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Review Report

A Review of Brain Extraction Techniques in Fetal MRI

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ABSTRACT
Sonography, Maternal Serum Screening, amniocentesis, and sampling are among the techniques utilized to examine a developing fetus and diagnose fetal abnormalities in the uterus. Despite the fact that Sonography is the main technique used for imaging and monitoring, the use of Magnetic Resonance Imaging (MRI) to evaluate the fetus is growing. Moreover, MRI is used for further examinations in case of abnormalities diagnosed in the ultrasound scan.
MRI, in comparison with other imaging techniques, provides the advantage of fetal brain study with higher precision and quality. The first step to study the fetal brain is its extraction from the MRI of the fetal brain. Since the maternal tissue is also present in the MRI of the fetal brain tissue, and due to the differences in the adult and fetus signals of brain tissue, it is not possible to use the adult brain extraction techniques for fetus.
Given that semi-automatic segmentation is a time-consuming and tedious task, the need for automatic segmentation is highlighted. This is while the development of the stages of automatic segmentation of brain structures is still a challenge to overcome. In the present paper, we review the techniques for automatic segmentation or brain extraction of fetal MRI.

Keywords: MRI Imaging, Fetus, Segmentation, Brain Extraction

INTRODUCTION
Sonography is the imaging technique currently used for fetus evaluation. Ultrasound evaluation of fetal central nervous system, however, is restricted by a number of factors such the non-specific appearance of certain abnormalities and technical features that limit the precision. Other examples are ossification which prevents the illustration of brain structures, and delicate brain tissue that cannot always be observed through Sonography. On this account, the use of MRI is increasingly growing. It is important to note that MRI is not a reference method for fetal

monitoring even though it is a known fact that it is of no danger to the fetus. MRI is performed when additional information is required for decision-making at the time of pregnancy .(3-1)

Fetal MRI is usually performed after 20 weeks gestational age (GA) when the main steps of organogenesis are completed (4). Following is a list of advantages of MIR over Sonography of the fetus:

1. Less limited by decreased amniotic fluid, maternal obesity, or difficult fetal position
2. Large FOV
3. High spatial resolution
4. Generation of different tissue contrasts
5. The ability to collect functional information (4-8)

Study of the fetus in the uterus using MRI is one of the most important methods for the fetal brain measurement, fetal growth monitoring, study of fetal brain anatomy, abnormal brain, and the pathology of central nervous system (CNS)-9) (11.

As we know, although there exists methods for child and adult brain extraction and segmentation, they cannot be extended for the fetus since the fetal MRI signals are different from the observed samples belonging to children and adults. The fact that little myelination exists in the fetal brain leads to differences between the signals related to the white and gray matter in fetus and the samples belonging to children and adults. Furthermore, the presence of maternal tissue in the images does not allow us to be able to utilize these algorithms for the fetus (10 ,9 ,2). Automatic segmentation is winning favor mainly because segmentation is time-consuming and tedious, requires sufficient knowledge of the filed, and may have various results at different times, which ultimately reduce the reliability and significance of the results (4).

Review of Literature

In most studies some preprocessing is performed in order to do non-uniformity intensity correction and remove maternal or skull tissue. The fetuses are within the same age range and the segmentations of brain structures have been conducted on T2w MRI. Table 1 illustrates the techniques used by different people to extract fetal brain.

Table 1: The techniques employed by scholars for fetal brain extraction

Year	Author	Title of the article	Technique
2004	Claude et al	Fetal Brain MRI: Segmentation and Biometric Analysis of the Posterior Fossa	Region growing
2008	Ferrario et al	Brain surface segmentation of magnetic resonance images of the fetus	Two-step approach: first, Finite Gaussian Mixture Model (FGMM) Second, Extended MRF Neighborhood
2008	Habas et al	Atlas-based Segmentation of the Germinal Matrix from in Utero Clinical MRI of the Fetal Brain	Atlas-based
2009	Anquez et al	Automatic segmentation of head structures on fetal MRI	Two-step approach: First: template matching Second: graph cut
2009	Cuadra et al	Brain tissue segmentation of fetal MR images	Expectation Maximization Markov Random Field
2010	Habas et al	Atlas-Based Segmentation of Developing Tissues in the Human Brain with Quantitative Validation in Young Fetuses	Atlas-based Expectation Maximization
2011	Gholipour et al	Fetal brain volumetry through MRI volumetric reconstruction and segmentation	Geodesic active contours level set segmentation
2011	Caldairou et al	Segmentation of the cortex in fetal MRI using a topological model	Topological model
2011	Dittrich et al	Learning a spatio-temporal latent atlas for fetal brain segmentation	Spatio-temporal latent atlas
2012	Ison et al	Fully automated brain extraction and orientation in raw fetal mri	Two-step approach: first, two-phase random forest classifier Second, approximate high-order Markov

			random field
2013	Keraudren et al	Localisation of the Brain in Fetal MRI Using Bundled SIFT Features	bundled SIFT (Scale-Invariant Feature Transform) features
2013	Taleb et al	Automatic Template-based Brain Extraction in Fetal MR Images	Template-based
2014	Kainz et al	Fast fully automatic brain detection in fetal MRI using dense rotation invariant image descriptors	rotation invariant volume descriptors in combination with machine learning methods
2015	Tourbier et al	Automatic Brain Extraction in Fetal MRI using Multi-Atlas-based Segmentation	Multi-Atlas-based

