MRI based semi-automatic volumetric measurements of the fetal brain

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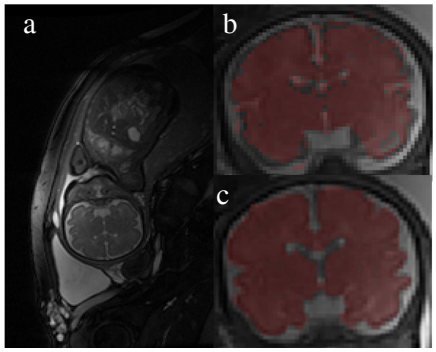
Target audience: Scientists and clinicians with an interest in fetal MRI, brain development and automatic segmentation methods.

Purpose: Accurate volumetric measurement of the fetal brain is of great importance for the assessment of fetal growth and is an early identification of various developmental disorders. Although ultrasound is the method of choice in obstetrics, it has limitations in many aspects due to its low contrast and restricted field of view. MRI is increasingly being used in fetal imaging, and has the potential to obtain accurate structural and functional information of the developing fetus. However, the use of advanced MRI methods, acquisition and analyses in fetal imaging, is currently limited. ***The aims*** of this study were: (i) to develop a semi-automatic segmentation method for the assessment of fetal brain volume based on MRI data, which will be fast, accurate and with high reproducibility; and (ii) to evaluate the capabilities of this method to identify early developmental disorders such as intra uterine growth restriction (IUGR), by comparing growth measurements of the brains of typically developed fetuses with those with intra-uterine-growth restriction.

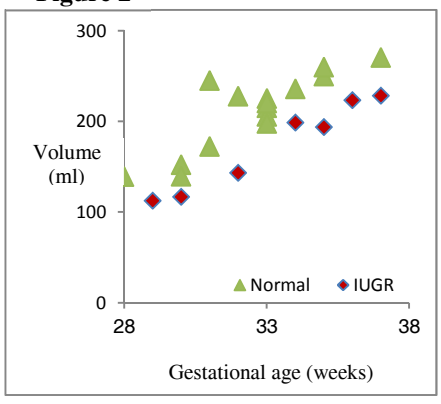
Methods: Fifteen normal fetuses and seven with IUGR diagnosed by the US unit of the prenatal diagnostics center and validated by a neuro-radiologist were referred for fetal MRI prior to 34 weeks 'of gestation and were included in our study. Scans were performed as part of the clinical follow-up and included high resolution 3D anatomical sequence (TR/TE=3/1.3sec, Matrix=256x256, 4mm slice thickness) of the entire fetus. A novel semi-automatic segmentation method was developed, consisting of five steps: 1) Manual selection of the Region of Interest; 2) Generation of a matrix-of-constraints; 3) Seeded Region Growing (SRG) segmentation with a pre-defined threshold; 4) Automatic out-of-brain leaks removal; 5) Manual user-guided corrections of the resulting segmentation. The accuracy of the algorithm was tested against manual segmentation performed using AnalyzeDirect software, validated by a senior neuro-radiologist by measuring volume difference and volume overlap difference.

Figure 1



Results: *Brain segmentations:* The semi-automatic segmentation method was successfully applied in all cases. Fig. 1 shows a representative MRI scan of the entire fetus (a), and the results obtained using the developed algorithm (b), in comparison to the gold standard manual segmentation (c). A good correlation was obtained between the algorithm and the gold standard segmentation results, with a mean of 4.77% volume difference (VD) and 18.13% of volume overlap difference (VOD). The semi-automatic segmentation method requires much less time compared to manual segmentation: a mean of 74 secs (or 196 secs when using the semi-automatic correction tool option) for the semi-automatic total brain segmentation compared to 2 hours for manual segmentation (gold standard). *Differences between normal and IUGR fetuses:* Significant differences were detected between brain volumes of typically developed fetus and fetuses with IUGR. Figure 2 shows total brain volumes of 15 typically developed and seven IUGR fetuses as a function of gestational age, obtained using the proposed segmentation method.

Figure 2



Summary:

- A good correlation was detected between the developed semi- automatic segmentation method and the gold standard.
- Brain volumes of the normally developed fetus measured using our method were in line with known brain volume values from the literature[1].
- Automatic segmentation saves a substantial amount of time compared to manual segmentation (a reduction of ~99%).
- Differences in total brain volumes were detected between typically developed and IUGR fetuses.

Conclusions: This study shows the applicability of the developed semi-automatic segmentation method to measure fetal brain volume accurately, quickly and with high sensitivity to detect abnormal brain development, and suggests the use of such semi-automatic volumetric methods in routine clinical practice for fast, accurate and reproducible monitoring of fetal development, especially in cases of ambiguity regarding fetal brain growth and development.

References: [1]Gong QY et al. Fetal and fetal brain volume estimation in the third trimester of human pregnancy using gradient echo MR imaging. Magn Reson Imaging. 1998 Apr;16(3):235-40.