ASMRM & ICMRI 2020
November 03 - 04, 2020 Virtual Congress http://2020.ksmrm.org
ASMRM Korean Society of Magnetic Resonance in Medicine

iMRI Invited Session
SY14-2

Learning-Based Approaches In-Utero MRI

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In-utero MRI is a powerful tool to characterize fetal development and developmental disorders. However, acquisition and analysis of the in-utero images remain extremely challenging due to the excessive motion, and therefore, deep learning-based approaches could play an important role.

Fetal brain is the primary focus that exhibits superior contrast in in-utero images. We have collected a large dataset of routine clinical fetal brain MRI, based on which, we designed an automated image processing pipeline with U-net based fetal brain extraction, slice-to-volume registration, super-resolution reconstruction. With this pipeline, we generated the first version of Chinese fetal brain atlas and reveal the spatiotemporal development of the fetal brain between 23-36 weeks of gestation. Next, we designed attention-based deep ensembles to estimate brain age in normal developing fetuses, and achieved high performance with a mean absolute error of 0.8 weeks and R2 of 0.93. Furthermore, we proposed to use predictive uncertainty and estimation confidence from the network as markers of fetal brain anomalies, which demonstrated potential in detecting fetal brains with small head circumstance, malformations, and ventriculomegaly.

Beyond the fetal brain, placenta is a vital organ that supports the fetal development, and placental dysfunction is an important cause of fetal disorders, such as intra-utero growth restriction (IUGR). Intravoxel incoherent motion (IVIM) has shown to be a useful tool in assessing the microcirculatory flow in the placenta, with potential values in the diagnosis of abnormal placental function. We proposed a learning framework to estimate IVIM parameters from a small number of b values in the human placenta, which help to accelerate the acquisition and reduce motion for placental IVIM. In addition, we developed a new IVIM acquisition paradigm using flow-compensated and non-compensated diffusion-weighted sequences to obtain both the fraction of the microcirculatory flow and flow velocity in the placenta, which showed high consistency with Doppler ultrasound result.

In summary, we incorporated learning-based approaches for the acquisition and analysis of fetal brain and placenta MRI. The results are encouraging, and the procedures can be readily translated to clinical in-utero MRI examinations.

Keywords: Deep learning, In-utero MRI, Fetal brain, Placenta