Fetal MRI is a relatively new field, with little work published on fully automatic processing and semi-automatic processing of these datasets.

In (11, 12), 3D template matching is used to detect the eyes, enabling a subsequent 2D/3D graph-cut segmentation to extract the brain. This approach based on 3D rigid templates lacks the flexibility necessary to deal with motion artifacts as well as fetal malformations. The methods proposed In (13) and (14) address the variability of fetal MRI through machine learning. In (13), a Random Forest classifier first distinguishes between maternal and fetal tissues before identifying different tissues of the fetal head, while (14) combines prior knowledge of the fetal head size with MSER detection and a bag-of-words model. In contrast to (13), which obtains rotation invariance by rotating the training data and (14), which focuses on 2D slice detection, in (15) operates fully in 3D space, learning rotation invariant features, and is likely to be faster than all the methods proposed so far.

The method is used in (2) (based on pixel aggregation around germ points) is easy to implement, computationally efficient and reproducible. They developed a semi-automatic segmentation method based on region growing techniques with pixel aggregation. This approach uses both intensity and gradient information, which are updated when growing the regions.

In (9) FGMM and MRF scheme performs well but limited accuracy has been obtained in gyri and sulci. Despite better depth resolution obtained, in plane segmentation presents less precision in sulci. This is mainly due to very large slice thickness and fetal motion. Even if rigid registration is applied to correct fetal movement between acquisition volumes, intra-volume fetus motion still remains. One of the proposed techniques to correct fetal motion is to perform 2D/3D registration. In (2) presented an approach to segmentation and biometric analysis of the posterior fossa from midline sagittal cross-sections. A semi-automatic method based on region growing was used to segment various components of the posterior fossa such as the brain stem or vermis and calculate biometric markers that may be indicative of fetal cerebellar growth. In (4) presented an approach to automatic segmentation of individual tissues from motion-corrected 3D MR images of the fetal brain. In (8) developed an image processing pipeline based on inter-slice motion correction, super-resolution volume reconstruction, intensity non-uniformity correction and supervised segmentation, in order to overcome the limitations of fetal brain MRI volumetry techniques.

Current atlas-based segmentation approaches perform well in the adult population, but they are unable to cover the rapid changes during early development phases in fetal. In (16), introduced a spatio-temporal group-wise segmentation of fetal brain structures given a single annotated example. The method is based on an emerging spatio-temporal latent atlas that captures the age dependent characteristics in the training population, and supports the segmentation of brain structures. In (17) show that an increase of segmentation accuracy and robustness for multi-atlas methods when compared to single-best-atlas-selection.

CONCLUSION

Each of these techniques has advantages and disadvantages, which makes it impossible to favor one over another and decide on a best technique. What the future holds is a development of these techniques and better results as a consequence. The absence of an appropriate database to be utilized and perform algorithms on is one of the problems in the existing realm. This is the reason each group applies these methods based on their own database, which reduces the possibility of comparison. Creating a specific database, therefore, can alleviate the problem, resulting in an easier comparison of the outcomes.

Due to the endobiotic diversity of the developing brain, some intensity non-uniformity remains still after bias field correction. Preprocessing, however, improves the results of segmentation and reduces the number of false pixels segmentation. Also, a comparison drawn between the image segmentation done by an expert with and without preprocessing revealed that, in case of prepossessing, the contours of prepossessed images are reported by the expert more accurately than the contours without prepossessing (2).

As we know, in order to reduce fetal motion artifact, it is possible to use thicker cuts for higher image quality. However, this can lead to a reduction in the resolution of the three-dimensional image reconstructed from a two-dimensional one, which by itself affects the precision of the 3D model since no matter what kind of interpolation is employed, it cannot depict the fetal skull well enough. The other impediment is the partial volume effect. Fast MRI sequences are also an option. They can cause a reduction in spatial resolution, which is of course to a large extent overcome by the new protocols (20-18 ,10 ,9).

