Free Breathing Radial Acquisitions of the Heart

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Abstract

Due to the respiratory motion of the heart it is difficult to collect sufficient data to form high quality images. Multiple long breath-holds are unsatisfactory in the clinical setting but free-breathing acquisitions of the heart suffer from motion artifact. Here a method is presented for overcoming 3D motion; it is based upon image registration of in-plane data combined with through-plane slice tracking. A number of fast radial, undersampled images are acquired, each one is free of motion artifacts, but is of low quality due to undersampling. The images are combined to give higher-quality, respiratory motion compensated images. Initially, in-plane translational and rotational motion between each image is corrected. At the next stage, correction of in-plane deformation is performed in the image domain. Through plane translational motion is compensated using a navigator echo to move the acquisition plane. Using this method, information on the motion of the heart is captured at the same time as acquiring the image data. No motion model, assumptions about the motion or training data are required. The method is demonstrated on volunteers.

Method

1. An interleaved acquisition consisting of five, 20% sampled sub-images is performed on free breathing volunteers using a radial, balanced fast field echo (BFFE) sequence. Navigators are used for slice tracking in the LR direction, ECG triggered sagittal slices are acquired at end-diastole. Acquisition time for each sub-image ~135ms, matrix size 51×256, FOV=320mm, TR / TE/ Flip= 2.7ms/ 1.35ms/ 80°.
2. Reconstruction is performed in Matlab using the re-gridding algorithm 'griddata' and nearest neighbour interpolation. This method was found to be superior to re-gridding based on Kaiser Bessel convolution functions that lead to substantial blurring artifact which detrimentally affected the image registration and subsequent image combination stages
3. First sub-image in each series is segmented to exclude regions that move independently of the heart, e.g. spine and chest wall.
4. Rigid registration is used to determine translations and rotations between the sub-images, data are corrected in k-space.
5. The rigid body corrected images are registered to the unsegmented first sub-image using a non-rigid algorithm.
6. Images are transformed using non-rigid results and summed to give final image.

Results

Figure 1 shows results for two volunteers, the subtracted images use a sub-image, i.e. an undersampled image that is effectively static. Without correction, motion blurring in the reconstructed image is evident, rigid body correction in the region of the heart compensates for much of the motion but causes blurring of the rest of the image. Additional correction of deformation leads to a further improvement in image quality in the region of the heart and in other parts of the image that are brought back into alignment undoing the negative effect of the rigid registration.

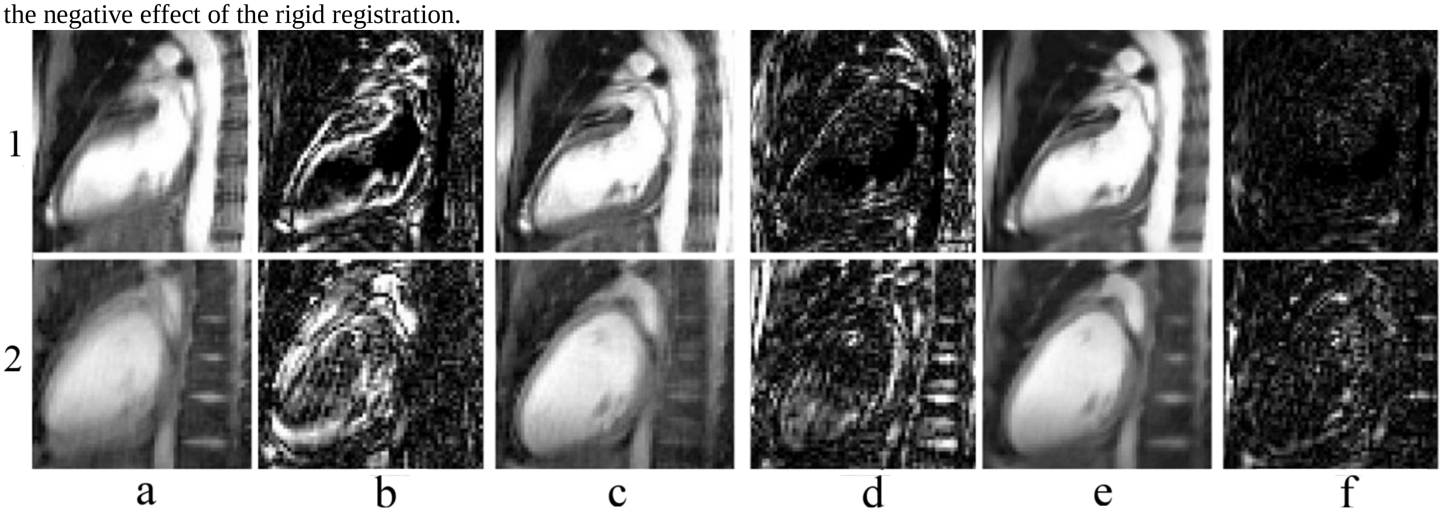

Figure 1: Sagittal views, a) uncorrected full image; b) magnitude subtracted image (sub-image –uncorrected image); c) rigid body corrected full image; d) magnitude subtracted image (sub-image- rigid corrected); e) combined image with deformation correction; f) magnitude subtracted image (sub-image-deformation corrected). Misaligned areas are bright areas in the subtracted images.

Conclusion

The method described here can be used to compensate for respiratory motion during free-breathing acquisitions. Here we show single cardiac phase acquisitions but the technique could be easily applied to multi-phase imaging and potentially to 3D imaging.