The role of MR Imaging and post-processing advances in understanding the developing fetal brain, 6th May 2010

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Development of the fetal brain surface with concomitant gyrification is one of the major maturational processes of the human brain. First delineated by postmortem studies (1) or by ultrasound (2), MRI has more recently become a powerful tool for studying in vivo the structural correlates of brain maturation. Fascinating studies have delineated the main milestones of gyral development, through the progressive identification of the primary and secondary gyri along the second and third trimesters of the pregnancy (3,4,5). However, the analysis of early brain development often remains qualitative. Nowadays, the quantitative measurement of fetal brain development is a major challenge for several reasons. First, movement of the fetus inside the amniotic cavity reduces image quality. Therefore, a few groups of researchers proposed the use of cerebral MRI obtained from premature neonates to quantitatively measure early brain development (6,7). However, this strategy does not allow the study of normal brain development over a large age range, since the most premature births are not likely to represent appropriate specimen for the study of normal development. Sedation of the *in utero* fetus is another option to reduce image motion, but ethical reasons impair the feasibility of large-scale studies with sedated fetuses, and motion artifact is never fully solved. Nowadays, MRI sequences with short acquisition time have been developed to cope with motion artifact. However, very fast MRI sequences result in a poor spatial resolution and / or in a lower signal-to-noise (SNR) ratio. In turn, due to low resolution, fetal MR images considerably suffer of partial volume (PV) effect, sometimes in large areas. Today extensive efforts are made to deal with the "post-acquisition" reconstruction of high-resolution 3D fetal volumes based on several acquisitions with lower resolution (8,9). Another important challenge in the field of quantitative fetal brain imaging is the changing appearance of the developing brain. On one hand, the rapidly growing structures impair the construction of reliable brain atlas. One the other hand, due to the ongoing myelination and cortical maturation, the contrast of the fetal brain differs widely from the easily segmented homogenous tissue types found in adults. Therefore, only few studies to date have used automated segmentation of MR fetal imaging. Claude et al. (10) and Habas et al. (11) have proposed segmentations of specific areas of the fetal brain such as posterior fossa, brainstem or germinal matrix. More recently, first attempts have been proposed for the automated segmentation of brain tissue without the use of anatomical atlas prior (12,13). Ultimately, new techniques aim at the automated extraction of accurate three-dimensional cortical surface of the fetal brain. These cortical reconstructions will allow the precise quantification of the normal gyral development, as well as the quantification of subtle and early but clinically relevant deviations. Further, a precise understanding of the gyral development process may help to build hypotheses to understand the pathogenesis of several neurodevelopmental conditions in which gyrification have been shown to be altered (e.g. schizophrenia, autism…).

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