Accelerated Breath-hold Liver Imaging Using Additional Information from Free-breathing Acquisitions

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Target audience: Radiologists and MR scientists working on dynamic contrast-enhanced MR imaging of the liver.

Purpose: Dynamic contrast-enhanced MR imaging is a promising technique for treating various hepatic diseases. Breath-hold 3D Gradient echo sequence is currently used for achieving multi-phase volumetric images of the liver. However, conventional 3D whole-liver imaging requires a breath-hold duration of more than 30 seconds [1]. 2D-CAIPIRINHA, which accelerates the acquisition through controlled-aliased under-sampling, has been applied to reducing breath-hold duration to eight seconds at a reduction factor of four [2]. However, down-sampling of k-spaces leads to aliasing artifacts in reconstructed images. In this research, we propose a new method combining temporal-shifted 2D-CAIPIRINHA sequence with PEAK-GRAPPA reconstruction [3]. This approach further utilizes additional information acquired from the free-breathing periods before and after breath-holding, which were wasted in conventional acquisition, to reduce the aliasing artifacts.

Methods: One breath-holding period and two free-breathing periods before and after the breath-holding period were acquired (Fig.1) on five volunteers in a 3T scanner (Philips, Best, the Netherlands) with a 32-channel cardiac coil (Invivo Corp., Gainesville, FL). Down-sampling using a temporal-shifted 2D-CAIPIRINHA trajectory was implemented in a 3D single-shot TFE sequence with 32 ACS lines at a reduction factor of four (Fig.2). The sampling pattern was shifted along k_y direction between neighboring acquisitions to equally distribute the kspace samples. Acquired data during free-breathing periods before and after breath-holding were used to reconstruct the missing k-space points in breath-holding period (Fig.2). Coil images were reconstructed using the 3D PEAK-GRAPPA [4] algorithm with a kernel size of $3(k_x)\times5(k_y)\times5(k_z)\times3(t)$. Conventional 2D-CAIPIRINHA method with 2D-GRAPPA reconstruction using the same sampling pattern was implemented for comparison. Parameters for the single-shot TFE sequence were: TR/TE 2.9/1.37ms, flip angle 15°, BW 868Hz/pixel, acquisition matrix size $160(k_x)\times200(k_y)\times50(k_z)$, FOV $256\times320\times128\text{mm}^3$.

Results: Conventional 2D-CAIPIRINHA method shows significant aliasing artifacts at an acceleration factor of four. These artifacts were eliminated by applying the proposed method. The red arrows point out the main difference between the conventional and proposed method (Fig.3).

Discussion: Sharable information in free-breathing periods can be exploited to help reduce aliasing artifacts caused by reconstructing under-sampled k-spaces in the 2D-CAIPIRINHA method. The weighted kernel of PEAK-GRAPPA exploits the correlations between free-breathing and breath-holding acquisitions, and enables robust reconstruction of breath-hold images. This method also provides more feasibility for breath-hold imaging; if the patient can hold breath for a longer time for continuously acquiring extra under-sampled kspaces, these kspaces can be further utilized to improve the quality of breath-hold images by increasing the kernel size along temporal direction.

Conclusion: In this work, we evaluated the feasibility of combining accelerated breath-hold imaging with additional free-breathing acquisitions to improve the quality of breath-hold liver imaging. The proposed method is feasible in reducing down-sampling-induced aliasing artifacts occurred in conventional accelerated acquisitions. This approach allows a single breath-hold process of eight seconds and results in improved images for breath-hold 3D Gradient echo sequence of the liver.

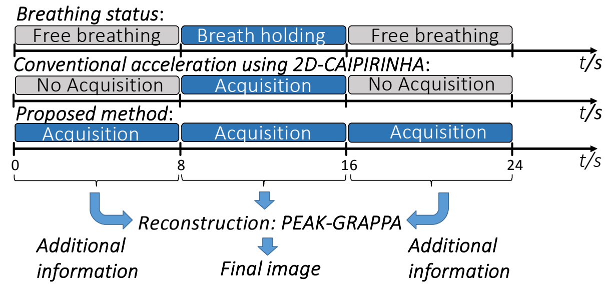

Fig.1 *In the proposed method, data were acquired in both free-breathing (FB) and breath-holding (BH) periods. On the contrary, conventional method only acquires data in BH periods.*

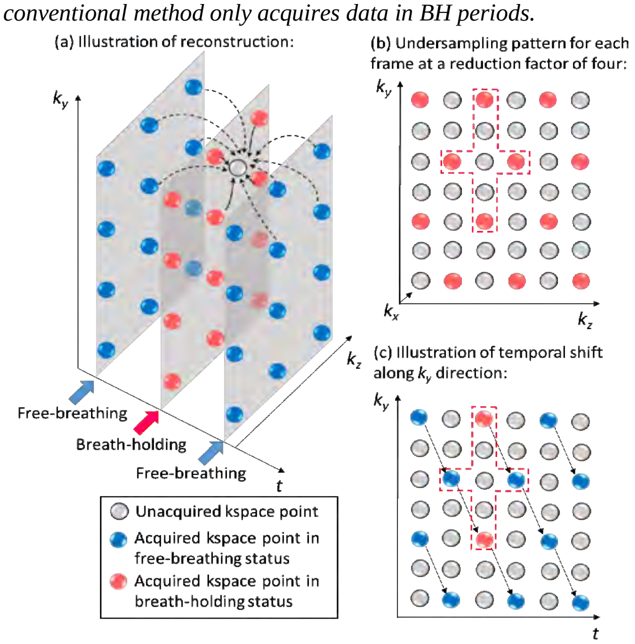

Fig.2 *(a) Additional information from FB acquisitions is used to reconstruct breath-hold images. (b) 2D-CAIPIRINHA sampling pattern is used in both FB and BH acquisitions. (c) Temporal shifts were added to improve the efficiency of acquisitions.*

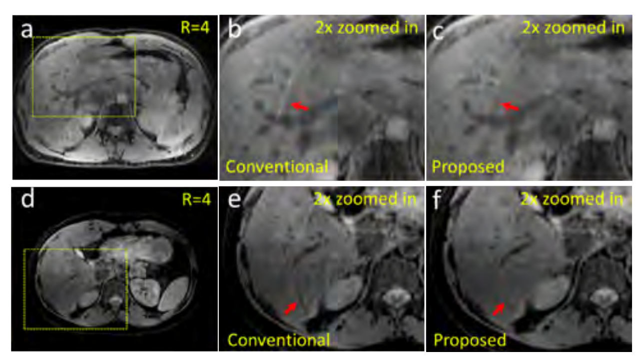

Fig.3 *Comparison of reconstructed images using conventional method (b,e) and the proposed method (c,f) on two volunteers. The whole-FOV images are shown in (a,d). The main difference is pointed by red arrows in (b,c,e,f).*

References: [1] Kwak HS et al., *European radiology* 2005; 15: 140-147; [2] Yu MH et al., *Journal of Magnetic Resonance Imaging* 2013; 38: 1020-1026; [3] Jung B et al., *Journal of Magnetic Resonance Imaging* 2008; 28: 1226-1232; [4] Jung B et al., *Magnetic Resonance in Medicine* 2011; 66: 966-975.