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Editorial Open Access

Advanced MR Imaging Technologies in Fetuses

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Abstract

Fetal Magnetic Resonance Imaging (MRI) on clinical scanners has increasingly been realized as a powerful imaging tool and applied for studying the brain abnormalities and the potential of neurodevelopmental disabilities *in vivo*. The primarily used multi-echo fast imaging sequences reduce the motion artifacts with a tradeoff of image Signal-to-Noise Ratio (SNR) and resolution. In Radio Frequency (RF) hardware for MR signal excitation and reception, there are lack of dedicated RF coils for fetal imaging providing optimized performance in acquisition and safety. There is an urgent demand for novel hardware and fast imaging technology developments to overcome motion artifacts and improve sensitivity and safety. Recent studies have demonstrated that dedicated fetal RF transceiver arrays can improve the SNR, image coverage, and safety. In addition, emerging fast imaging technologies such as parallel imaging and compressed sensing would be advantageous in improving imaging speed and thus reducing motion artifacts in fetal imaging.

Editorial

Since 1990s when the T2-weighted ultrafast sequences were developed, fetal MRI on clinical scanners has increasingly been realized as a powerful imaging tool and applied for studying the brain abnormalities and the potential of neurodevelopmental disabilities *in vivo* [1-5]. Performing fetal MRI can provide additional information for diagnosed or suspected pathologies that are not apparent on ultrasound [6-25]. The limitations and challenges of current fetal MRI include RF safety caused mainly by RF deposition (Specific Absorption Rate, SAR), limited sensitivity, fetal motion and the small size of fetal brain structure. Due to the nature of slow acquisition in the conventional MR imaging, motion artifacts have been one of the major issues in MRI, particularly when imaging normally mobile fetuses. Over the years, tremendous research efforts have been made to lessen motion effects in conventional slow MR imaging acquisition [26-29]. In fetal imaging, because of the small structure, especially in the brain, the optimal resolution required to establish a diagnosis is usually lower than 1 mm generally. In addition, the Field Of View (FOV) of fetal MRI has to be large enough to cover not only the fetus but also the maternal body in order to avoid fold-over artifacts. This FOV enlargement increases acquisition time up to 50% to remain the high resolution requirement. With the advent of the fast imaging techniques such as parallel imaging and compressed sensing, parallel excitation for image homogenization and SAR optimization, and novel and efficient RF hardware techniques, it is possible to develop new strategies for ultrafast fetal MR imaging with high spatial resolution, low SAR and reduced motion artifacts, and translate those advanced imaging technologies to clinical fetal imaging.

In RF hardware aspects of current fetal MRI, because of lack of dedicated RF coil arrays available for fetal imaging, commercial torso or cardiac phased arrays for adults are routinely used instead. Although those substitutes can provide reasonable quality of images, they are not optimized for SNR, safety, and imaging speed for fetal imaging due to the limited coil elements, coverage and filling factor. Current research [30,31] has demonstrated that dedicated fetal RF arrays with the use of parallel imaging reconstruction algorithms are capable of improving image quality and safety for fetal MRI. The results indicate fetal arrays can improve SNR and B_1 homogeneity by increasing the number of coil elements and the filling factor. The artifacts of parallel reconstructed images and g-factors are reduced dramatically with the use of the dedicated fetal RF arrays.

Parallel MRI using an array of RF receivers or coils is a well accepted fast imaging method [32-35]. It can dramatically reduce the minimum MR data acquisition time by replacing phase-encoding steps with the encoding inherent in the sensitivity profiles of the coil array elements. Therefore, the total scan time of fetal MRI and effects of the T_2 decay of Single Shot Fast Spin Echo (SSFSE) sequence can be reduced by utilizing parallel MRI. Unlike the conventional fast MR imaging method, parallel imaging technique accelerates imaging acquisition without significantly sacrificing of signal-to-noise ratio (SNR). Recent studies have demonstrated that fetal MRI images are diagnostically improved and the scan time has been reduced with the parallel imaging. Compressed Sensing (CS) is another emerging fast imaging technique which is firstly proposed and investigated in information and approximation theory [36-38]. CS aims to reconstruct MRI images from much fewer encoding steps by exploiting the sparsity of the images in appropriate transform domain [39-45]. Nowadays, CS combining with parallel imaging has been employed in many applications of adult MRI and pediatric MRI [46-51] in brain imaging, angiography, dynamic heart imaging and spectroscopic imaging. These results show potential to implement this technology to further improve imaging speed of fetal MRI.

Parallel excitation is advantageous and desired for fetal MRI due to reduced focal SAR hot spots, better transmit homogeneity and capability of performing fast selective excitation [52]. Current studies have shown that parallel excitation with multichannel RF transceiver arrays is a promising technique to reduce SAR, RF pulse length and B_1 inhomogeneity [53-61] despite the technical difficulties in designing the required multichannel transceiver arrays [62-66]. Research on RF array hardware [63,67-69] demonstrates that well designed flexible

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transceiver arrays using microstrip technology can achieve superior performance with improved element decoupling and filling factor for various subjects with different sizes. This transceiver array design technique should be beneficial to, and also help to implement parallel excitation for fetal imaging where the size and shape of maternal bodies often vary. In excitation methodology, sparse pulse excitation based on sparse k-space has been proposed and investigated to shorten the excitation pulse width, and thus accelerate the excitation and improve imaging safety. This technique is needed to be developed for fetal imaging.

In summary, MR imaging as a non-ionizing and non-invasive imaging tool has increasingly been applied in studying fetuses. Current fetal imaging techniques, however, are facing technical challenges such as, the sensitivity to motion artifacts in the conventional slow MR imaging, safety issues, lack of dedicated RF hardware, and the requirements for high spatial resolution and large FOV. Therefore there is an urgent demand for developing novel and dedicated RF transmit/receive hardware and imaging acquisition/excitation strategies for fetal imaging using advanced RF array techniques and fast imaging technologies such as parallel acquisition, compressed sensing and parallel excitation to accelerate imaging speed, reduce SAR and motion artifacts, and translating the developed technology to clinical fetal imaging.

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