Ultrafast Fetal MR Imaging using Interpolated Compressed Sensing

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Introduction: Sparse MRI [1, 2] is able to reduce raw data size by significantly undersampling the *k*-space, and the interpolated Compressed Sensing [3] has been used to reduce the acquisition time for multiple slice two-dimensional MR imaging. By combining iCS with SENSE parallel imaging and utilizing the sensitivity images provided by parallel imaging, the scan time can be further reduced. In fetal imaging, MRI is able to provide detailed fetal anatomy and is being increasingly used to evaluate fetal development and also the brain, e.g. the ventriculomegaly, abnormalities of the corpus callosum and the posterior fossa. However, fetal MR image is degraded by the fetal motion and maternal respiratory and involuntary movements during the long acquisition time. In this study, we applied the iCS method to fetal MR imaging to dramatically shorten the acquisition time for multi-slice two-dimensional fetal MRI. The raw data of each slice is multiplied by a weighting function and then used to estimate the missed k-space data of the neighboring slice, which helps improve the contrast to noise ratio (CNR) of the significantly undersampled neighboring slice.

Theory and method: A total of 6 slices were acquired in this study. Based on the concept of the iCS method, the *k*-space samples in the phase encoding direction of each slice were firstly undersampled using the variable-density sampling scheme and Mote-Carlo incoherent sampling strategy. For the slice#2 and slice#5, the undersampling rates were 1/4, while for the other 4 slices the undersampling rate were 1/20. A low resolution image of each slice was also acquired for estimating the weighting function. The weighting function, together with the raw data of slice#2 will be used for data interpolation for slice#1 and slice#3, while the raw data of slice#5 will be used for interpolating slice#4 and slice#6. Therefore the total acquisition time of this strategy is equivalent to a conventional compressed sensing acquisition with undersampling rate of 1/9 for 6 slices, which will be used for comparison in our study. Non-linear conjugated gradient was used to perform image reconstruction.

A healthy pregnant woman was used in in-vivo MR imaging at GE 1.5Tesla scanner with the following imaging parameters: TE=1.784ms, TR=4.086ms, Flip Angle = 65°, matrix size =512×512, field of view (FOV) =40cm, slice thickness = 8mm, slice spacing = 9mm, number of excitation=1. In plane resolution was 0.78mm. The pulse sequence was a product Fast Gradient Echo sequence,

Results: For comparison, the conventional Compressed Sensing was also used to perform reconstruction at sampling rate of 1/9. The reason to choose the sampling rate of 1/9 is the acquisition time and raw data size of our proposed strategy (one slice at 1/4 undersampling rate with two neighboring slices at 1/20 sampling rate) are identical to a CS acquisition at 1/9 sampling rate. Fig.1 shows fetal MR images, including the full k-space image (as reference), CS images and the iCS images by using our proposed method. The contrast to noise ratio (CNR) was calculated for all the images, as shown in Fig.2. By using the iCS method, the CNR for each slice can be increased by up to 30% compared with the CS reconstructed images.

Conclusions and discussions: In this work, the iCS acquisition strategy has been applied to shorten the acquisition time and improve the CNR for fetal imaging. Comparison results demonstrated that this method is potentially to bring less scan time and more accurate diagnosis outcome due to the increased CNR, which is clinically valuable for evaluating the fetal development.

References: [1] Lustig M, et al, Magn Reson Med 2007; 58: 1182-1195. [2] Jung H, et al, Magn Reson Med 2009; 61: 103-116. [3] Pang Y, et al, Plos ONE 2013; 8(2): e56098. doi:10.1371/journal.pone.0056098.

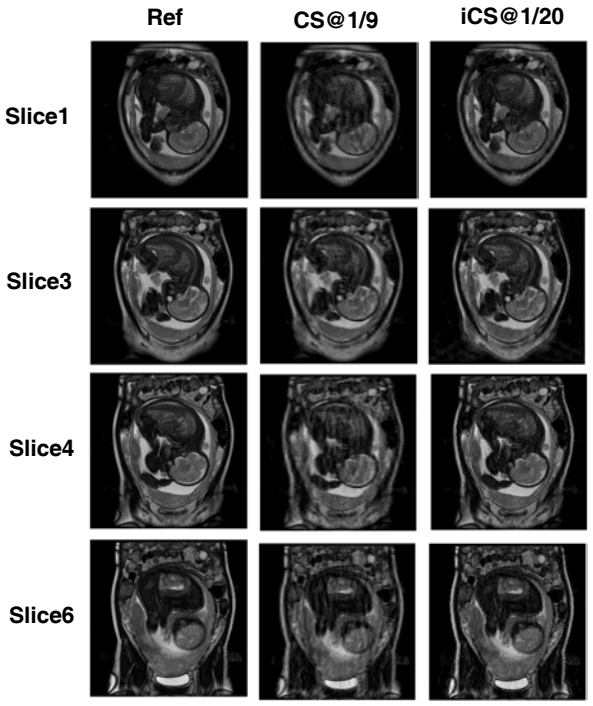

Fig.1 In-vivo MR images of fetus. The first column are reference images reconstructed from full k-space; the second column are images reconstructed using CS at 1/9 sampling rate; the third column are images reconstructed using proposed iCS method at the sampling rate of 1/20. The quality of the iCS reconstructed images is not worse than those of the CS reconstructed images.

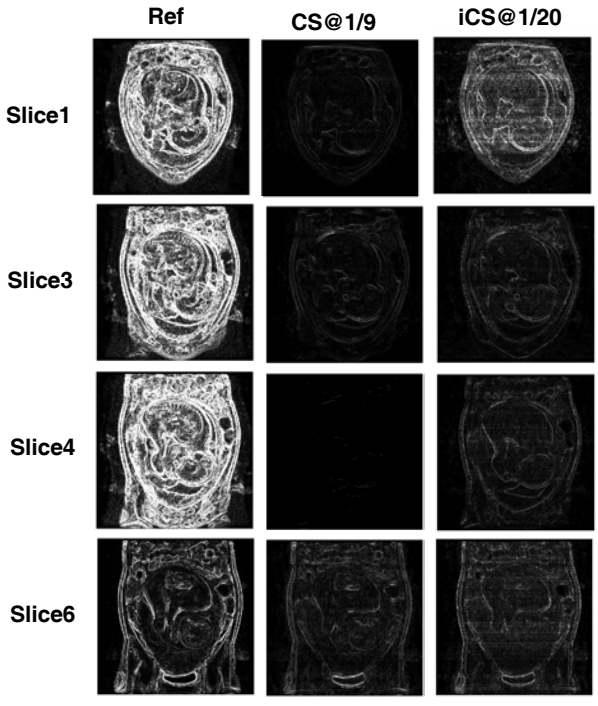

Fig.2 CNR of the images. The first column are the CNR of reference images; the second column are the CNR of the CS reconstructed images at 1/9 sampling rate; the third column are the CNR of the images reconstructed using proposed iCS method at sampling rate of 1/20. It is shown that the CNR of the iCS images can be increased by up to 30% compared with CS images.