerful tool for the in vivo study of brain development. However, we currently lack a clear understanding of 'normal' fetal brain development. The ability to reliably acquire 3-D volumetric sequences and to delineate volumetric brain growth in the non-sedated fetus is challenging, but essential for the accurate assessment of the progression of normal and abnormal fetal brain growth in the second and third trimester. The development of a fetal brain atlas would enable a comprehensive and quantitative approach for the study of healthy and high-risk fetal brain growth, and ultimately improve the sensitivity, specificity and prognostic utility of fetal MRI.

Material and Methods

A fetal brain atlas was created using 50 non-sedated normal fetal MRI studies using multi-axial T2 acquisitions ranging from 25 to 37 weeks of gestation with a resolution of 2x1x1mm.
First, the subject acquisitions (axial, sagittal, and coronal) were all manually registered to a random subject and right/left symmetric images were created to avoid right/left bias. Then, we applied an iterative 6-parameter linear registration[1], followed by averaging the registered brains, until a stable linear model was obtained[2] (Fig. 1). Using this first linear model, or atlas, a non-linear registration was performed[3]. To correct for the fetal motion during the acquisition, we applied a slice-by-slice linear registration of each subject slice in the linear space to the averaged slice in order to increase the quality of the total volume registration. Finally, we reconstructed the volume and repeated the non-linear inter-subject registration and the slice-by-slice subject/target registration until a stable registration point was reached[2]. The slice-by-slice registration stage also corrected for intensity normalization, with the target slice as reference.

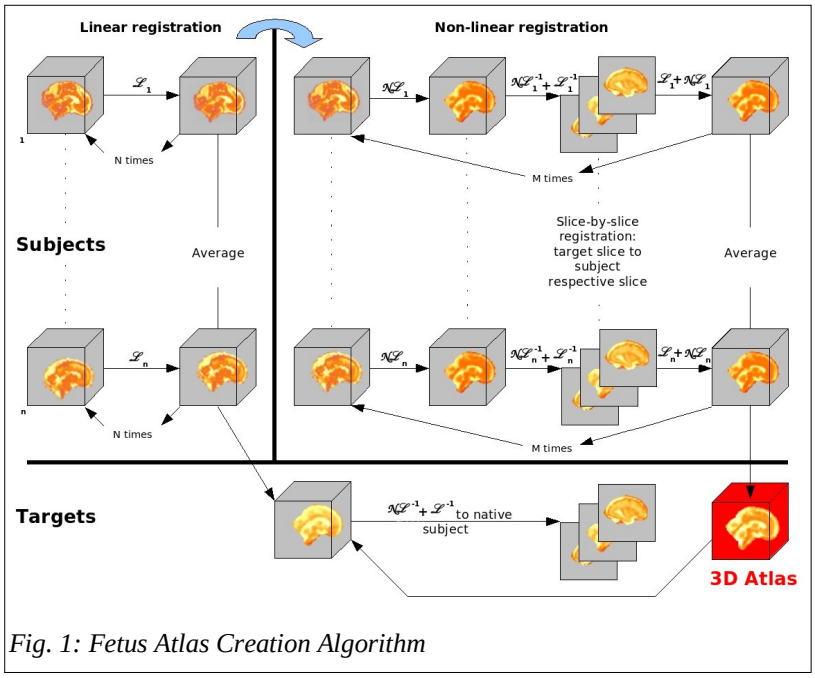
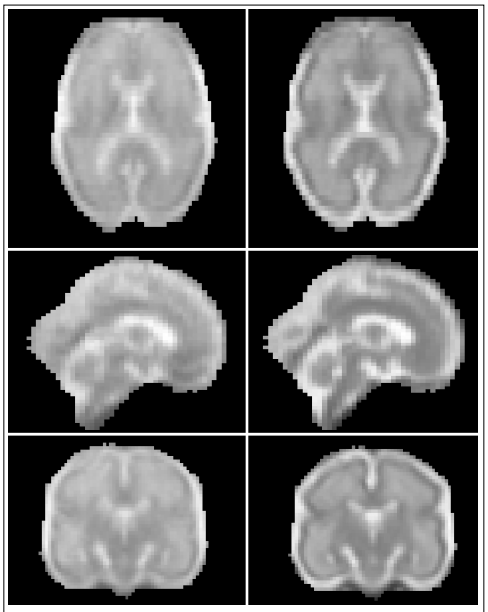


Fig. 1: Fetus Atlas Creation Algorithm



Linear *Non-Linear*
Fig. 2: Linear Versus Non-Linear Registration

Results

The atlas creation process converged after 3 linear registration steps and 12 non-linear registration steps. Non-linear averaging enabled us to obtain an atlas with a significantly better tissue contrast (Fig. 2). Gross anatomical segmentation, then, allowed us to create probabilistic regional maps for the cerebrum, the cerebellum, the brain stem, and cerebral spinal fluid as these regions could be predefined manually. The use of the non-linear atlas also allowed us to improve inter-slice registration, a particularly challenging problem for group analysis of non-sedated fetal acquisition[4].

Conclusion

We have successfully demonstrated the feasibility of acquiring 3-D volumetric data using fetal non-sedated MRI studies allowing for 3-D reconstruction and volume rendering of fetal brain parenchyma and extra-axial cerebral spinal fluid. The development of this atlas will provide the basis for characterizing healthy fetal brain development and provide an unprecedented opportunity to study acquired and congenital fetal brain lesions.

References

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