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REFERENCES:

1. Garel C, Brisse H, Sebag G, Elmaleh M, Oury J-F, Hassan M. Magnetic resonance imaging of the fetus. Pediatric radiology. 1998;28(4):201-11.
2. Claude I, Daire J-L, Sebag G. Fetal brain MRI: segmentation and biometric analysis of the posterior fossa. Biomedical Engineering, IEEE Transactions on. 2004;51(4):617-26.
3. Jokhi RP, Whitby EH. Magnetic resonance imaging of the fetus. Developmental Medicine & Child Neurology. 2011;53(1):18-28.
4. Habas PA, Kim K, Rousseau F, Glenn OA, Barkovich AJ, Studholme C .Atlas-based segmentation of developing tissues in the human brain with quantitative validation in young fetuses. Human brain mapping. 2010;31(9):1348-58.
5. Brugger PC, Stuhr F, Lindner C, Prayer D. Methods of fetal MR: beyond T2-weighted imaging. European journal of radiology. 2006;57(2):172-81.
6. Rutherford M, Jiang S, Allsop J, Perkins L, Srinivasan L, Hayat T, et al. MR imaging methods for assessing fetal brain development. Developmental neurobiology. 2008;68(6):700-11.
7. Girard N, Raybaud C, Poncet M. In vivo MR study of brain maturation in normal fetuses. American journal of neuroradiology. 1995;16(2):407-13.
8. Gholipour A, Estroff JA, Barnewolt CE, Connolly SA, Warfield SK. Fetal brain volumetry through MRI volumetric reconstruction and segmentation. International journal of computer assisted radiology and surgery. 2011;6(3):329-39.
9. Ferrario D, Cuadra MB, Schaer M, Houhou N, Zosso D, Eliez S, et al., editors. Brain Surface Segmentation of Magnetic

Resonance Images of the Fetus. 16th European Signal Processing Conference (EUSIPCO-2008) Lausanne, Switzerland; 2008.

10. Habas PA, Kim K, Rousseau F, Glenn OA, Barkovich AJ, Studholme C. Atlas-based segmentation of the germinal matrix from in utero clinical MRI of the fetal brain. Medical Image Computing and Computer-Assisted Intervention–MICCAI 2008: Springer; 2008. p. 351-8.
11. Anquez J, Angelini ED, Bloch I, editors. Automatic segmentation of head structures on fetal MRI. Biomedical Imaging: From Nano to Macro, 2009 ISBI'09 IEEE International Symposium on; 2009: IEEE.
12. Taleb Y, Schweitzer M, Studholme C, Koob M, Dietemann J-L, Rousseau F. Automatic Template-based Brain Extraction in Fetal MR Images. 2013.
13. Ison M, Donner R, Dittrich E, Kasprian G, Prayer D, Langs G, editors. Fully Automated Brain Extraction and Orientation in Raw Fetal MRI. Workshop on Paediatric and Perinatal Imaging, MICCAI; 2012.
14. Keraudren K, Kyriakopoulou V, Rutherford M, Hajnal JV, Rueckert D. Localisation of the Brain in Fetal MRI Using Bundled SIFT Features .Medical Image Computing and Computer-Assisted Intervention–MICCAI 2013: Springer; 2013. p. 582-9.
15. Kainz B, Keraudren K, Kyriakopoulou V, Rutherford M, Hajnal JV, Rueckert D, editors. Fast fully automatic brain detection in fetal mri using dense rotation invariant image descriptors. Biomedical Imaging (ISBI), 2014 IEEE 11th International Symposium on; 2014: IEEE.
16. Dittrich E, Riklin-Raviv T, Kasprian G, Brugger PC, Prayer D, Langs G, editors. Learning a spatio-temporal latent atlas for fetal brain segmentation. Proceedings of the MICCAI 2011 Workshop on Image Analysis of Human Brain Development (IAHBD 2011); 2011.
17. Tourbier S, Hagmann P, Cagneaux M, Guibaud L, Gorthi S, Schaer M, et al., editors. Automatic brain extraction in fetal MRI using multi-atlas-based segmentation. SPIE Medical Imaging; 2015: International Society for Optics and Photonics.
18. Rousseau F, Glenn OA, Iordanova B, Rodriguez-Carranza C, Vigneron DB, Barkovich JA, et al. Registration-based approach for reconstruction of high-resolution in utero fetal MR brain images. Academic radiology. 2006;13(9):1072-81.
19. Jiang S, Xue H, Glover A, Rutherford M, Rueckert D, Hajnal JV. MRI of moving subjects using multislice snapshot images with volume reconstruction (SVR): application to fetal, neonatal, and adult brain studies. Medical Imaging, IEEE Transactions on. 2007;26(7):967-80.
20. Cuadra MB, Schaer M, André A, Guibaud L, Eliez S, Thiran J-P, editors. Brain tissue segmentation of fetal MR images. Workshop on Image Analysis for Developing Brain, in 12th International Conference on Medical Image Computing and Computer Assisted Intervention; 2009.