Fast 4D Coronary MRA with k-t GRAPPA

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Introduction:

Four-dimensional (4D) coronary MRA (CMRA) has been developed to allow cardiac motion-resolved data acquisition, enabling retrospective selection of the best vessel delineation from contiguous cardiac phase images [1]. However, this technique puts additional demands on imaging speed for sufficient spatial and temporal resolution. In recent years, a number of strategies have been proposed to speed up data acquisition by exploiting spatiotemporal correlations in dynamic imaging. Among them, k-t GRAPPA has the advantage of requiring no sensitivity prescan and has been successfully applied in cardiac cine imaging [2]. The objective of this work was to evaluate the performance of this fast imaging technique in 4D CMRA.

Materials and Methods:

Full k-space data for 4D CMRA were acquired using respiratory self-gating [3] and undersampled off-line with various acceleration factors in a time-interleaved fashion as described in the original k-t GRAPPA paper [1]. 16 ACS (auto calibrate signal) at center k-space were used for acceleration factors of 2 to 4 and 11 ACS lines were used for acceleration factors of 5 and 6. For comparison, images were also reconstructed using GRAPPA without using temporal correlation between adjacent cardiac phase images. The corresponding numbers of the ACS lines were 24, 20 and 16 for acceleration factors of 2, 3 and 4, respectively. Human studies were conducted on 9 healthy volunteers using a 1.5T Siemens Sonata system. The basic sequence parameters included: 350×250 mm^2 FOV, 8 partitions interpolated from 4, 1.75 mm slice thickness, 256×154 acquisition matrix, 1.4×1.6 mm^2 in-plane resolution, 60º flip angle, TR/TE=4.30/2.15 ms, 11 lines for each cardiac phase/heartbeat.

Mid-diastolic images were reconstructed from the full k-space data and the undersampled k-space datasets. The full k-space images were used as the reference. Artifact power (AP) was calculated to evaluate the level of artifacts introduced by k-t GRAPPA and GRAPPA. Also, image quality and coronary artery delineation were graded by a blinded cardiac MR specialist (0: worst; 4: best) and comparison was made between the reference images and the GRAPPA and k-t GRAPPA images to assess the effectiveness of these two fast imaging techniques.

Results:

As shown in Fig.1, the AP of GRAPPA increases dramatically with higher acceleration factors. In comparison, the AP of k-t GRAPPA is significantly lower ($p<0.05$) at the same acceleration factors. The mean scores of the reference, GRAPPA and k-t GRAPPA images are shown in Fig.2. The images reconstructed with GRAPPA exhibit significantly poorer image quality and vessel delineation than the reference images ($p<0.05$). However, using k-t GRAPPA, image quality and vessel delineation is not significantly different from the reference images with acceleration factors up to 4 ($p<0.05$). Even with a reduction factor of 5, k-t GRAPPA images still maintain a good-plus image quality (3.22±0.22). Fig. 3 shows the reference image of one subject and the corresponding GRAPPA and k-t GRAPPA images with various reduction factors. Identical image quality score was given to reference image (a) and k-t GRAPPA images with acceleration factors 2-4 (b~d). When the acceleration factor is increased to 5 (e), although some artifacts appear, depiction of the coronary artery is still acceptable. On the other hand, GRAPPA images are severely contaminated by noise and artifacts with acceleration factors 3-4 (h,i).

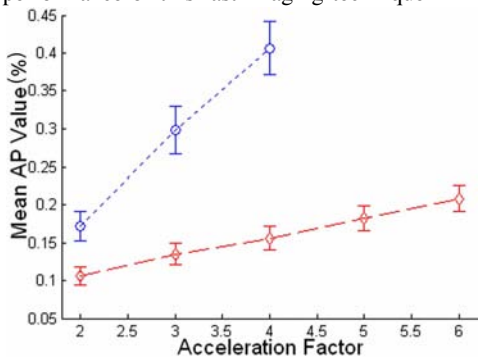

Fig 1. The mean AP values of GRAPPA (dotted, circles), and k-t GRAPPA (dashed, diamonds) with various acceleration factor values.

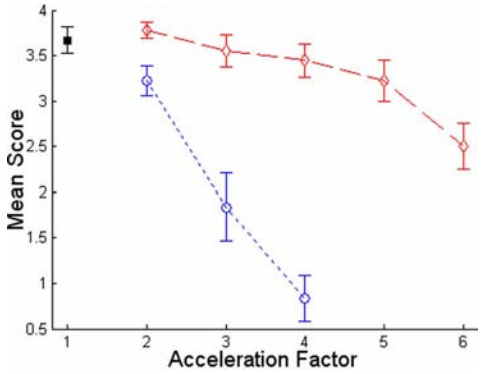

Fig. 2. The mean scores of the reference images (square), k-t GRAPPA (diamonds) and GRAPPA (circles). * indicates significant difference compared with the reference images.

Fig. 3. a) The MIP image at mid-diastole reconstructed from the full k-space and the corresponding k-t GRAPPA images with acceleration factors of 2~6 (b~f) and GRAPPA images with acceleration factors of 2~4 (g~i).

Discussion and conclusion:

As cardiac motion is periodic, coronary artery images exhibit significant correlations among adjacent cardiac phases, especially at mid-diastole. By exploiting the correlations in both spatial and temporal dimensions, k-t GRAPPA is much more effective and robust than GRAPPA. High acceleration factor of 4 or 5 can be achieved without introducing significant loss in vessel delineation. In conclusion, this technique is promising for either substantially reducing scan time or greatly increasing spatial/temporal resolution in 4D CMRA.

Reference: [1] Bi X, et al. MRM, 2005, 54:470; [2] Huang F, et al. MRM, 2005, 54:1172-84; [3] Lai P, et al. ISMRM, 2006:p364