Estimation of foetal brain volume using MRI and three stereological methods

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Keywords

Stereology, Isotropic Cavalieri, Invariator, Discretized Nucleator, Magnetic resonance imaging, Foetal Brain.

Introduction

In this study we compared results obtained by applying three unbiased stereological methods for efficient manual estimation of human foetal brain volume in-vivo using in Magnetic Resonance Imaging (MRI).

Materials and Methods

Ten pregnant women (n=5 healthy; n=3 maternal psychological stress; n=2 maternal substance misuse) were recruited and MRI investigations were performed for each subject in both the 2nd and 3rd trimester of gestational age (GA). High resolution 3D images of the foetal brain were obtained from series of T2-weighted MRI images using the Slice MRI Motion Estimation and Reconstruction (SLIMMER) tool for motion correction. The unbiased Cavalieri method (in particular the Isotropic Cavalieri design, ICav) and two group mean comparison methods (the Invariator (INV) and Discretized Nucleator (DN)) were applied using ANALYZE software (MAYO Clinic, Minnesota, USA) to estimate foetal whole brain volume (Figure 1).
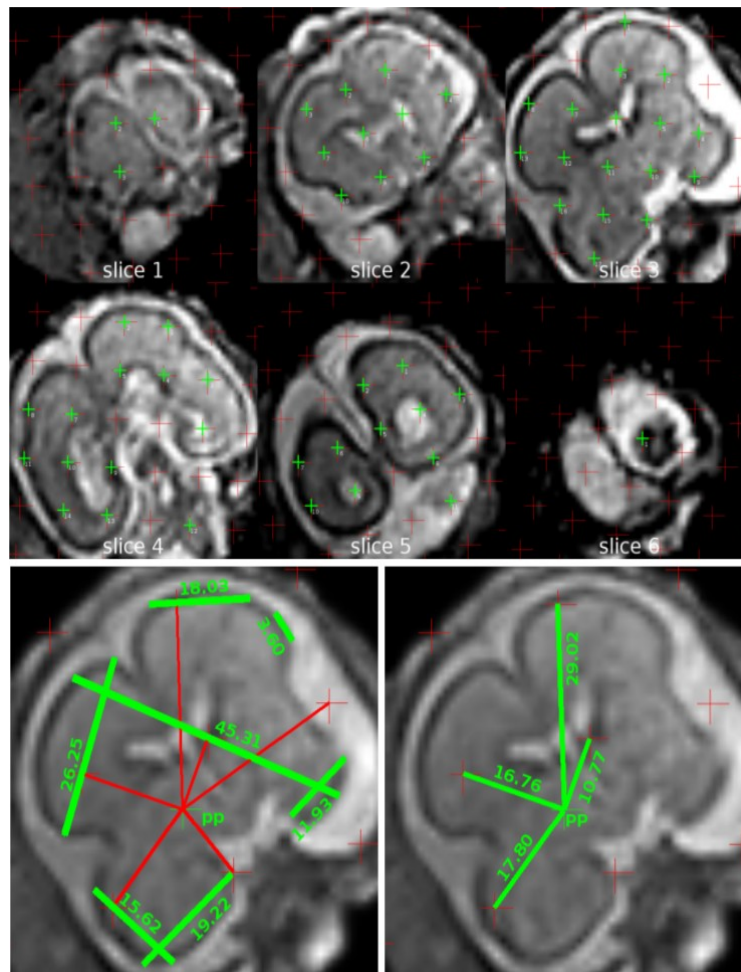
Figure 1. Examples of point counting for the Isotropic Cavalieri method (top), the Invariator method (bottom left) and the Discretized Nucleator method (bottom right) for the same data in MRI images.

Results and Discussion

Average brain volume estimates obtained using the ICav, INV and DN were in close agreement (p value: 0.29–0.99), although as expected the variation in individual volume estimates was high for the INV and DN methods. Predicted Coefficient of Error (CE) for individual volume estimates obtained using the ICav method were less than 2.5%. Empirical CEs for INV and DN methods were between 10%–40%, and decreased to <10% when corresponding results were combined for three orthogonal sampling directions. There was no significant difference (p value: 0.08–0.88) in average foetal brain obtained for the three groups of patients using any of the methods. The inter-rater reproducibility and intra-rater repeatability assessment for point counting in the ICav method and length measuring in the INV and DN methods showed high reliability with Pearson's r > 0.997.

Conclusion

This protocol provides a practical way of combining the usage of three stereological methods with ANALYZE software in volume measurement on human brain MRI images. The sampling and counting protocols developed in ANALYZE software provide

convenient means of applying ICav, INV and DN stereological methods for the study of appropriate 3D imaging datasets. Notably, ANALYZE provided the opportunity to pioneer the application of the attractive (i.e. direct prediction of CE, opportunity for additional unbiased estimation of surface area) ICav method in MRI studies. The INV and DN methods may be useful for comparison of group mean volumes and again ANALYZE makes it highly practical to perform these investigations.

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